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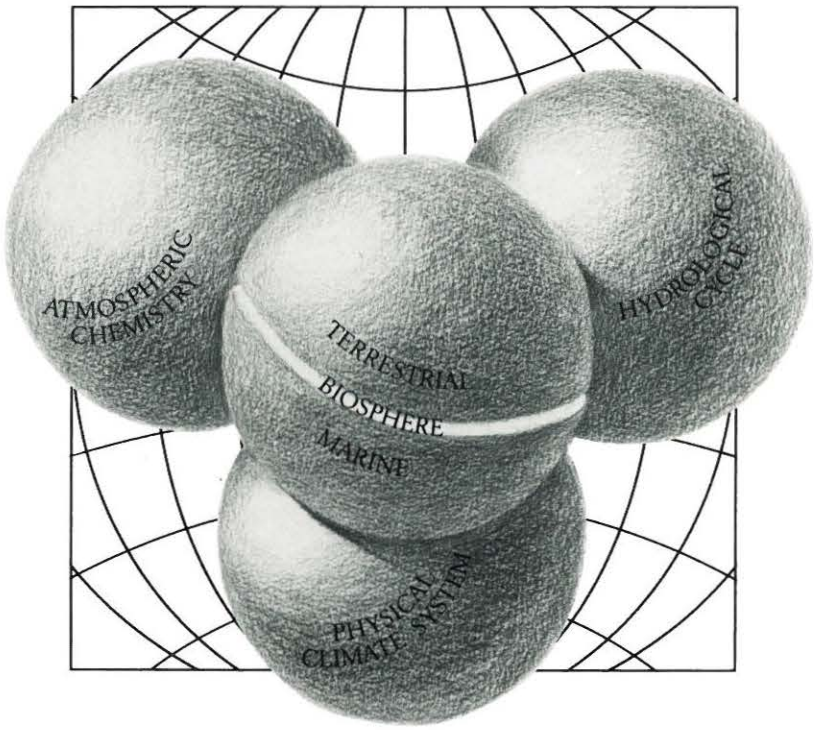
REPORT No. 7:2



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

A Report from the First Meeting of the Scientific Advisory Council for the IGBP

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

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A Report from the First Meeting of
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held at The Royal Swedish Academy of Sciences
Stockholm, Sweden
24–28 October, 1988

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

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NATIONAL COMMITTEE REPORTS

AUSTRALIA

Introduction

The Australian Academy of Science established a National Committee for the IGBP in 1986. The current membership consists of

Professor K.D. Cole, Chairman
Professor K. Lambeck
Dr K.G. McCracken
Dr A.D. McEwan
Professor C.B. Osmond
Dr G.I. Pearman
Professor J.P. Quirk
Professor B.G. Thom
Dr E.M. Truswell
Dr B.H. Walker, Ex-officio member of ICSU's SC-IGBP
Dr J.W. Zillman, Representing the Academy of Technological Sciences and Engineering
Mr N. Quinn,Representing the Department of Arts, Sport the Environment, Tourism and Territories

This committee has the responsibility for the planning of Australia's scientific contributions to the IGBP. The first major exercise of the committee was the organization of a meeting of the Academy on 24-27 February 1988 to discuss the outstanding scientific problem involved in an IGBP and to hold a set of workshops to commence Australia's planning for the IGBP. The Proceedings of that meeting are now available. Two days were devoted to scientific papers and discussion of them and two days to working group activities.

The Working Group topics at the meeting were

- Terrestrial Biosphere-Atmosphere Chemistry Interactions
  Chaired by G. Farquhar

- Marine Biosphere-Atmosphere Interactions
  Chaired by G. Harris

- Biosphere Aspects of the Hydrological Cycle
  Chaired by N. Body

- Effects of Climate Change on Terrestrial Ecosystems and Lend Use
  Chaired by R. Slatyer

- Solar-Terrestrial Physics Inputs
  Chaired by D.G. Cole

- Earth Science Inputs
  Chaired by B. Thom

In addition there were special papers and discussion on the subject of data and information. These were

- Coordination and data information systems - J. Richards

- Geosphere-Biosphere observation - R. Specht

- Techniques of extracting environmental data of one past
  - A. Chivas

- Global geosphere-biosphere modelling - G.E. Tucker

- Greenhouse 87 report - G.I. Pearman.

Interaction with several Federal government departments is being developed because of their special interests in aspects of IGBP results for their policy and planning purposes. The mechanism of funding of Australia's participation in the IGBP is being developed through discussions with these departments and also with State governments.

The planning would be in two phases: (a) Pre-IGBP and (5) IGBP proper. In the pre-IGBP phases it is planned to have a series of workshops in order to plan for the scientific research that can be foreseen as needed to be done for the IGBP in Australia and to cost it out in order to be able to go to governments and other agencies with reasoned cases for funds. In this phase also a register of activities already going on in Australia relevant to the IGBP will be generated and interactions encouraged which will, in due course, address the significant scientific problems of the IGBP. At this stage we need funds for the pre-IGBP workshops and related planning activities.

In the IGBP proper we hope to be able to convince governments and other agencies to put significant sums of money towards the research needed to be done in Australia.

Recent changes in Federal government department responsibilities and consequent changes in public service personnel have hindered these processes greatly in the last year.

The workshops which it is hoped to run in Australia in the next two years are as follows:

Biosphere-Chemistry
Climate-Vegetation
Observatories
Models in Hydrology
JCOFS
WOCE
Extreme Events
Land Use/Remote Sensing
Paleo-Environmental
Antarctica
International Collaboration.

The draft IGBP programme

It can be seen from the working groups topics at our February 1988 meeting that they run fairly parallel to working groups mentioned in IGBP Report No. 2, except that we added "Solar-terrestrial Physics" and "Earth Science Inputs" which we as a committee consider important.

Crucial scientific areas of concern in the environment

Contexts which are not yet sufficiently emphasized in SC-IGBP reports are

- Dynamics of native vegetation and climate coupling;
- The middle atmosphere and its impact on the biospheres;
- Solar activity and its impact on the atmosphere and biospheres;
- Nature and significance of extreme events.

National priorities

It is not possible to do this at this time. We hope to learn in the sequence of planned workshops what we can and will do. There is clearly great potential in contributions of Australian science to the IGBP. But that will be decided by the community of scientists in the workshops over the next couple of years.

It has not been possible for our committee to consider Report No. 4 as it was received only in mid-September and we were not able to meet after that.

BELGIUM

Introduction

In response to the initiative of the IGBP, the Belgian National SCOPE Committee, together with several other National Science Committees of the Academies, undertook to organize a symposium, which took place on 22nd April 1988, in order to review Belgian research relevant to "Global Change" and to promote actions in relation to the IGBP. At the same time the symposium was considered as a starting point for setting up a platform for future Belgian involvement in the programme. Its proceedings are now available in print.

The symposium was introduced by Dr. F.W.G. Baker, Executive Secretary of ICSU, who reviewed the state of development of the IGBP and pointed out that the symposium would contribute positively to the preparation of a draft programme to be discussed at the first meeting of the Scientific Advisory Council of the IGBP in Stockholm in October 1988.

Brief presentation of the review papers

The program of the symposium was subdivided into eight subjects corresponding to those of the 4 Working Groups and 4 Coordinating Panels set up by the IGBP Special Committee, namely: Terrestrial Biosphere - Atmospheric Chemistry Interactions; Marine Biosphere - Atmosphere Interactions; Biospheric Aspects of the Hydrological Cycle; Effects of Climate Change on Terrestrial Ecosystems; Global Geosphere-Biosphere Modelling; Data and Information Systems; Techniques for Extracting Environmental Data from the Past; Geo-Biosphere Observatories. This corresponds with the different Chapters of these proceedings.

For each area a coordinator had been appointed to review and to present the relevant research potential and achievements in Belgium.

- **Global Geosphere Biosphere Modelling:** Coordinator Prof. A. Berger (UCL). In the 2 review papers presented in this panel, long- and short-term speculations based on multiple records and geological observations, as well as on man's activities, are considered. After a brief introduction on the climate system, A. Berger's paper shows the results obtained for the last five years in transient response of climate to the astronomical forcing of the last 150,000 years, and to the doubling of (equivalent) CO_2 by 2020. In conclusion, Prof. Berger recommends that the study of climatic changes over time scales ranging from millennia to millions of years should be emphasized within the IGBP.

Dr. Gerard, for his part, gives a review of the existing studies on the various aspects of the Earth's global cycles and atmosphere-climate interactions, and suggests future national efforts to be developed on some of the themes defined for the IGBP, such as the interactions between the climate and the chemical composition of the atmosphere and the numerical modelling of global cycles.

- **Data and Information Systems:** Coordinator Dr. M. Ackerman (IASB/BIRA). Remote sensing of the Earth's surface and the atmospheric changes, as well as controlling the quality of the data by means of ground truth checks and careful calibration, are the main subjects treated in this panel. The contributions show the Belgian potential in this field of Global Change research.

P. Simon reports on model calculations, based on current knowledge of aeronomic processes and on solar variations observed during the last solar cycle. Problems in long-term measurements for both solar variations and trace species, like ozone, are reviewed, and strategies for future monitoring of atmospheric constituents are proposed.

While R. Combeer's paper contains several recommendations for coordinated contribution to the IGBP in the field of remote sensing applied to land use studies, C. Müller refers to the high number of Belgian scientists who have been associated with the discovery of atmospheric constituents and their measurement in the last fifty years. A. Guissard's paper points out the key elements of microwave remote sensing research in Belgium.

The present effort in data and information systems would considerably benefit from a larger programme extending to the whole biosphere which would include the soil and marine sources and modifications in atmospheric constituents.

- **Techniques for extracting environmental data from the past:** From the different papers of this panel it appears that observations and predictions of the effects of changes in the global biogeochemical processes of the Earth system require a good understanding of the ecological functioning of ecosystem. Their variation as a function of time is observed by measurement of several parameters, and examples of such studies in selected ecosystem-areas are presented.

A.I. Mokadem describes a study carried out in Belgium on the use of remote sensing to detect changes in vegetation cover in relation to climate and human activities.

- **Terrestrial Biosphere-Atmospheric Chemistry Interactions:** Coordinator Dr. E. Arijs (BIRA/IASB). Photochemical processes and chemical reactions are to be taken into account when selecting observable indicators of Global Change. M. ACKERMAN describes key atmospheric reactions occurring at various altitudes and emphasizes the need for a three-dimensional approach to climate studies. Further studies are required for the quantification of reaction rates. Concentrations of trace gases and elements in the atmosphere originating from natural or artificial sources are extremely variable. However, they may give rise to possible correlations which are used for determining fluxes, as discussed by C. Ronneau.

- **Marine Biosphere-Atmospheric Interactions:** Coordinator Prof. A. Disteche (ULg). Important and various research programmes are commented on in this panel. J. Nihoul in his paper describes how the techniques of mathematical modelling may be used to reconstitute a data base from sparse data and to evaluate the fluxes at the ocean margins. The example of the Northern Bering Sea is given as an illustration. Prof. Nihoul takes this opportunity to emphasize that sufficient sets of synoptic data for reliable studies on global ocean fluxes are very rarely available.

In Belgium, the carbon and nutrient cycles have been well studied in coastal systems such as the North Sea, which is very much perturbed by man, and the Mediterranean Sea (around Corsica) which is much less affected. The accumulation of anthropogenic substances have been intensively studied in the Scheldt Estuary and in the Southern Bight (North Sea). The synthesis of all these studies and their comparison with other marine ecosystems lead R. Wollast to propose models of biogeochemical cycles at Earth scale.

- **Biospheric aspects of the hydrological cycle:** The coordinator, Dr. F. Bultot (IRM), pays attention to the effect of plant cover modifications on the microclimate and on certain terms of the water balance. A study carried out with D. Gellens on three Belgian catchments having definitely distinct characteristics, shows that the responses to a climatic change can be quite different from one catchment to another. Various suggestions in view of improving sensitivity studies are put forward.

- **Effects of Climate Change on Terrestrial Ecosystems:** Coordinator Prof. R. Impens (FSAGx). Vegetation structure and species composition of terrestrial ecosystems will be affected by the different factors of climate change and vary between different regions of the world. H. Clijsters has studied the biochemical and physiological regulatory mechanisms of CO_2 uptake and fixation in order to test the assumption that atmospheric CO_2-enrichment should exercise a beneficial effect on the vegetation by increasing net photosynthesis. R. Lemeur, on the other hand, is studying the positive correlation between the transpiration rate of the vegetation and the CO_2 concentration of the atmosphere. As a result, water use efficiency seems improved with CO_2-enrichment.

- **Human factor in Global Change:** Prof. J.R. Nuttin (KUL) was invited to introduce the subject of human behavior in relation to Global Change. Human cognition and actions may have a regulating impact while, on the other hand, man should refrain from acting in a way which might be disastrous in the long run. Research in the field of so-called "environmental psychology" is quite developed in Belgium, while little is done to study the impact of the "psychosphere" on global geosphere change.

Conclusions

This symposium gave an opportunity for the presentation of relevant research carried out in Belgium on the themes defined by the IGBP for "A Study of Global Change". It was very stimulating to discover the substantial existing studies undertaken by the different research teams and it is hoped that the crucial issues which have been pinpointed during the Symposium will help to sketch out plans for a Belgian contribution to the IGBP.

CANADA

Introduction

With close ties to the International Geosphere-Biosphere Programme (IGBP), Canada's Global Change Programme is aimed at developing and improving our ability to model and predict future change, allowing us to gauge the role of human activity in dynamic earth systems. The CGCP, Canadian Global Change Programme, is designed to operate under the IGBP theme:

To describe and understand the interactive physical, chemical and biological processes that regulate the earth's unique environments for life, the changes that are occurring in this system, and the manner in which they are influenced by human actions.

Both the IGBP and the CGCP place emphasis on interactions between the hydrosphere, the atmosphere, the solid earth, the sun and, most importantly, the biosphere. Each of these areas is critical to understanding the dynamics and evolution of earth systems.

ICSU's Special Committee on the IGBP (the SC-IGBP) is responsible for planning an international program on Global Change. In 1987, the SC-IGBP called for studies of (a) ecosystems that are particularly sensitive to change, eg. the Arctic, (b) the impact of human activity, (c) paleoenvironments, (d) global water cycles, (e) data and information systems and (f) a global network of IGBP observatories. Based on these objectives, organizers plan to launch IGBP operations in 1990, with activities continuing for one and perhaps several decades. The Canadian Program is expected to follow suit. The end result will be a detailed analysis of global dynamic processes - including how they are influenced by human populations - and improved predictive capabilities for decades ahead.

Part 1 of this report describes CGCP milestones within the past 3 years. This is followed by details of the emerging CGCP structure (part 2) and explanations of each element within the Program. Finally, Part 3 presents the current status of Canada's contribution to the IGBP, with reports on each of the Working and Resource Groups, details of a proposed Global Change book and plans for a parallel Global Change program in the social sciences.

Milestones

The IGBP was formally adopted by ICSU at Berne, Switzerland, in 1986. At that meeting, Canada reported on a Global Change workshop 1 that had been held in December 1985, with support from the National Research Council of Canada (NRC). The RSC organized a second meeting on Global Change in December 1986, again with NRC support. This time a number of Working/Resource Groups were proposed to mark the formation of a CGCP. Each Group was asked to identify ongoing Canadian studies that touched on Global Change, and to propose future projects that might fill gaps in existing Canadian activity.

Early in 1987, representatives from the RSC-CGCP attended two Workshops on Arctic science that were held in Boulder, Colorado. Sponsored by the American National Academy of Sciences, these meetings considered joint US-Canada proposals for research in Arctic regions. Canadian delegates contributed to a comprehensive report, which was released in the summer of 1988 by the University Corporation for Atmospheric Research, in cooperation with the US Institute for Arctic and Alpine Research and the RSC.

The RSC has also taken steps in developing aspects of Global Change that relate to the social sciences and humanities. In June 1987, the Society held a workshop called the "Human Dimensions of Global Change; The Challenge to the Humanities and the Social Sciences". A parallel initiative was launched at the same time by the International Federation of Institutes for Advanced Study (IFIAS), whose director, Dr. Ian Burton, organized a meeting in Toronto on the "Human Response to Global Change". Dr. Burton's meeting led to a proposal for an international program, which is being organized under the auspices of IFIAS, the International Social Sciences Council (ISSC) and the UN University in Tokyo. The social consequences of Global Change were also emphasized during a "Cost of Inaction" symposium held in January 1988, and during a meeting on "The Brundtland Challenge" held in March of the same year.

Both of the latter activities were jointly sponsored by the RSC and the Canadian institute for Research on Public Policy (IRPP), with support from several other organizations.

Following the "Human Dimensions" symposium, the RSC's ad hoc Steering Committee for Global Change met to discuss further development within the program. On recommendation from the NRC, ICSU recognized the RSC Committee as Canada's National Committee on the IGBP (July, 1988). Dr. W.S. Fyfe, who had chaired the inaugural meetings of the Committee, agreed to remain on the Steering Committee, but disqualified himself from the chair position in view of his place on ICSU's SC-IGBP (see above). Dr. W.R. Peltier from the University of Toronto was appointed as Chair of the formal Steering Committee, and Mr. M.R. Dence, Executive Director of the RSC, was appointed as Secretary.

The general mandate of Working and Resource Groups within the CGCP calls for regular correspondence in the form of status and progress reports. Four Groups have been active since December 1986, and each have submitted reports to the RSC. The RSC, for its part, has organized several CGCP activities, including (a) meetings of the Working Groups on Arctic-Atmospheric and Terrestrial-Atmospheric interactions, (b) a meeting of the Resource Group on Remote Sensing, (c) a preliminary discussion to examine the need for a Resource Group on Data and information Systems, and (d) a workshop for authors of a Global Change book. Discussions have also taken place to consider the possible role of several other Groups, with emphasis on Proxy Environmental Data, Observatories and Global Models and Processes.

Organization

The CGCP's secretariat is officially housed in the RSC. One possible administrative structure has been outlined for discussion by all of the parties concerned. Implementing this or a similar plan hinges on continued support for the overall Program.

The Board of Directors will be responsible for (a) managing all scientific endeavors within the CGCP, (b) distributing funds in support of projects, (c) developing financial policies and criteria, and (d) interacting with federal granting agencies and other organizations which provide sustaining resources.

The Board will consist of representatives from university, government and industry, and will include two non-Canadian scientists who are active in the IGBP. University members will be appointed by the RSC, while government members will include representatives of an Inter-departmental Committee for Global/Climate Change drawn from appropriate government science departments. Members from industry will be appointed by the Natural Sciences and Engineering Research Council (NSERC) in consultation with appropriate professional societies. An NSERC representative will be appointed by the President of the Boards, and the social sciences will be represented by at least one appointee. The Board of Directors will be responsible for naming a member as Scientific Director for the CGCP; this individual will then be a non-voting member of the Board.

The Scientific Director of the CGCP will be a senior, university-based Canadian scientist with an international reputation for research in disciplines related to Global Change. The Board of Directors will negotiate the details of his/her appointment with the administration of the university involved. The Scientific Director will maintain close liaison with the CGCP Secretariat.

The CGCP Secretariat will be administered by the RSC under contract to the Board of Directors. The Secretariat will handle all organizational details related to scientific meetings that are sponsored by the CGCP, as well as all expenditures by the Board for scientific studies. The latter function will require authorizing signatures from the Scientific Director or his/her designate, as well as the Director of the Secretariat.

The Scientific Steering Committee (SSC) will be the main operational arm of the CGCP. It will be chaired by the Scientific Director, and its members will be appointed by the Board of Directors. The SSC will consist of Leaders from the Working/Resource Groups, the Director of the CGCP Secretariat and international members invited by the SSC.

The SSC will be responsible for determining the priority of scientific projects that relate to Global Change, and for developing budgets for each initiative. The latter documents will be subject to approval from the Board of Directors. The SSC will also stimulate new projects from members of the Working/Resources Groups, and maintain close collaboration with other scientific elements of the CGCP.

Working and Resource Groups. The proposed structure of the CGCP currently includes four Working Groups and four Resource Groups. The former are concerned with Terrestrial-Atmospheric Interactions, Marine-Atmospheric Interactions, Arctic-Atmospheric Interactions and Global Models and Processes. These Working Groups are expected to provide scientific motivation by formulating individual or collaborative projects within the CGCP. The resource Groups, on the other hand, are designed to augment the Working Groups, providing the tools and data needed for specific projects, as well as being a source of project proposals. The four Resource Groups which already exist, or are under active discussion, involve Remote Sensing, Data and Information Systems, Proxy Environmental Data and Observatories.

Present status

The CGCP has been progressing in three general directions: through meetings of the Steering Committee and various Working/Resource Groups; through production of a book on Global Change from a Canadian perspective; and through a parallel program in the social sciences and humanities.

Status of the Working and Resource Groups

Appended to the complete Canadian report are individual status reports for each Working and Resource Group in the CGCP. Reports I-IV consider Groups that were active as of July, 1988. All Groups, including those mentioned in Additional Notes, are expected to be active by the time the Steering Committee meets in 1989.

Report VI summarizes papers on proxy environmental data that were presented at a meeting of the CGCP Steering Committee on May 2-3, 1988. These documents included a position paper by Dr. D.A. St. Onge, Director of the Terrain Sciences Division of the Geological Survey of Canada. He and Dr. A. Morgan, President of the Canadian Quaternary Association and Professor at the University of Waterloo, were invited to develop a detailed plan and suggested membership for a Resource Group on Proxy Environmental Data.

At the May meeting, the Steering Committee also considered a Resource Group on Data and Information Systems (Report V); the membership of this Group is still under discussion.

The Global Change Book

Phase I of the CGCP involves communicating Global Change through a book, which is tentatively called TO KNOW THIS PLANET: Global Change, A Canadian Challenge. As a vital source book, this publication is being designed to focus on environmental dangers that now face our planet, providing a summary of pertinent scientific information as a necessary background for rational policy decisions. The book will be directed at a lay readership with high school graduation (11 million Canadians in 1986), and its theme will be the normal fragility and constant change that we observe on the surface of the earth. The book will emphasize that our current problems can only be solved through further scientific research, by increasing public awareness and by promoting international and inter-regional cooperation.

As with other publications and reports from the CGCP, production of TO KNOW THIS PLANET will be managed by the RSC, using in-house expertise and commercial publishers as appropriate. A managing editor, Mr. Constance Mungall, has already begun to coordinate, design and assemble the book, with assistance from the following Editorial Committee:

Dr. D.J. McLaren, President, RSC (Chair)
Mr. M. R. Dence, Executive Director, RSC
Dr. W. S. Fyfe, Dean of Science, University of Western Ontario
Dr. J. Fyles, Geological Survey of Canada

M. G. Paquet, Dean of Administration Studies University of Ottawa
Mr. J.D. Heyland, Editorial Associate, Canada Center for Remote Sensing

The authorship of TO KNOW THIS PLANET represents a wide range of disciplines. Most contributors have gone beyond their own disciplines to speak directly to their peers and the informed public. The book will be fully illustrated, with plates and 2-color line drawings. A series of box inserts will highlight specific topics in science, as well as the political and social aspects of Global Change. A current outline for TO KNOW THIS PLANET is available from the RSC.

The Social Sciences Connection

Although the IGBP is generally viewed in terms of the physical sciences, a great number of related issues lie squarely in the domain of the social sciences. One of the most obvious benefits of launching the CGCP from within the RSC is that a parallel program can be developed to focus on the human dimensions of Global Change. This parallel effort considers how and why we should respond to the situation revealed by the natural sciences.

The RSC called on members of its Humanities and Social Science Academies to attend the CGCP workshop held in December 1986. In conjunction with its Annual Meeting, the Society also staged a Research Council of Canada on the topic of "Managing Global Change" at McMaster University in June 1987. Results of the latter event and enumerated plans for future direction are available in a report 4 written by D. Braybrooke and G. Paguet.

Another meeting on this theme was subsequently organized by Prof. Ian Burton, director of IFIAS, to explore the concept of international program. The IFIAS meeting, entitled "Human Dimensions of Global Change", has been followed by several others in preparation for a Tokyo conference in September 1988. The Tokyo meeting is being supported by IFIAS, the International Social Sciences Council and the UN University in Tokyo.

Canada's social sciences program on Global Change was recently promoted by the workshop on "Cost of Inaction" that was held in Hull, Québec, in January, 1988. The symposium was cosponsored by the RSC and the Institute for Research on Public Policy (IRPP), and was supported by the Social Sciences and Humanities Research council (SSHRC), NSERC, NRC, the Science Council of Canada and other organizations. "Cost of Inaction" brought together almost 50 environmentalists, economists and experts in health and social care to consider the long-term effects and costs of environmental degradation. With similar, broad-based support, a complementary meeting called "The Brundtland Challenge" was held on March 4-5, 1988 at the University of Waterloo to study the impact of the World Commission on the Environment and Development. The Waterloo meeting considered how environmental matters might be included in plans for sustainable development, especially from an economic point of view. A summary report on the "Cost of Inaction" and "The Brundtland Challenge" has been prepared by the IRPP in collaboration with the RSC.

Further cooperation between the IRPP and the RSC appeared in a joint IRPP-RSC submission to SSHRC that answered a call for one-time proposals for planning major national projects in the social sciences and humanities. The submission was awarded development funding from SSHRC, which received an interim report 5 in mid-August 1988. Detailed plans for a long-term program will consider problems like the economic impact of pollution, waste, population pressures and similar issues. An appropriate research agenda will be developed to focus on policy in the fields of energy, resources, urbanization and industry. Resource issues to be studied include both traditional renewable resources, such as agriculture and forestry as well as environmental resources like air and water. Each issue will be examined under several themes, including economics, social and cultural values, government and technology. Many other dimensions have also been recognized, including legal, political and public health concerns, as well as international trade and security. Ultimately, the latter issues may be included within the general framework of the proposal. The final submission to SSHRC will also consider problems of modeling and appropriate links to the natural sciences program on Global Change.

On the basis of this submission, a joint IRPP-RSC workshop was held to explore related processes and the scope of the overall proposal. This meeting gave rise to a request for comments and ideas that was sent to over 1000 social scientists and humanists in Canada.

Conclusion

As of August, 1988, financial support for the CGCP has been provided by a contract with the NRC, with additional interim funding from NSERC. Proposals requesting support for the natural science side of Canada's Program are now before NSERC. Parallel proposals aimed at social sciences and humanities aspects are to be submitted to SSHRC and other agencies. Decisions on all of these requests are expected by the end of 1988 or early 1989.

If future support is forthcoming, plans within the CGCP call for further meetings, both of the Steering Committee and the Working and Resource Group. The first phase of the Program will beginning to appear and will be revised by the Science Steering Committee as they mature. Progress will be reported in periodic newsletters which, along with and other information about Canada's role in Global Change and the IGBP, will be distributed according to a mailing list of involved and interested parties. This mailing list is now being developed.

The urgent problems that underline Global Change were highlighted and widely publicized by the successful conference on "The Changing Atmosphere" held in Toronto on June 27-30, 1988. The presence of two Prime Ministers, other prominent political figures and the world media, as well as the high profiles that each gave to global problems, marked an astounding shift in public and political attention. Major economic and other policy decisions are anticipated in light of Global Change perceptions, as exemplified by the Montreal Protocol on emissions affecting the ozone layer. There is a clear and urgent need for accurate data, careful analysis and detailed interpretation. Great care must be taken to provide decision makers with the best possible advice.

CZECHOSLOVAKIA

The Czechoslovakian National Committee for the IGBP was officially established in June 1988. The Committee consists of 18 scientists, who represent the Czechoslovakian Academy of Sciences, the Slovak Academy of Sciences and Czechoslovakian Universities. The committee is chaired by Prof. V. Bucha, Vice-President of the Czechoslovak Academy of Sciences; Prof. L. Weissmann is Vice-Chairman, the secretaries, Dr. J. Rusek, Dr. J. Lastovicka and Dr. F. Pertl.

The Czechoslovakian national programme is still under preparation. Among others, we plan to participate in the following fields of research:

a) Czechoslovakian national programme "Consequences of Solar-Terrestrial Relationships to Changes of Climate and Environment" - the influence of solar activity (including solar wind and geomagnetic activity) on global geophysical processes and their relations to tropospheric processes with the object to clarify and establish sun-weather and sun-climate relationships, especially for Central Europe but also on global scale, and to estimate their effects on the environment. It involves investigations into the influence of solar activity under man-made changes of environmental conditions.

b) Physics of the atmosphere under the influence of anthropogenic factors. Investigations of man-made atmospheric pollution, which are of great importance for some regions in Czechoslovakia.

c) An analysis of climatic changes in the past (archeological, pedological, geomorphological, biological).

d) Studies of natural disasters, of earthquakes in particular, and possibilities of their predictions.

e) Investigations into global events in the biosphere - magnitude and efficiency of motions, vertical and horizontal transport, anthropogenic effects.

f) Biological changes at the present time and their relations to IGBP - successions; degradation of communities; their interactions with the atmosphere, geosphere, hydrosphere, cycles of biogenic elements (including CO_2 production), soil-production processes (pedological processes), ecosystems.

g) Investigations of the hydrological cycle for the development of agriculture.

h) Studies of biochemical cycles and geochemical cycles of some chemical components, especially for the purpose of agricultural research.

i) Creation and devastation of soil and problems of water balance, devastation of forests. The output of these investigations for environmental and agricultural research.

j) Experimental investigations of small-size ecological systems, their non-linear behavior and their modelling.

k) Global anthropogenic influence on the biosphere, troposphere and other "spheres" of our Earth.

Priorities of research that have not been enough stressed by the Special Committee

There is an urgent need for defining the background of natural processes if we want to read an anthropogenic effect. Changes in carbon dioxide concentration are believed to be the main factor which influence the temperature fluctuations on the globe. High CO_2 is invariably associated with warm conditions globe. High CO_2 is invariably associated with warm conditions low CO2 with cold. It is of course also possible that the increase in temperature due to the processes occurring in the auroral oval under enhanced corpuscular radiation and influencing atmospheric circulation types, led to an increased concentration of atmospheric CO_2.

The auroral electron precipitation during geomagnetically disturbed periods is considered to be the most likely source of charged particle radiation and bremsstrahlung which initiate the formation of cirrus cloudiness and thus change the heat balance of the troposphere. This source was shown to lead to an increase in temperature and pressure in the auroral oval even in the troposphere and to the change of the meridional flow into zonal flow of atmospheric circulation.

To prove there is a link a between these processes, more investigations are needed to verify the validity of the suggested possible mechanism.

Action plan

Primary emphasis will be on the development of conceptual models which could explain meteorological fluctuations as a result of a strengthened zonal flow due to the processes in the auroral oval at the time of increased corpuscular radiation alternating with the meridional flow due to the orography when corpuscular radiation was low.

If we want to prove the validity of the suggested mechanism we must be able to explain why the data are regional rather than global and why correlations established for short time - series disappear or change sign when time - series are extended. Even though some objections were answered more evidence is needed to explain irregular types of atmospheric circulation leading to extreme climatic conditions in different regions of the world, e.g. heat waves in the north America.

The issue

There are indications that both long-term and short-term fluctuations of the climate and weather can be explained on the basis of the connections between the corpuscular radiation and the changes in atmospheric circulation due to the processes in the auroral oval. On the other hand, changes in CO_2 appearing to precede changes in the climate suggest that the geologic record can provide an important means to check models for present climate and enhance our ability in predicting the response of the atmosphere-biosphere system to modern changes in CO_2.

Increase in the atmospheric CO_2 concentration during the past 30 years is believed to result in part from human activities and to influence the increase in global surface air temperature as observed for the past century. At the same time an increase in geomagnetic activity indicating corpuscular radiation is observed as well. Moreover the features of fluctuations of geomagnetic activity and global surface air temperature are very similar during the past 45 years. On the other hand there is a striking disagreement for the last 3 years. This could mean that the increase in temperature will be still stronger than expected in case the global values in temperature were determined correctly.

From these ideas we can decide that new data and methods are needed to verify suggested mechanism with the aim to decide which of them that can explain more reliably climatic and meteorological fluctuation in their full diapason.

CHINA

CAST, Beijing

Introduction

The "International Geosphere-Biosphere Programme - A Study of Global Change" (IGBP) is the most ambitious, most wide-range scientific programme approved by the 21st General Assembly of ICSU in September 1986. Following the decision of the ICSU General Assembly that encourages the formation of National Committee, the China Association for Science and Technology (CAST) has established the Chinese National Committee for the IGBP (CNC-IGBP) with Professor Duzheng Ye as Chairman. The Committee consists of 26 members who come from 14 societies and associations, including Geographical Society of China, Meteorological Society of China, Botanical Society of China, Soil Science Society of China, Soil and Water Conservation Society of China, Chinese Society of Oceanography, Chinese Society of Environmental Sciences, Chinese Society of Mineralogy, Petrology and Geochemistry, Chinese Society of Hydraulic Engineering, Chinese Society of Forestry, China Research Society of Natural Resources, and Chinese Association of Agricultural Science Societies.

The main tasks of the Chinese National Committee for the IGBP are:

- To represent PRC and coordinate various communities in China to participate activities of the IGBP;
- To exchange ideas and make as much as possible contributions to the IGBP.

In order to actively participate scientific activities, the Chinese National Committee has decided to set up several working groups and panels. At present time, the following working groups are being formed:

- Working group on the effects of disastrous climate on agriculture and ecosystems.
- Working group on changes of ancient environment.
- Working group on network of geo-biosphere observatory.

Research activities related to IGBP in China (Beijing)

While a national programme for global change has not been set up yet, there are some ongoing programmes which are related to it. Examples of these are as follows: The Sino-Japanese Cooperational Programme of Atmosphere-Land Surface Processes Experiment at Heihe River Basin (HEIFE); The CO_2 Induced Climate Change and Sea-level Change and its Impact on the Chinese Coastal Regions; Comprehensive Survey on Kalakunlun Mountain and Its Impact Eco-environment; Air-Sea Interactions in ENSO Period; Solar-Terrestrial Observations; Comprehensive Survey of the Loess Plateau in China; The Impact of Human Activity on CNSP cycles; Impact of Huge Hydraulic Project on Eco-Environment; Experimental Studies on Formation and Evolution of Natural Conditions, Prevention of Disasters and Eco-Agriculture; and so on. Besides the organized programmes, there also exists in China a wide-range of scattered research activities related to IGBP. To name a few of them as examples: the studies on the past climate change are now being carried out in various institutions; hydrological cycle investigations are undertaken in the Bureau of Hydrology; the greenhouse gases (mainly CO_2 CH_4.....) are being monitored in various regions of China by various scientific organizations; studies on the vegetation cover in China (including its past change) are also going on; and sea level height is measured in quite a few coastal regions of China by State Bureau of Oceanography and its past change is also under study.

The Chinese National Committee hopes that some of the ongoing project can be continued and expanded in order to meet needs of the IGBP more closely. For example, some observational stations in the HEIFE will be maintained after its implementation (Oct. 1990-Oct. 1992) for

continuous monitoring of trace gases and meteorological elements if financial funding can be found.

It should be mentioned that The National Natural Science Foundation of China (NSFC) has played an important role in organizing the research activities related to IGBP. It has supported wholely or mainly about 10 projects in China either directly or more or less related to global change. Some of the above mentioned programmes are chiefly supported by this organization. NSFC has further promised to continue its role in the study of global change in future.

In China prior to the establishment of CNC-IGBP, the Chinese Academy of Sciences (CAS) started a little earlier. Right after the 21st General Assembly of ICSU, the CAS established a group of scientists to investigate the scientific significance and application of the IGBP; to discuss the practical environmental problems faced by human being and Chinese people and how to make contribution to the IGBP; and finally to find our scientific focus. After about a year's hard work, the scientists in the CAS proposed a tentative idea on planning their global change study which is supported by the scientists attending the meeting of establishing the Chinese National Committee for the IGBP.

The focus for the study of global change in the CAS has been put on the impact of land use and water use on the interactive physical, chemical and biological processes and the feedback of these processes on the environment. Because land and water use is one of the practical problems in China and we do think it is also a world wide urgent environmental problem, especially for the developing countries.

The goals for the near term (2 yrs. or so) are:

To collect data and evidences on land and water use and environment in the past years in China (back into the historical and geological records as far as possible).

To analyze the important environmental change due to land and water use by method of system analysis and simple geosphere-biosphere model to find the major factors (natural or man-made) inducing the deterioration of the environment and direct consequences of the ill-use of land and water.

Long-term goals:

To reveal and predict the important environmental changes, especially the changes induced by land and water use.

To reach the goal, we plan to select two transects for the study. One is the latitudinal, the other is longitudinal (the former is the major one and the later is the complementary one). The latitudinal transect roughly crosses the latitude of 40° N, from 75° E to 125° E with a distance of about 3500 km, including most of the Xinjiang Autonomous Region, Qinghai, Gansu, Shanxi and Hebei provinces. The climate characteristics in this area are arid and semiarid which is sensitive to environmental change because it is a climate transitional zone. The reasons for choosing this transect are that 1) it is a transitional zone in climate where environmental change can be easily found: 2) there exist plenty of data sources that can be digged out. The longitudinal transect runs along 115° E longitude from 45° N latitude to 18° N latitude with distance about 3000 km, which covers Inner Mongolia Autonomous region, Hebei, Shandong, Jiangsu, Zhejiang, Fujian, and Guangdong provinces and Hainan Island. This transect crosses different climate zones. The emphasis will put on the different type of crops in order to see the impacts of vegetation on climate and environment.

Besides the above two transects, CAS also plant to upgrade in various degrees the already existed more than 50 stations (widely scattered over China) to monitor various parameters directly for IGBP.

The elements for the study of global change in the CAS consist of observation and data collection (historical and geological records), process studies and modelling.

At present, a review study (a comprehensive review of the existed papers, published or unpublished) on land-water-use-induced climate and environmental change is going on in the

CAS. The ideas for the review study are that we want to see what changes that have already occurred; to try to locate where our present environment in China stands and try find some dominant factors and processes that regulate the changes due to land and water use, etc.. Based on the existing data and papers we are now analyzing and reviewing:

- Changes of atmospheric composition and climate (precipitation, temperature, trace gases, such as CO_2, CH_4, NO_x, etc).
- Changes of types of vegetation (forests, grassland, crops) and their relationships with human activities (e.g. over graze, deforestation, etc.).
- Changes of soils (loess, salty soil, desertification, soil erosion, soil acidification, pollution and degradation) and their relationships with human activities.
- Changes of environment related to water (area of water body, run off of rivers, lake level, swamps, sea level, iced snow cover in winter, recession and advance of glacier, etc.), the causes of these occurrences (if can be found) and impacts on climate, as well as their relationships with human activities.

In order to find relationships between those changes we need powerful tools and analysis methods. So that we shall set up a special group to do the following research work:

- System analysis and simple model by which we may analyze those affecting factors and physical, chemical and biological processes important to land-water-use-induced changes.

In doing so we believe, a much better, more efficient long-term programme for the study of global change in the CAS may be expected.

Besides the above mentioned plan in CAS, CAS and U.S. National Academy of Sciences are discussing of establishing A Joint Study of Climate-Vegetation-Soil Interactions in Semi-Arid Regions. We choose semiarid region as our area of study because it is a kind of climate transitional zone which is sensitive to climate change. The northwest part of China and U.S. Great Plains will be our target regions of study.

Comments on the IGBP planning (Report No. 4)

We think that the Report No. 4 is excellently written. Our overall impression is that it has very clearly documented the reason, the significance in science, as well as the rationale for launching such a new world-wide programme. We do agree that it is the time to mobilize scientists all over the world to involve in the programme.

The scientific objective set out by the Report "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 actions" is certainly very sound. It grasps the essence of the scientific nature of the problem. Further, that a primary goal of the programme is set to be the advance of our capability to predict changes in global environment is very practical. Long-term prediction of the global environmental change is very important for almost all human activities, especially it is essential for long-term planning.

Further an integral picture is important for a programme. The report very well illustrates the four scientific IGBP components and their interdependencies, and makes them into an interconnected integral. Report also raises four important common problems among the components on which we think much attention must be paid.

Although the Report is very well written in general and the scientific objective and a primary goal are very well set, yet we think that under this general scientific objective we need still a more or less concrete focus in scientific aim and under the overall prediction of global environmental change we need more or less specific aim in prediction. If we can find a practically important and scientifically challenging problem, then we can establish a more or less focused scientific objective which meets the general scientific objective of the Report and

our prediction will also become a more or less focused one. An example of this problem is the problem of land use and water use which is our focus in China as described in section II.

Some suggestions

Whereas the study of global change will be a worldwide programme, we should mobilize scientists all over the world to participate. Thus, we have to think some of the practical problems facing the third world countries because they need help in science and technology and support in finance.

To hear their voice there will better be a number of scientists from developing countries to participate in the working groups and panels.

Academy of Sciences, Taipei

Organizing effort

A committee has been organized under the auspices of the Academia Sinica to coordinate all our national effort related to the IGBP activities. During its first meeting held at Taipei in September, 1988, fifteen members were appointed by the president of the academy; the officers were elected by these members; and the by-laws were drafted and adopted.

Present status of related research

(i) Environment Monitoring - Major efforts have been initialized by the National Committee for SCOPE in 1974. One and a half decade of data have been accumulated from a network of stations distributed mainly around the two nuclear power plant sites in Taiwan to monitor radioactivity, heavy metal, and toxic organic compounds. Since 1980, the Mussel Watch Program has been set up to monitor the chemical changes in the coastal zones. More recently, extensive research on the heavy metal concentration, organic content, and carbon/oxygen isotopic composition in living corals have been undertaken hoping to delineate changes on decade time scale caused by modern industrialization. Additionally, there exist a number of networks operated by governmental agencies as well as utility companies.

(ii) Biogeochemical Cycles - for carbon cycle studies, the primary productivity in Taiwan coastal waters has been measured. Furthermore, there are also significant participation of R.O.C. scientists in the international studies of Indian Ocean gases, both observation and modeling. As to the nitrogen cycle, the C and N isotopic compositions of the shelf sediments from the East China Sea and Eastern U.S as well as in nitrate from major water masses in the Atlantic and Pacific Oceans are being measured in order to trace the origin of the organic matter and to understand nutrient chemistry.

(iii) Paleo-environmental Record - Quaternary study is one of the most active research field in earth sciences in Taiwan. Pollen, foram, mollusk, ^{14}C, paleo-magnetism, C/O isotopic composition, ^{10}Be, and U-disequilibrium nuclides have all been applied to sediment. Uplifting, erosion, and deposition rates can be estimated sometimes. In addition, some sudden episode such as island-wide flooding seem to have been indicated.

(iv) Modeling of Local Ecosystems - Several interdisciplinary studies are being carried out with an intention to devise quantitative models for the ecosystems in major river estuaries in Taiwan.

(v) Fundamental Data for Atmospheric Chemistry - A few key rates important for atmospheric chemistry are being measured, experimentally in several laboratories. Examples are those involving NH: NO, CH and SO_2.

Taiwan as a testing ground for environmental changes

From the point of view of geosphere-biosphere program, the island of Taiwan possesses a number of distinctive, perhaps attractive, characteristics: a relatively isolated location, a subtropical setting in the monsoon-typhoon area, extreme erosion, fast uplifting, ecological diversity associated with huge contrast in elevation, an episodic population increase 40 years ago due to the exodus from mainland China, and a sudden and breathtaking industrialization over mainly the past 20 years. All of these should make Taiwan an interesting testing ground for environmental changes, especially those associated with human impact. Therefore, although one can not over-emphasize the importance of keeping a global perspective, the local situation definitely adds to the list of possible contributions to IGBP by scientists of this country.

National priority

In view of the facts that the awareness of the populace of Taiwan toward environmental issues has been sharply increasing lately and that her economy has developed to the point of being able to share some responsibilities on our global environment, this country should and must create a credible research program in environmental studies. The IGBP offers us an opportunity to raise the level of such research to international standard. Furthermore, it enhances our global perspective thus prevents us from focusing too narrowly on purely local issues. For these reasons we intend to promote establishing IGBP related research as a high priority item in the national agenda.

More specifically, we intend to take advantage of the distinctive characteristic of Taiwan areas outlined in section II but concentrate on topics that are both scientifically important and regionally even globally significant. An example is the KEEP project (Kuroshio Edge Exchange Process) which is likely to be endorsed by the National Science Council (R.O.C.) and will be operated as a part of the World Ocean Circulation Experiment. Another is the ongoing studies on local coral, both living and dead. Because of the rapid uplifting, corals covering a wide age spectrum are abundantly exposed on land. With the improved accuracy of the ^{230}Th chronology now obtainable using mass spectrometry, it is expected that their record may be deciphered to reveal unprecedented details. In addition, the lake and tree records have hardly been tapped previously. They may yield surprising insight on the Holocene changes. One aspect of the IGBP which has not received enough of our attention in the past is predictive modeling especially in the global sense. In this we urgently need help through international cooperation. The appearance of power supercomputers for academic research in Taiwan should provide a boost to this subject.

FEDERAL REPUBLIC OF GERMANY

Introduction

This is a summary of the report endorsed by the Working Group of the Senate Committee for Environmental Research of the Deutsche Forschungsgemeinschaft on the International Geosphere-Biosphere Programme (IGBP) as the first scientific planning document for the contribution of the Federal Republic of Germany to this international research programme. It is so far not endorsed by governmental authorities and no funding is currently budgeted for new research initiatives in its framework. International harmonization is sought before the next steps towards an execution of this programme may be initiated.

In general accordance with the IGBP planning - as far as it has been announced - and with plans developed by international scientific organizations, scientists of the Federal Republic of Germany were so far thinking along the lines of three major themes which they feel have to be given very high priority in an international research programme on global change. They are also confident that there exists considerable potential and skill in the Federal Republic of Germany to contribute substantially to the required research. These main areas are:

- The bio-geochemical cycles that have a major impact on the habitability of Earth;
- The coupling of the Earth's subsystems by hydrological processes and the impacts of changes in the water cycle on the whole system;
- Short term processes that occur in the Earth system, effect life on Earth, and may cause major problems with respect to the predictability of terrestrial and oceanic phenomena.

In all of these topics a wide range of interdisciplinary work is necessary to obtain the complete picture of the processes that change the Earth on time scales from decades to centuries and to develop the capability to predict future changes.

The substances that are considered as important for the habitability of the planet originate in the Earth interior being ejected by volcanos, in the soil from where they are liberated by weathering processes and in the biosphere, where many processes are effective to generate substances that escape to the atmosphere, the oceans or are deposited at the ground. These materials are transported between the continents and the oceans by surface and sub-surface run off, they are picked up by the atmospheric circulation and are transportated over long distances and up into the middle atmosphere. Chemical and photochemical reactions transform the substances during these transports.

Water is regarded separately from the other substances because of the overwhelming importance for life and the quite different nature of the processes in which it is involved. Detailed insight into these processes is urgently needed not only in the context of climate research but also for regional studies of erosion processes, desertification, water supply, agriculture and livestock breeding. For these applications it is necessary to shed light upon the water exchange processes between the Earth surface where precipitation is deposited, the adjacent soil layer, the ground water and aquifer systems, the surface and sub-surface run off into the oceans, the evaporation from the oceans into the atmosphere and the global transport by the atmosphere back over the continents and also up into the middle atmosphere where water is decomposed by photochemical processes. Of overriding importance is the controlling role that vegetation and the structure of the Earth's surface plays for the evapotranspiration of water from the continents into the atmosphere and for the partitioning of the precipitated water into the different reservoirs. Water exchange through the upper layer of the oceans's crust has recently emerged as another highly variable but important process that affects the chemistry of the hydrosphere.

In the Earth's history evidently short term events that originated in the Earth's interior played a larger role than believed even a few years ago. Rapid temperature changes in the atmosphere have recently been discovered by high resolution ice-core analysis. Volcanic eruptions are known to be one mechanism with very rapid impact on the chemistry and radiative transfer of the atmosphere with consequences for the middle and lower atmospheres as well as for the biosphere. At the mid-ocean ridges permanent magma-water interaction processes occur that

create the environment for new forms of life. The variations of the sea-level are believed to be partly controlled by processes in the interior of the Earth. These new findings of short terms processes in the solid earth and their possible interaction with the climate system may have considerable impact on the predictive capability of present models for the future development of the Earth's system. There exists therefore a demand for intensification of interdisciplinary research in this area.

For technical reasons the group of German scientists that developed the views presented in the report did not strictly follow the interdisciplinary road which is indicated above in the description of the three major research themes, since these are more or less result of the preparatory work. Instead it worked out research plans in four slightly different structured working groups concerned with:

- Tropospheric chemistry and its interactions with the biosphere;
- Global water cycle and the biosphere (including marine chemistry and marine biosphere);
- Reaction and feedback of the middle atmosphere to changes in the geosphere-biosphere system;
- Interactions of the solid earth and the biosphere.

The general research needs as well as the specific research projects, which are of major interest to German scientists, are summarized below under these four heading, though this does not prejudice a future structure of the German research approach. The proposed contributions of the Federal Republic of Germany are based upon research topics which seem to be feasible with respect to geographical accessibility, logistics and available resources. It should at this point, however, be made clear that certain goals can only be met, if the German efforts be complemented by activities of other nations that are aiming at the same direction. It seems especially necessary to establish an European and further more an international network of activities, which puts the research work of national groups into the global perspective. This starts with a certain standardization and intercalibration of methods, goes on with coordinated research in the critical areas of the globe and ends with the synthesis of all the individual research approaches.

In the report first each topic is introduced in a broader and more general way. It follows an outline of the research which is found to be essential, and a short discussion of its relevance for IGBP. The proposed contribution of the Federal Republic of Germany is then specified, and finally the data needs are summarized.

Major recommendations

A. Working Group on Tropospheric Chemistry and its Interactions with the Biosphere.

General research needs:

- Distribution of trace constituents in the troposphere;
- Processes that govern the production and decomposition of trace gases in the biosphere;
- Reactions of trace constituents in the troposphere;
- Modelling of biosphere - atmosphere interactions.

Contribution of the Federal Republic of Germany:

- Exploration of the role of tropical forests and savannas in Africa;
- Role of the oceans as source for trace constituents;
- Man-made and natural trace constituent emissions of the European region.

B. Working Group on the Global Water Cycle and the Biosphere.

General research needs:

(i) General circulation, carbon dioxide cycle and biologically relevant fluxes in the ocean and at its boundaries:

- Modelling of the large-scale wind-driven and thermohaline circulation in the ocean as well as of the connected fresh waters and determination of the heat fluxes as well as temperature and evaporation fields at the sea surface;
- Verification of the model results by means of historical data sets and specific measuring programs in the ocean;
- Improvement of parametrizations in the models, especially for the oceanic surface layer and at the sea surface;
- Data assimilation, especially inclusion of satellite data for the operation of the models;
- Determination of the solar heat supply to the ocean in dependence of season and sea water turbidity.

(ii) Carbon cycle.

- Modelling of convective processes in high latitudes and their inclusion in ocean circulation models;
- Improvement of our knowledge about gas exchange between ocean and atmosphere;
- Assessment of data sets about sinking processes at high latitudes;
- Assessment of data sets about dissolved CO_2 in the ocean;
- Assessment of data sets of the spatial distribution of the difference between the partial pressures of CO_2 on both sides of the sea surface to calculate the net flux of CO_2 through the sea surface;
- Determination of the solution of organic carbon particles when sinking from the euphotic zone into the deep sea;
- Investigation of the biological and chemical processes in the carbon cycle.

(iii) Biologically relevant fluxes in the ocean and at its border areas.

- Measurements of the primary production and determination of its relation to the particle flux through the water column;
- Interactions between particles and dissolved substances.;
- Influence of the fauna and of microorganisms on the production, decomposition and size distribution of the particles and their chemical composition as well as on chemosynthesis (CO_2 fixation);
- The role of horizontal advection for particle distribution and fluxes;
- Recycling of metals and organic substances at the ocean bottom and the uppermost sediment layers;
- Atmospheric deposition to the ocean and its impact on biogeochemical cycles;
- Deduction of earlier stream fields from sediment distributions and reconstruction of paleo-climatic situations.

(iv) Hydrological cycle above the oceans and interaction with the continents.

- Precipitation above the oceans and the uninhabited areas of the continents (especially by means of satellite remote sensing);
- Moisture distribution above the oceans and the continents by improved application of microwave technology;
- Verification of methods and models by means of experimental studies and data analysis;
- Deduction of the water vapor transport in critical areas by means of improved observations;
- Diagnosis in application to results of numerical models.;
- Determination of the area that contributes to the local precipitation (determination of moisture import to the continents);
- Development of coupled models with improved computation of fluxes between ocean and atmosphere;
- Use of numerical weather forecasts to determine the water and water vapor transport between from satellite data.

(v) Hydrological interactions between land-surfaces, vegetation and the atmosphere.

a) Modelling of single processes that determine the interaction of vegetation with the water cycle:

- Interaction between plant communities and radiation;
- Partitioning of the precipitated water between the different micro-pathways in plant communities;
- Regulation of transpiration by stomata;
- Infiltration of water into the soil;

b) Modelling of complex processes:

- Partitioning of precipitated water between the different reservoirs;
- Area averaged evapotranspiration in dependence of topographic structures;
- Mesoscale modelling of water budgets;

c) Global modelling:

- Parametrization of area averaged hydrological processes in global models;
- Simulation of the global water cycle and its vergencies over the continents;
- Evolution models ("inverse models") for the evaluation and assimilation of satellite data;
- Verification of models and methods of satellite data evaluation;
- Experiments in the scale of single pixels;
- Experiments in the scale of pixel-arrays;
- Experiments in the spatial extent of model grid widths;

- Diagnostics of land-surface and vegetation changes in terms of their hydrological impact;
- Analysis of satellite data;
- Geo-Biosphere Observatories.

(vi) Run-off at the surface and through sub-surface pathways

- Modelling and parametrization of the run-off and the amounts of transported substances;
- Validation in the context of field experiments.

(vii) Man's impact on the water cycle: Determination of changes to anthropogenic influences in the system atmosphere - land surface/land-use-surface and sub-surface run-off

- Sealing of the terrain;
- Canalization in connection with urbanization;
- Irrigation and drainage;
- Intensification of agriculture;
- Deforestation;
- Impact of dying forest on water pathways, erosion;
- Impact of overgrazing;
- Use of water power;
- Tourism.

Application of the models mentioned under (v) to predict the effect of external forcing by man's action on water and substance transports.

Impact of soil erosion on agriculture.

Contribution of the Federal Republic of Germany:

In the Federal Republic of Germany a number of aspects of this general research theme is dealt with by individual research groups. The following areas are of specific interest for interdisciplinary work:

- Oceanic research on the meridional heat and water transports, on marine chemistry and exchange of substances of biological origin between ocean and atmosphere in the northern Atlantic as well as along the European west-coasts;
- Evaluation of satellite data to determine oceanic properties that are related to water vapor and substance fluxes;
- Experimental validation including the application of remote sensing techniques from the ground and from space of water transports through the atmosphere in areas where the present models give doubtful results;
- Hydrological experiments to validate model simulations of the water transfer from the atmosphere to the soil including groundwater and aquifer systems in Europe as well as in Africa;
- Hydrological experiments in areas, where land-surface and vegetation changes occur in order to clarify and to model the role that vegetation plays in these processes;

- Development and experimental validation of algorithms which are necessary to use satellite data for the global assessment of soil and vegetation properties related to hydrological processes and application of satellite data to analyze changes of these properties.

C. Working Group on the Reaction and Feedback of the Middle Atmosphere to changes in the Geosphere-Biosphere System.

General research needs:

- Changes of the concentrations and spatial distributions of atmospheric constituents that originate in the biospere or solid earth and their impact on the radiative transfer as well as on the chemistry in the middle atmosphere;
- Development of coupled photochemical and dynamical models for the middle atmosphere and their coupling to the troposphere;
- Application of new techniques in combination with conventional observations to monitor the changes that occur in the middle atmosphere over time scales relevant for global change;
- Research to explain the magnitude and latitude dependence of observed temperature trends in the middle atmosphere and its impact on the middle atmosphere - troposphere coupling;
- The effect of changes in the hydrological cycle on the troposphere - middle atmosphere coupling;
- Biological effects of changing UV radiation due to ozone depletion.

Contributions of the Federal Republic of Germany:

- Middle atmosphere modelling (dynamics and photo-chemistry);
- Participation in the establishment of middle atmosphere observatories for model validation and long time measurements including remote sensing from the surface (e.g. Spitzbergen) and multitemporal flights with aircraft;
- Evaluation of aerological and satellite data for long term diagnostic studies of changes in the troposphere - middle atmosphere coupling;
- Participation in multinational measuring campaigns (from ground, aircraft, balloons) to explore critical components, investigate processes and support long term monitoring by supplemental measurements, intercomparisons and re-calibration.

D. Working Group on the Interaction of the Solid Earth and the Biosphere.

General research needs:

- Investigations of short term paleoclimatic changes, of the processes that lead to such changes and of their impact on the biosphere
- Endogenic and exogenic causes of sea-level changes
- Research on the release of constituents into the troposphere and the middle atmosphere by volcanic eruptions, its effect on the biosphere and the hydrosphere
- Measurements of geodynamic processes in nearly real time

- Extent and development of substance transports in the rivers and its dependence on natural and anthropogenic influences

Contributions of the Federal Republic of Germany:

- Paleoclimatological reconstructions for the time intervals 18 000 - 10 000 and 125 000 - 115 000 B.P.
- Evaluation of data from geodetic satellites
- Investigations of mid-ocean ridges
- Measurements of substance fluxes at characteristic sites in different climatic zones
- Investigation of the impact of sea-level rise at European coasts
- Participation in Geo-Biosphere Observatories.

E. Data Needs.

The scientists of the Federal Republic of Germany welcome the instrument of Geo-Biosphere Observatories to perform long-time research of excellent quality in critical spots of the world which are representative for larger areas or for specific processes of global importance. They have to be operated by, if necessary, multinational cooperation of highly qualified institutions. The first order observatories must be equipped with modern instrumentation to allow

- observations of the changes of vegetation and hydrology (from the lithosphere to the atmosphere) at the site and in its surrounding in order to achieve representative data.
- measurements of chemical components of interest for global change,
- observations in the middle atmosphere by means of remote sensing from the ground,
- calibration of satellite observations and quality control of the products derived from satellite measurements,
- possibility of field experiments in the surroundings of the station to investigate processes of special concern.

IGBP relevant individual scientific results scattered throughout the literature should be complied under the aspect of multidisciplinary research.

The distribution of data by means of electronic mail should be fostered and user-friendly data banks be established that include also e.g. hydrological data which are now not yet assessed by national services as well as geochemical and paleoclimatic data.

In different sectors of the IGBP research satellite data are urgently needed and the products derived from these data have to be combined with conventional and other remote sensing data in geocoded information systems. Full use should be made of the activities initiated by ISCCP and ISLCP. Future satellite systems have therefore to be designed according to the needs of IGBP and an easy and cheap access to the data for IGBP studies has to be guaranteed.

For air chemistry, middle atmosphere and biospheric research well equipped aircraft are mandatory. An internationally coordinated aircraft measuring program should be initiated.

User-friendly banks for geochemical and paleoclimatic data should be established.

FRANCE

Scientific rationale

Since man first appeared on the face of the Earth, he has seen considerable changes to his environment. Until the last century, these were essentially due to natural causes triggered by variations in the planet's weather patterns. Man thus lived through the ice ages, which cause significant cooling of the upper latitudes and widespread drought in the tropics. These major climatic variations were accompanied by appreciable physio-chemical changes in the ocean-atmosphere system and the continental environment: during the ice ages, the atmosphere contained less carbon dioxide and methane (which have a direct effect on the radiation reaching the planet), vegetation was generally sparse and the deserts were spreading. The minute human communities were able to survive these upheavals in their environment by continuously migrating in search of areas where they could find food.

Since the middle of the last century, human activity has reached such a level that it is now likely radically to alter both our environment and that which humankind will have to live with in the 21 st century. Indeed, anthropogenic waste is altering the chemical composition of the atmosphere and the ocean. It is disturbing the radiation balance of the planet, the ozone layer which screens out ultraviolet rays, and the disturbing of nutrients enabling the continental and marine ecosystems to survive. Desertic areas are spreading, the aerosol load of the atmosphere is increasing, inducing a feedback change on climate and an irreversible disturbance in the continental ecosystems.

The gravity of the situation can easily seen by comparing the speed of environmental change for purely natural reasons with that resulting from human activity. The change in the carbon dioxide level in the atmosphere resulting from transition from a glacial period to an interglacial period is about the same as that resulting from human activities. However, in natural conditions, these variations took place over several thousands of years, whereas man has managed to produce them in one century. Human activities increase with the growth in the number of industrialized nations and it is now clear that the carbon dioxide content in the atmosphere will have doubled during the next century and that of other gases such as methane or nitrogen oxides will have increased in even greater proportions.

Simulations performed on climatic models developed over the twenty years have shown that alterations to the chemical composition of the atmosphere will result in a significant change in the balance of the planet's weather. Predicting the short-term (next century) consequences of human activities is made all the mode complex as they are following an almost exponential growth curve. The weather system does not therefore have the time to adapt to the new conditions imposed on it, since it involves not only the atmosphere, but also the ocean and the cryosphere, whose time constants are much longer. The optimistic view that the effects of anthropogenic interference will thus be delayed by several decades should be treated with caution: study of ancient climates has shown that the weather system does not react to external forces in a linear manner and is quite capable of extremely sudden and large-scale variations.

Forecasts on the condition and habitability of planet Earth by the next century cannot therefore simply be deduced by extrapolating current trends. Considerable progress has nonetheless been made in the last decade, since we now know how to simulate climates using general atmospheric circulation models, how to describe the main atmospheric and marine phase of the principal biogeochemical cycles and how to simulate the reaction of some ecosystems to changes in average weather conditions.

The purpose of the International Geosphere-Biosphere Programme is to organize coordinated action to describe and understand the physical, chemical and biological processes which interact to regulate the environmental conditions prevailing on the surface of the Earth. In the long run, this research will lead to a prediction of how human activities will disrupt this system.

It is clearly impossible for a country like France to deal with the entire problem. It does however have internationally recognized specialists in various fields. The French contribution to this program is aimed at stimulating collaboration between physicists, chemist, geochemists, geologists, pedologists, hydrologists and biologists in order to achieve the following objectives:

1 - With a view to creation of models, describe and understand the essential processes controlling the Geosphere-Biosphere system and how they interact.

French teams have achieved recognition in the main fields concerned, in particular weather dynamics, the physical chemistry of the atmosphere and the ocean, and continental and marine ecology. The main effort will be on the interaction of these various fields.

2 - Describe the evolution of the Geosphere-Biosphere system

The recreation of past changes, mainly during the last climatic cycle, in order to examine the entire range of planetary natural variations, requires study of samples from continental, marine and glacial sediments.

The evolution of the Geosphere-Biosphere system in the coming years will use satellite observations. This should be closely linked with ground-based observation, which is essential for calibrating the data recorded from space. France can play an important role in obtaining global data thanks to its presence in countries overseas.

The quantity of data accumulated during the coming decades will be considerable. It would be desirable for the teams which are the world leaders in their particular fields to play an active role in the achieving effort, which would facilitate their access to data and thus increase their effectiveness.

3 - Integrate all the process studies conducted in France and abroad into a global model.

The objective here is the development of global models including the physical, chemical and biological mechanisms which govern the evolution of the geosphere-biosphere system.

Understanding the geosphere-biosphere system

The climate, the physico-chemistry of the atmosphere, the marine geochemistry - closely linked to the activity of plankton - and the continental ecosystems, are the essential links in the interactive chain controlling the Geosphere-Biosphere system.

The national symposium held in Meudon on 19th and 20th April 1988 showed that the action undertaken by the CNRS, the Environment Ministry, the CNES, the National Meteorological Office, the ORSTOM and the TAAF constitutes a solid basis which can be built on for the French participation in the IGBP programme. These research programs already under way, should receive the additional funds enabling them to meet the extra objectives set for them under the IGBP. In other areas, the national capacity is not concentrated in incentive projects and the development of coordinated research programs to fill this gap is one of the aims of the French IGBP scientific committee.

The climate

The zones of vegetation are closely linked to the large climatic zones, characterized by a seasonal temperature and precipitation distribution. To make a reasonably reliable forecast of the state of the surface of the planet and the continental biosphere in the coming century requires a realistic simulation of climatic conditions as its starting point.

In doing this, it is out of the question simply to use statistics, covering periods of varying lengths as supplied by the world's meteorological network. Since modifications to the content of the minor components of the atmosphere resulting from human activities has a significant influence on the radiative balance of the atmosphere, the climate of the next century will not be the same as that we have known.

Any attempt to forecast it must therefore be based on a climatic model and on a clear understanding of the basic physical processes involved. Models of this nature are being developed in the majority of industrialized countries and France has made a major effort in this field with the implementation of the National Study Programme of Climate Dynamics (PNEDC in French), the French component of the World Climate Research Programme (WCRP).

The main lines of this action comprise participation in several international programmes: the above mentioned WCRP, the CO_2 cycle study, the long-term variability of the world climate and programmes as TOGA and WOCE which aim towards a better understanding of the interaction between atmospheric circulation and transient modes of different basins of the tropical ocean, for the first one, and the sensitivity of the world climate to global oceanic circulation.

For the second one, a set of studies, the majority of which concerns the first objective of the World Climate Research Programme, aim at extending forecasting to several weeks. This is necessary in understanding the response of the biosphere to climatic fluctuations and chiefly entails.

- The study of the radiation balance and its cloud-related disturbances: recent studies of the sensitivity of the atmospheric general circulation models to an increase of carbon dioxide in the atmosphere have shown a large dependence on radiative forcing by clouds. Thus, the reliability of the simulations using climatic models depends upon their ability to take into account the three-dimensional distribution of the clouds, their optical properties and the feedback of the cloud coverage in response to external forcing.

- The study of the continental surface processes and the effect of the water cycle on the structure and variability of the atmosphere, including an active participation in the ISLSCP project which aims to study the energy exchange at the surface-atmosphere interface using satellite observations.

- The study of ocean-atmosphere interaction to improve the determination of sensible heat and latent heat exchanges at the air-sea surface.

- The study of the carbon dioxide cycle and its disruption by human activities, including monitoring of the variation of the concentration of CO_2 in the atmosphere and the study of the penetration of the anthropogenic CO_2 in the superficial and deep ocean.

- Numerical modelling of general atmospheric and ocean surface circulation, on a monthly and seasonal scale,

- Development of a 3-dimensional general circulation model combining the ocean and the atmosphere.

This action has been stated up in a document already published and will not be repeated here again. In relation to these objectives, the IGBP programme requires an increased effort to take account of the water cycle, the trace elements, the aerosols and the energy and chemical exchanges between the biosphere and the atmosphere, as well as how they interact with each other. In addition, the mechanism of how the Geosphere-Biosphere reacts to external factors such as variations in solar flux, volcanic eruptions, etc., must be sufficiently well understood and modelled for natural effects to be clearly distinguishable from anthropogenic effects.

In view of the high degree of collaboration between scientific teams encouraged by the PNEDC, this programme constitutes the natural framework for these developments, provided that it receives the appropriate resources.

The interaction between climate, biosphere and marine chemistry

To forecast the condition of the planet in the next century implies that we are capable of simulating the physical, chemical and biological characteristics of the euphotic layer (the illuminated zone in which photosynthesis occurs) in response to the conditions imposed by the atmosphere, and to estimate the variations in the primary production and oceanic cycle of carbon dioxide. This is the major objective of the Oceanic Matter Flux (OMF) programme, the French component of the Joint Global Ocean Flux Study (JGOFS). This is aimed at finding out how the ocean regulates the cycle of its main elements, by quantifying the biogeochemical processes controlling the production and the future of mineral and organic matter in the sea.

The originality of the approach followed in the FMO programme lies in testing the quality of our understanding of the processes, studied locally, by attempting to acquire a global view of

the oceanic system, itself leading to an understanding of the role of oceanic behavior in the planetary whole. This approach, which firmly intends to be quantitative and global, should enable an estimate to be made of the flux of matter entering and leaving the various oceanic compartments and the causes of variations therein to be evaluated. This particular requires establishment of the relationships between the carbon cycle and that of the other elements, in order to be able to model the process of interaction between living matter and the chemical compounds present in the sea in particle or solution form.

The problem has recently become more acute owing to the impact of man's activities on the chemical composition of the ocean: industrial development has reached such a level that waste release into the ocean (direct or via the atmosphere) is no longer negligible in comparison with the matter brought in by the rivers or the atmosphere. This means that the oceanic basins bordered by the most industrialized continents (the Mediterranean or even the North Atlantic), the natural flux of many elements is now significantly disturbed and will be even more so in the coming decades.

It is not as yet possible to establish predictive models to estimate the large-scale impact of industrial vast on the ocean and to evaluate the amplitude of the disruption on the natural cycles of the main elements. The primary cause of this stems from the fact that we so not understand all the processes controlling the marine part of the biogeochemical cycles at a regional level, at an oceanic basin level and at a global scale, and that we have not yet determined the time constants associated with the predominant chemical reactions. Parametrization of the major processes governing the biogeochemical cycles will therefore have to be determined if the impact of disruptions of anthropogenic or simply climatic origin on the global oceanic balance is to be assessed.

These problems were the basic reasons for the FMO programme, its aims being:

1) To examine the behavior of the elements involved in the biological process, with respect to the carbon cycle, and to measure their flux in a few typical stations,

2) To clear up certain doubts on the carbon cycle (and primary production) which have a direct effect on the evaluation of the fluxes of the other elements in the ocean,

3) To establish models simulating ocean flux at an oceanic basin level, in order to establish the factors to be included in a global model.

The main lines of this program have already been published and will not be repeated here. The FMO Programme, which has now entered its operational phase, brings together some eighty researchers from a dozen laboratories and its activity will peak in the period 1990-1996.

It should constitute the main areas of participation by marine biologists and geochemists in the IGBP programme.

Interaction between the biosphere and the physics and chemistry of the atmosphere

The physico-chemical balance of the terrestrial atmosphere is the result of a complex set of phenomena which can be described in terms of cycles: source components in gas or particle form are emitted on the surface by physical or biological processes. They diffuse into the atmosphere, where, under the influence of solar radiation, chemical interactions occur, leading to a breakdown into minor components according to the altitude. They cycle is then closed by sink species, which disappear from the atmospheric component by destruction on the surface, dry deposit or leaching by rain. The natural balance of the terrestrial environment is thus the result of interaction between those giant reservoirs of energy and matter; the atmosphere, the oceans, the biosphere, and the cryosphere.

Human activities, linked to industrial and agricultural development, have led to the release of components into the atmosphere which either already existed naturally, such as carbon dioxide CO_2, methane CH_4, nitrogen monoxide N_2O, or the nitrogen oxides NO and NO_2, or which did not exist, such as chlorinated compounds or certain hydrocarbons. The effect of these additional sources appears very clearly, since the relative concentrations of these species have been rapidly increasing in the atmosphere over the last thirty years: +1% per year for CO_2, +1.5% per year

for CH_4, +0.4% per year for N_2O, and between +5 and +10% per year for chlorinated compounds. This modification of the chemical composition of the sources, whose anthropogenic component is of the same order of magnitude as the natural component, and on the response times of a system, the atmosphere, corresponding to several tens of years and thus extremely short in comparison with the time constants characteristic of the large climatic balances.

For the troposphere, the action taken within the framework of the Atmospheric Phase of the Biogeochemical Cycles programme (CNRS, Environment Ministry) and in the EUROTRAC Programme within Europe, is aimed at describing and quantifying the processes which control the biogeochemical cycles of the trace, gas and particle elements which are physically and chemically active in the atmosphere. This research is along six main lines:

1) Parameterization of the processes controlling the distribution and intensity of natural sources of trace components (marine and terrestrial biospheres),

2) Study of homogeneous or heterogeneous chemical reactions which produce compounds in the troposphere whose physical and chemical properties can vary widely from those of the initial components,

3) Modelling of the horizontal and vertical transport processes governing the spatial distribution of the trace components,

4) Quantification of the processes of dry and wet elimination from the tropospheric reservoir,

5) Climatology of the trace components in the troposphere and evaluation of the short and long-term composition of the air, whether dealing with current trends on a regional and global scale, or past evolution

6) Feasibility studies on new instruments and methods.

Study of the middle atmosphere (10-80 km) is today closely linked to the problem of the ozone balance and its possible modification under the effect of human industrial and agricultural activities. Understanding and describing a change in the ozone layer requires a number of precise measurements with scales of time and space far lower than the envisaged trends, so that the natural variability can be extracted. The measurements strategy is currently being redefined by the international scientific community. It is based on joint satellite and ground measurements, since these latter alone are capable of providing precise calibration of the on board instruments. The French community played a major role in defining the new generation of ground-based and balloon-borne instruments for measuring the ozone layer, the physical structure of the middle atmosphere and its chemical composition. This research will be conducted further under the programmes, already existing in France (CNRS, Environment Ministry, CNES).

These projects occupy about eighty researchers from fifteen or so laboratories. The experimental and modelling skills developed within the framework of these national programmes enables the French community to envisage a contribution to the various aspects of research into the physics and chemistry of the atmosphere under the IGBP Programme and in particular under IGAC (International Global Atmospheric Chemistry), MARC (Middle Atmosphere Response to Changes) and STEP (Solar Terrestrial Energy Program).

The specific steps to be implemented and coordinated are:

- Study of atmosphere-biosphere interaction: spatial signature of the characteristic parameters of the ecosystems and of the sources of chemical compounds. Modelling of fluxes and scale integration,

- Study of two major terrestrial ecosystems: the equatorial rain forests and the savannas, using the special contacts enjoyed by the French community with African countries. The emphasis will be placed on the role of biomass combustion on a regional and global scale,

- Study of the cycle of the desert dust (Saharan dust) and its climatic and biogeochemical impact. Parameterization of the raising function - modelling of large scale transportation,

- Regional ozone budget - quantification of exchanges, transportation and chemical interactions,

- Global study of the composition and structure of the middle atmosphere by coordinated utilization of data from the UARS satellite and other sources.

Response of the ecosystems to climatic and chemical forcing

The ecosystem plays a key role in the biogeochemical cycles: vegetation traps the atmospheric CO_2 and synthesizes organic matter, while releasing the water taken from the soil in vapor form. The gas exchanges between the atmosphere and the vegetation depend on the foliation index (surface of leaves per ground surface unit) and the stoma openings. When plants or animals die, their components return to the soil. The majority is broken down by the fauna and microflora in the soil into simple mineral elements, which can be absorbed by plant roots, or evacuated from the system by drainage or trickling. A small part is incorporated into the organic matter of the soil, which also breaks down, but much more slowly.

This qualitative description has been known for a long time. At the present time, and for certain ecosystems, we have models allowing predictions to be made of the CO_2 and water vapor exchanges at an hourly, daily or seasonal level. We are however lacking in models of the evolution of the ecosystem, in particular its ground component, over longer periods (10 to 100 years). Further, the effect of the coral ecosystem, which can trap considerable quantities of CO_2 in the form of $CaCO_3$ should be quantified. The main aim of the research will be to understand and model the functioning of the ecosystem and its evolution on a time scale from a season to a hundred years.

It is particularly important to test the effect of the changes wrought by man (CO_2 enrichment and climatic modifications) on the stocks of carbon in the vegetation and the soil: This requires interactive linkage between the biosphere and the atmosphere, which can be envisaged in several ways: aerodynamic and energy linkage, hydric linkage, physico-chemical linkage. We will therefore have to look for the parameters - if possible observable by satellite - which characterize the earth's surface (albedo, surface temperature, foliation index, rugosity, etc.) and which will allow calculation of the radiation, water vapor, sensible heat and moment fluxes with several levels of spatial precision. However, for a surface covered with vegetation, these fluxes are not independent: their regulation by primary production, evapotranspiration and decomposition must be taken into account, along with their own specific reactions to environmental variations. With this in mind, an ascending hierarchy approach would seem appropriate, in order to simplify the functional models established for the main types of vegetation, with spatial extrapolation to attain the biosphere integration level and compatibility with the global atmospheric models.

This general objective, to reach a functional model of the biosphere with a medium and long-term predictive capacity, can only be reached by combining several approaches:

1 Mapping of the main types of vegetation and soil: Satellite data are vital in updating ground utilization maps in fast-changing zones (deforestation in the tropics).

2 Process studies:
study of photosynthesis, transpiration, decomposition of organic matter on representative systems: effect of CO_2 enrichment, temperature variations, contribution of water and minerals. These studies should lead to the creation of process models and their integration into an ecosystem model.

3 Field studies:
measurement of gas fluxes at the vegetation-atmosphere interface (CO_2, H_2O, CH_4, NH_3, etc.) vegetable production, hydric balance of the soil, biogeochemical cycles, These studies will enable ecosystem models to be tested locally and regionally.

4 Spatialization:
The ecosystem studies must be transferred to a global scale (100 km x 100 km) using satellite mapping and measurement.

Of the lines of research to be promoted within the IGBP programme, we should mention the following:

- in-situ and remote measurement of the foliation index, a key parameter in ecosystem models,
- experimental and modelling studies of the soil component of the ecosystems,
- production of continental geochemical balances: organic matter - mineral matter linkage in transportation by water, sedimentary fluxes linked with climate and anthropozation
- integration of the functional ecosystem approach and the approaches based on the biological properties of species and specific diversity (vegetable succession models),
- quantitative analyses of spatial structures (geostatistical, fractial analysis, etc.) to understand the diversity and heterogeneous nature of vegetable formations.
- study of the evolution of the interfaces between vegetable formations (forest-prairie boundary at altitude, steppe-desert limits, forest-savanna limits, etc.) which constitute transitional zones CO_2 (ecotones) which are in theory more sensitive to climatic changes.

France possesses skills in the study of functional ecosystem processes: evapotranspiration (in particular following the HAPEX-MOBILHY operation and the work done within the ISLSCP Programme), CO_2 exchanges (in low vegetation rather than forests), evolution of organic matter in soils, erosion, as well as in the field of remote-sensing image processing. A considerable effort remains to be made in the theoretical aspects of the change in the level of integration of functional processes and modelling at the biosphere level, which can now be approached in a quantitative manner using remote-sensing satellite data.

Describing the evolution of the geosphere-biosphere system

Neither the biosphere nor the geosphere is stable with time. It is therefore essential to document this variation on a time scale comparable with that which governs the fluctuations of the main processes involved.

Past evolution

A reconstruction of the last climatic cycles (several hundred millennia) constitutes a remarkable test bench, since it allows exploration of a range of the greatest biospheric fluctuations of the last million years. It is made easier by the presence of a large number of "archives" in the glacial, continental and marine environments. In addition, current technology enables us to recover continuous samples in environments as hostile as the heart of the Antarctic and the roaring forties.

This theme was first of all tackled by a quantitative approach under the PNEDC's paleoclimatology programme. It involves about sixty researchers from fifteen or so laboratories. Their work has revealed phenomena of unsuspected magnitude, such as the natural variability of the atmospheric content of carbon dioxide or the extreme rapidity with which certain climatic changes occur. The variability of the hydrological cycle at the continental surface is also one of the selected themes of research.

The linking of glacial, continental and marine data should allow a reconstruction of the natural evolution of the geosphere-biosphere system to be made, in association with glacial-interglacial climatic oscillations, in particular:

- evolution of temperatures on a world scale,
- evolution of the chemical composition of the atmosphere (CO_2, CH_4, NO_x),
- evolution of the dust content of the atmosphere,
- evolution of the water cycle on the continents,
- evolution of vegetation cover,
- evolution of the quantity of carbon stored on the continents,
- variability of the oceanic environment (circulation, chemistry, ecosystems),
- reconstruction of the major biogeochemical cycles.

A major effort will be made on the search for linkages within the carbon cycle, involving the ocean, the atmosphere and the continental ecosystems. Under the Geosphere-Biosphere programme, it will be essential to clear up a certain number of uncertainties remaining on the continental phase of this cycle.

This existence of very large scale fluctuations, likely to occur on a time scale of about a century, demands that a technological effort be made to obtain long series enabling reconstruction of environmental variations to a very high level of resolution (several decades). This will notably require drilling into the icecaps of both hemispheres and extremely long core samples being taken, or ocean drilling using dynamic positioning vessels.

Evolution over the coming decades

There are two main types of tools for monitoring the evolution of the planet's surface: permanent networks of ground-based observatories, and satellites. The two types of data supplied by these tools complement each other well.

Satellites give an overview which is repetitive and integrated into an appropriate mesch, but only measure the luminance at the top of the atmosphere. These luminance values are then subjected to spectral and spatial integration, thus giving an average view of surfaces of between 100 m^2 and 1000 km^2 depending on the satellite. It is then necessary to use analysis methods to convert these luminance values into parameters able to describe the Earth. For their part, the geophysical observatories allow more direct measurement of the parameters involved in the processes, although these measurements are of course local. Understanding and monitoring the changes on our planet and its climate therefore rests on joint analysis of the data received from satellites and observatories, analysis which requires the use of models taking account of the nature of the phenomena, the spatial and temporal scale on which they are seen, and the parameters which can be measured. During the current development period, it is essential to validate and calibrate the analysis models. This leads to cross-comparison between the in-situ measurements taken by the various observatories.

This procedure has already been used in a large number of national or international programmes, such as ISCCP, thus enabling the French scientific community to make an effective contribution to the observation programmes to be conducted under the IGBP. It is based on:

1. Highlighting and examining the parameters and indices accessible to space-based measurement and sensitive to the processes under study. We are not yet familiar with all those parameters and indices accessible to space-based measurement and whose variations are closely linked to those of the geosphere-biosphere system. For example, it was possible to note the satisfactory correlation between the AVHRR standardized reflectance index, vegetation, the biomass, the fraction of solar energy absorbed, etc. This opens up a whole new field of investigation: the search for such parameters, their theoretical justification, and then their utilization.

2. Development and finalization of algorithms for analyzing satellite data, and their validation. A large number of parameters have already been developed under major international programmes such as ISCCP or ISLSCP to determine surface parameters: the task here will not simply be to make these algorithms more accurate and more stable, but also to create algorithms giving access to the measurement of the characteristic parameters and indices of new processes. One of the new needs will be to look for the signatures induced on the surface of the earth by these processes (for example, emission of CH_4 (or other gases), wind or water erosion, changes in surface condition, etc.).

3. Application of the methods developed to studying and monitoring the Geosphere-Biosphere system:
   - monitoring of vegetation, in particular the "green wave", whose space-time variation in relation to rainfall, radiation and humidity will in particular be examined,
   - highlighting of CO_2 and CH_4 sources and how they relate to evapotranspiration, temperature and humidity,
   - study of the water cycle under the GEWEX project (Global Energy and Water experiment).

Modelling the geosphere-biosphere system

The aim of the "modelling" part of the IGBP is to develop global models of the environment, including the physical, chemical and biological mechanisms which control its evolution. Current models of the climate system naturally constitute the basis of these future models, but their application to the problems of forecasting the environment on time scales of several decades or less means that drastic improvements will have to be made to their accuracy, effectiveness and reliability. The physico-chemical and biological aspects are currently much less advanced and often correspond to local models, which have to made more systematic and generalized to meet the objective mentioned above.

Development of physical models of the climate system

The coming years will have to be devoted to improving our models of general atmospheric circulation and linking them up to the ocean surface and general oceanic circulation models, as well as to developing simplified models, notably two-dimensional (latitude-altitude) models of the climate system.

The need for future modelling of the interactions between the ecosystems, in particular continental, and the climate, means that for the general atmospheric circulation models, we will have to go beyond realistic simulation of the mean and variance values to achieve a good representation of the many different atmospheric circulation conditions which give rise to extreme meteorological situations, along with their probability of occurrence and duration. Furthermore, an intensive numerical examination of environmental evolution on time scales of about half a century will only be possible if the appropriate tools are developed, in other words, efficient models with low spatitial resolution. This presupposes that the as yet unsolved and delicate problems of scale parameterization find a solution.

A major critical point is representation of the water cycle. This aspect requires narrow interpretation of the modelling programmes and observation programmes, notably from space, prepared under the GEWEX project. An particular effort will have to be made on modelling, not only of precipitation, but also of clouds and their different optical properties. The stabilizing or amplifying mechanisms linked to the interaction of clouds and radiation indeed play a determining role in the global and local climatic response to variations in the concentration of greenhouse-effect gases.

The other essential point of the physics of the water cycle is parameterization of the energy flux at the soil-atmosphere interface. We must evidently obtain representations of evapotranspiration from the vegetation cover, which are reliable but as simple as possible, integrating discrepancies on a scale smaller than the model mesh, and in close liaison with satellite observations of

foliation indices and the in-situ measurement programmes such as HAPEX-MOBILHY, HAPEX Niger or others to be defined in the future.

Even if it is not yet as advanced as its atmospheric twin, ocean modelling is today the subject of intensive numerical experimentation, and this will increase in the future. Priority is given in the near future to the linkage between atmospheric models and oceanic mixed layer models, which is a relatively simple and obviously temporary solution, but one which means that a certain number of the interesting problems posed by the IGBP can be dealt with in a reasonably realistic manner, in particular the impact of the greenhouse-effect gases on the climate, thus paving the way for future global models of primary production in the ocean and physico-chemical exchanges at the interface.

It should however be noted that a detailed simulation of general oceanic circulation remains a medium-term necessity. Preparation for this requires major investments in numerical experimentation. The first stage is the development of dynamic models of the development of dynamic models of the tropical ocean which, when linked with the general atmospheric circulation models, will reveal the inter-annual variability involved in the TOGA type mechanisms.

The physico-chemical and biological aspect

Certain physico-chemical or biological mechanisms have already been integrated, or can be integrated in the short-term, into global models of climate dynamics. Simulation of long-term variations in ozone distribution is, for example, well under way, with modelling of the linkage processes between dynamics and photochemistry. For the time being, the most complex photochemistry models have only been coupled with simplified (2-dimensional) models of atmospheric dynamics, and a general atmospheric circulation model has only been coupled with simplified photochemistry models. However, the coupling of a complete photochemistry model with a 3-dimensional general circulation model would seem to be not too far away.

General circulation models including atmospheric transportation of desert dust, or the water isotopes cycle, have already been developed and should be refined with respect to the parameterization of the raising of dry and wet deposits. These models could serve in part as the starting point for a numerical simulation of the cycles of other trace elements.

Matter transfers (CO_2, H_2O) at the continent-atmosphere interface are commonly represented by local models of primary production, validated by satellite observations. These models should be generalized and integrated into the mesh of general atmospheric circulation models, leading finally to a global model of the evolution of terrestrial ecosystems, interacting with a simulation of the climate.

Matter fluxes in the ocean are currently the subject of local models under the FMO programme, in particular with regard to the production and sedimentation of large biogenic particles and the distribution of metals in limited oceanic areas. Modelling of primary production in the mixed oceanic layer is well under way and the first linkages of this type of model with the physical models of the mixed layer allow interactive simulation of the optical properties of the ocean surface layers and the corresponding absorption of radiation.

The distribution of the CO_2 transfer coefficients on the surface is today modelled and validated by comparison with SEASAT data, pending NIMBUS-7 and ERS-1. The development of more complex mixed layer models will in the future give the distribution of the surface concentrations and lead to a better simulation of the exchanges involved. here again, the need for constructive interaction between modelling and observation should be underlined. The next stage, preparation for which must begin now, is the modelling of CO_2 distribution within the ocean.

The resources required

To see such a program through to a successful conclusion, the French community will need extra resources in addition to those of the programmes under way. To a large extent, these resources are destined for long-term surveillance of the critical parameters of the Geosphere-Biosphere system (with high-quality data) and to enabling modelling of this system to be

achieved with a level of complexity allowed by both a better understanding of the processes involved and the development of data processing means.

Satellite observations

The IGBP programme should first of all enjoy the benefits of the data supplied by the application satellites: SPOT (and more particularly SPOT 4 with its VEGETATION instrument), METEOSAT, and more generally the instruments on the European, American and Japanese polar platforms.

France already participates in the space aspect of the World Data Research Programme, in particular by its contribution to the ISCCP and ISLSCP programmes, its important role in TOPEX/POSEIDON, and its contribution to ERS-1. In addition, France submitted a proposal for an contribution to the GEWEX experiment, with the BEST project, aimed at examining the water cycle on an international cooperation basis. The recent French project for satellite observation of the water situation, proposed in answer to the EOS (Earth Observation System) call for tenders, is an important addition to this programme.

An instrument more specifically destined for continuous observation of the ozone layer should be decided on by the European Space Agency for installation on the polar platform. The French scientific community is well placed to play a major role in defining and launching an instrument of this nature. In the shorter term, the 1990's will be marked by the analysis and utilization of the data obtained by the UARS satellite, with which the French community is directly associated, and by the continuation of a solar flux and spectral distribution surveillance program(Spacelab flight and ATLAS mission).

Finally, within the framework of Franco-Soviet space cooperation, the IGBP was chosen as one of the priority topics for long-term cooperation. Following on from programs which are either current or at present being defined, the theme of this cooperation will be cloud behavior under the effect of the build-up of greenhouse-effect gases in the atmosphere and how this affects the climate through the radiative transfer process. Since this activity will require major space resources, it should be partially financed by the budget assigned to the development of civil space activities and should thus benefit from the CNES resources for this purpose.

Ground-based observations

The French scientific community anticipated the recommendations which should lead to the creation of a network of Geosphere-Biosphere Observatories. It has participated in the development and acquisition of surface parameters within the framework of several campaigns, in particular HAPEX-MOBILHY, and is preparing HAPEX-NIGER it has also a recognized experience in long-term surveillance of the atmosphere, and has both the advanced instrumentation and the particularly well-suited sites to play an important role in this network:

- With its full range of measuring instruments (lidar, UV/visible/microwave spectrometers, balloon sonders), the geophysical station of the Observatorie de Haute-Provence is a model example of the modern international atmospheric monitoring stations currently being built.

- The Observatorie du Pie du Midi, at 3000 meters altitude, is one of the least-polluted areas of Europe.

- New Amsterdam Island, an unpolluted site at medium latitude in the Southern hemisphere, where CO_2 surveillance has been under way for several tears.

- Dumont d'Urville base in Antarctica, where an ozone observation station is to be set up.

- The numerous ORSTOM stations, which would allow installation of observatories in areas of critical ecosystem change.

Balloon sond programme

The instrumentation developed in the French laboratories, and the CNES national balloon launching capacity means that two types of approach can be envisaged:

- Study of the dynamics and balance of long-life components in a Lagrangian approach, using long-duration balloons (STRSETOLE project).

- Physico-chemistry and dynamics on a local scale using traditional stratospheric balloons.

Aircraft programme

The Atmospheric Research and Teledetection Aircraft (ARAT will be extremely useful to test the instruments developed for measuring surface parameters from space and to study the spatial variability of the structure and composition of the atmosphere on a regional scale. Besides, the development of sophisticated remote-sensing experiments to be installed in the ARAT, and the cooperation programmes with NASA, are preparing France to play a leading role in the operation of the longer-range wide-bodied aircraft which the European community should be acquiring to study the chemical composition and troposphere-stratosphere exchanges on a much larger scale.

Data banks

An observation programme on this scale will certainly lead to large quantities of data which must be managed as efficiently as possible. This implies a consistent programme for the creation of data bases, already discussed by the IGBP ad hoc committee.

It should:

- Combine space data, ground-aircraft-balloon validation data and the data already stored,

- Identify the various data sources,

- Ensure interconnection and accessibility.

It is strongly felt that some of these data banks should remain in France, particularly when they concern our particular areas of competence. It is evident that such an initiative implies guarantees concerning long-term institutional support.

Modelling

The modelling effort must be continued so that the French scientific community obtains the integrating tools which alone will enable a comprehensive description, and hence prediction, to be made of the future evolution of our environment. This implies the use of the most powerful computers and direct access to data bases of all kinds: solar, atmospheric, meteorological, hydrological, geochemical, ecological, paleoclimatic, etc.

Training and recruitment

A program of this type can only succeed if sustained by a permanent flow of skilled young researchers who in the past were handicapped by discipline (not to mention sub-discipline) specialization. It would seem vital that a more global view of the environment with, if possible, its various physical, chemical and biological factors be introduced at university masters/doctorate level.

In addition, the importance of long-term environmental surveillance implies that "Observatory" type activities could soon benefit from special recruitment of scientists and technicians with this specific purpose.

GERMAN DEMOCRATIC REPUBLIC

Introduction

The scientists of the German Democratic Republic working in the fields of geo- and biosciences welcome the decision of ICSU to establish the International Geosphere-Biosphere Programme: A Study of Global Change (IGBP).

Cooperation in international research enterprises has a long and good tradition in the research institutions of the GDR. In the geo- and cosmophysical sciences, our country actively took part already in the International Geophysical Year 1957/58, and during the following decades in various programmes of atmospheric, geophysical, solar-terrestrial, oceanological and hydrological research, as presently, e.g., in the World Climate Research Programme, the Middle Atmosphere Programme, the International Hydrological Programme, etc. The same holds true for the biological sciences, where the GDR is active in the Man and Biosphere Programme as well as in projects of SCOPE.

Geophysical and meteorological observatories in the GDR provide long-term data series of parameters of the natural environment (climate, ozone, geomagnetic field, upper atmosphere) continuing over several decades, some of them even since the last century.

Discussions in the responsible scientific bodies resulted in a general agreement of the concerned scientists of our country with the rationale and the underlying themes of the IGBP. A provisional National Committee has been set up for planning the national contributions of the GDR to the IGBP.

Comments on the draft IGBP programme

The provisional GDR National Committee for the IGBP fully agrees with the view that understanding the total Earth system in order to solve the problems of global environmental changes needs to overcome disciplinary boundaries between geo- and bio-sciences. Therefore the Committee appreciates the initiative of the SC-IGBP to concentrate on core research projects which are to study the interactive processes between biotic and abiotic systems, thus complementing ongoing international programmes of the different scientific disciplines. It is considered that at the present stage the research objectives and methodical tasks identified and grouped under the 4 major scientific IGBP components and the 4 common problems sufficiently well cover the needs for achieving the goals of the IGBP, being aware that specifications and amendments will arise in the course of implementation of the programme. Therefore, our provisional National Committee feels no need to put forward additional suggestions at this stage.

National priorities and contributions

Research institutions of the GDR will be able to contribute to the IGBP in the following fields:

- Theoretical models, monitoring and field experiments of anthropogenically influenced biogeochemical cycles in the near-surface and middle atmosphere (deposition processes, transport, ozone) for research in terrestrial biosphere-atmospheric chemistry interactions.

- Cooperation in oceanological experimental studies as envisaged by SCOR and IOC, using research vessels and satellite remote-sensing programmes, for research on marine biosphere-atmosphere interactions.

- Process studies of interactions between
  soil, vegetation and atmosphere,
  aquatic and terrestrial ecosystems, and
  limnical and river systems,
  for research on biospheric aspects of the hydrological cycle.

- Diagnostics and modelling of climate changes in the framework of the WCRP, for research on the effects of climate change on terrestrial ecosystems.

- Contributions to general circulation modelling of the atmosphere with respect to spectral models and to interactions between land surface and atmosphere, for the development of global geosphere-biosphere modelling.

- Methodical contributions to international projects of remote sensing and geo-informatics systems in the framework of socialist countries (Interkosmos), and long-term data series of geophysical parameters of the environment (lower and upper atmosphere, geomagnetism, solar activity) obtained at observatories in the GDR, as far as relevant for the development of IGBP data and information systems.

- Paleoclimatic, paleolimnological, paleopedological, dendrological and paleovolcanic (mainly quaternary) studies in central Europe, and use of isotopic methods in studies of sediment formation in Europe and Antarctica, for extracting environmental data of the past.

- Use (and possibly, extension) of an ongoing long-term monitoring programme of biogeochemical and ecological processes in a lake and its environment (Neuglobsow, Stechlin Lake), as ell as in water storage reservoirs with forested and agricultural intake areas (Neunzehnhain and Saidenbach reservoirs) in the GDR, as possible cooperating geosphere-biosphere observatories.

PROVISIONAL NATIONAL COMMITTEE OF THE GDR FOR THE IGBP

Chairman: Prof. S. Dyck

Members: Prof. W. Boehme
Prof. J. Heinzmann
Prof. H. Kautzleben
Prof. W. Mundt
Prof. M. Ringpfeil
Prof. J. Taubemheim
Prof. K. Voigt

HUNGARY

The Hungarian National Committee of IGBP proposes the following research areas and topics as fields of contribution of the Hungarian science to the IGBP.

Coordinating panels

A. Terrestrial Biosphere - Atmospheric Chemistry Interactions

1. Cycling and large-scale distribution of atmospheric trace gases and their interactions with the human activity and the biosphere.
   Responsible: E. Mészáros, academician, director, Institute of Atmospheric Physics.

2. The increasing acidification of the environment and its effect on the flora and fauna, on the health condition of the forests and on the biomass production.
   Responsible: Gy. Várallyay, DSc. director, Institute of Soil Science and Agrochemistry, Hung. Acad. Sci.

3. Regional and continental distribution of radio-active matters.
   Responsible: L.B. Sztanyik, CSc. director, "Fréderic Joliot Curie" Institute of Radiology and Radiobiology.

B. Biospheric Aspects of the Hydrological Cycles

4. Trends in the changes of the big lakes. Hungarian case study: Lake Balaton.
   Responsible: J. Salánki, academician, director; Institute of Limnology, Hung. Acad. Sci. Tihany.

5. Global trends in the hydrobiological changes of the big rivers. Recommended model-river for Europe: Danube.
   Responsible: A. Berczik, academician, director; Institute of Ecology and Botany, Hung. Acad. Sci. Vácrátót

6. Changes in the chemical and microbiological properties of the underground drink-water basis. Hungarian case study: water resources of the Great Hungarian Plain.
   Responsible: M. Csanády, med.dr., head of department, State Institute of Public health.

C. Effects of Climate Change on Terrestrial Ecosystems

7. Anthropogenic Climate changes with special emphasis to the territory of Hungary.
   Responsible: G. Götz, CSc., Institute of Atmospheric Chemistry.

8. Anthropogenic climate, aerobiological and vegetation changes in the big cities. Hungarian case study: Budapest Agglomeration.
   Responsible: A. Borhidi, DSc. deputy director, Institute of Ecology and Botany, Hung. Acad. Sci., Vácrátót

9. Comparative analysis of stability and resilience in the terrestrial ecosystems modified by Global Change.
   Responsible: G. Fekete, academician, head of department, Institute of Ecology and Botany, Hung. Acad. Sci., Vácrátót

10. Effects of climate change to the alkalinization process of the European soils.
    Responsible: I. Szabolcs DSc. Institute of Soil Science and Agrochemistry, Hung. Acad. Sci., Budapest

11. Study of large-scale changes to the field value and land ecological potential.
    Responsible: L. Góczán DSc. Institute of Geography, Hung. Acad. Sci., Budapest.

Working Groups

A. Global Geosphere-Biosphere Modelling

12. Study of the flora and fauna of the last 140 000 years.
    Responsible: L. Kordos, CSc. Head of Department, Hungarian State Institute of Geology.

13. Description of the megacycles of the Global Sea-level Changes.
    Responsible: A. Meskó, DSc. professor, Department of Geophysics, Eötvös Lóránd University, Budapest

14. Mathematic modelling of the convective stream of the mantle.
    Responsible: A. Meskó,

B. Techniques for Extracting Environmental Data of the Past

15. Evolution of the bio-polymer systems of the cell-walls.
    Responsible: M. Kedves, DSc. Department of Systematic Botany József Attila University, Szeged

16. Adaptations mechanisms of plants and the paleogeographical changes based on micro- and macro-fossils.
    Responsible: M. Kedves,

C. Geosphere-Biosphere Observatories

17. Measurements, data collecting and processing of Geosphere-Biosphere processes.
    Responsible: E. Mészáros, academician, director, Institute of Atmospheric Chemistry.

Participating Institutions in the network of the Hungarian Geosphere-Biosphere Observatories:

Institute of Atmospheric Physics
Institute of Environmental Protection, Ministry of Environmental Resources and Water Management
Experiment Stations of the Research Institute of Forestry Institute of Soil Science and Agrochemistry, Acad.Sci,Hung. data base
Institute of Geophysics, Hung.Acad.Sci.
Research Group of Geophysics of the Hung.Acad.Sci.
Department of Geophysics, Eötvös Lóránd University
Department of Ecology, Kossuth Lajos University, Debrecon

INDIA

Introduction

The Indian National Science Academy, as the adhering body to ICSU, constituted a national committee for IGBP in October 1987, the composition of which is given below. This committee has initiated preparatory activities for defining and formulating the Indian programme so that it will be ready for implementation during the operational phase beginning 1990. The National Committee had its first meeting in January 1988. At this meeting member exchanged information to familiarize themselves with the vast scope, the needed long term commitment and the highly multidisciplinary nature of IGBP as being conceived by ICSU. The National Committee (NC) comprising of working scientists from different disciplines and a few scientist representatives of government funding agencies, recognizing the highly interdisciplinary nature of IGBP, agreed that there is a need to associate many more active scientists of the country to formulate the national plan. As a first step towards this it was decided to organize a national workshop of about 50 invited scientists well before the first meeting of the SAC-IGBP in October. The Committee also decided to recommend to the Academy the payment of a suitable IGBP contribution for 1988; this has been accepted by the Academy subsequently. The present report has been prepared primarily on the basis of discussions in the NC meetings and the deliberations of the national workshop held in August 18-20th.

The national workshop

The NC took the view that in the situation that existed during the beginning of 1988, the first step in formulating the national programme can be taken by identifying a few possible projects for in-depth study hoping that in this process we can learn not only about their national and international relevance to IGBP and the overall feasibility of their implementation but also about the methodologies to be adopted. With this in mind the following proposals from members of the NC were selected for discussions in the workshop:

(I) Estuarine and Coastal ecosystems with emphasis to the Bay of Bengal;

(II) Biogeochemical cycles of greenhouse gases;

(III) Geosphere-Biosphere Observatories;

(IV) Upwelling and monsoon modelling; and

(V) Earth radiation budget and clouds.

(A sixth one on Euphotic Zones in the Indian Ocean proposed along with the above five was later dropped because of unforeseen reasons.) Five working groups each with a convener and about 10 scientist members were constituted for the five topics.

The national workshop was held in Delhi during August 17-19th. About 50 scientists participated in the three day workshop which was inaugurated by Prof. M.G.K Menon who traced the origin and relevance of IGBP beginning with the earliest international scientific programs of the last century. On the first day of the workshop there were presentations to describe the scope of IGBP and to introduce the five working group topics. The second day was wholly devoted to parallel working group meetings. On the third day the conveners summarized the highlights of the discussions in a plenary meeting followed by general discussions.

This being the first meeting of working scientists, only a near primitive report could be drafted on the five topics. Notwithstanding it served a number of very useful purposes highlighting: (a) The severe dearth of scientists with interdisciplinary expertise of the kind needed for IGBP to understand the highly interactive feed back total Earth system; (b) some uncertainty about the relevance of the selected topics to be suitable elements of IGBP; (c) lack of information on the component parts of the topics which are being studied under other ongoing international programs; (d) co-ordination with similar projects elsewhere in the world; (e) data analysis on a

global scale; and (f) the need for an efficient and continuing management system to ensure the proper funding, implementation and co-ordination of all the national IGBP activities. In spite of these uncertainties, the above topics seemed on first examination to be suitable for IGBP.

It was recognized that at least some of the above difficulties and uncertainties will be eliminated when the international programme content and scope are more sharply defined through the many international subgroup meetings that are being held or planned, and IGBP itself evolves over the period 1988-89. Even so the participants felt strongly that the various proposed activities must be get priority because clearly we cannot do justice to all possible programmes even if their relevance to IGBP is high. The workshop also highlighted the need for further definition and elaboration of the projects already proposed and for considering many more possible topics before the final choice is made for implementation. It was hoped that the Draft IGBP Programme which is expected to be distributed in September 1988 and the deliberations of the SAC-IGBP meeting in October will enable a better overall appreciation and understanding of the IGBP to define and choose national programmes.

Some remarks on the effective participation of India and other developing countries in IGBP

Though there will be many difficulties and handicaps for India and other developing countries to participate and contribute fully and effectively in IGBP, an element of very serious concern we encountered was the lack of scientists with adequately broad and sound base in interdisciplinary matters which will ultimately determine the strategies to be adopted, the right choice of topics under the prevailing national constraints and the needed foresight for formulating and implementing the programme to reap the scientific benefits nationally and internationally. At least a few such people are needed in each country. How to motivate, train and grow such people should be one of the greatest concerns of IGBP. Such interdisciplinary and interdisciplinary experts are also needed to analyze, interpret and build models effectively. Without them, such countries will become, to a great extent, data suppliers to others.

Remark on IGBP Report No.4

The special committee need to be congratulated on the excellent preparatory work they have carried out so far and the Report No. 4 they have brought out for use in the SAC meeting. The comments on the report by members of our National Committee could not be incorporated in this report because the Report was received only in the last week of September.

In describing the IGBP related activities in chapter 7 three classifications are made of them. The first is called Core Research Projects of the SC-IGBP, and the second Supporting activities which though recognized by the SC-IGBP will not be their direct responsibility. It seems to be implied that the Core Programme will be identified and formulated by the SC while the second will be the full responsibility of the national committees. A little clarification here about the nature of these two categories their formulation and implementation would help to appreciate the difference between them though some indication is available from the document. This may be important if for example bulk of the analysis of global data, their interpretation and modelling is carried out as Core Projects leaving essentially data gathering to the national committees. This will mean in turn that countries which do not have the right kind of experts to start with not be able to participate satisfactorily in the Core Projects which really constitute the main fruits of the IGBP.

The second remark concerns a passing reference in chapter 9 that "all efforts be made to involve scientists from developing countries in the programme". This matter requires careful considerations and suitable organized approach and action to make the participation of such scientists truly meaningful in all respects. It will not be an easy task but without ensuring it the participation of scientists from developing countries will have no lasting scientific value to them and their country.

Summary

The Indian National Committee for IGBP has initiated preparations for formulating the national approach and scientific programme for IGBP. A national workshop was organized in August to examine the scope, relevance and feasibility of five proposed projects; other IGBP related matters were also discussed in a preliminary way. For the near future small working group meetings for in-depth study are planned after SAC-.IGBP meeting in October. A few matters of special interest to developing countries are pointed out for consideration by SC-IGBP.

Indian national committee for IGBP

Prof R.R. Daniel, chairman
Dr P.K. Das
Dr V.K. Gaur
Dr T.A. Hariharan
Dr T.N. Khoshoo
Dr A.P. Mitra
Dr J.S. Singh
Prof B.L.K Somayajulu
Dr M.N. Qureshi
Dr S.N. Dwivedi
Dr M. Parabrahman
Dr. M.K. Tewari, Non-member Secretary

IRELAND

The National Committee report from Ireland is presented as a series of articles on projects essential for the work within the IGBP

I The synoptic climatology of rainfall hazards in Europe

Dr. J. Sweeney, St. Patrick's College, Maynooth

Recent progress in the recognition of short to medium term variations in climate have established the existence of a greater variability in particular components of climate on such scales than was hitherto believed. In particular they imply that periodic precipitation fluctuations occur in response to medium term circulation changes, something which has implications both for hydrology and the frequency occurrence of extreme or hazardous events. Such consequences vary for different regions within Europe and although mechanisms have been suggested to explain the phenomena, no detailed link between synoptic weather types and precipitation yield exists at a European scale. New data sources (such as precipitation radar) are, for the first time, becoming coordinated at a European scale and, together with improved computing power, offer the opportunity of a wider scale of analysis. The anticipated changes in circulation associated with CO_2 led warming make anticipation of these climatological impacts important.

Aims of the proposed research:

(1) To establish precipitation yields (with particular reference to intensity and amount) on a pan-European scale in response to particular synoptic scenarios.

(2) To test the applicability of this synoptic approach to localized precipitation forecasting with particular reference to threshold events of hazard significance.

(3) To establish regional variations in precipitation receipt with particular synoptic categories with a view to improving localized precipitation forecasting and facilitating more widespread probability forecasting of precipitation amount on regional scales.

(4) To establish the impacts which regional changes in precipitation may have for selected economic activities, with special reference to agriculture.

Description of research work

This research will firstly examine a homogenized record of precipitation from the mid-nineteenth century for a large number of locations within Ireland and the U.K. Where possible, use will be made of data sets which already exist. The station network will aim to achieve a density of the order of 20-30 rainfall stations per country. The network will be constructed to incorporate the effects of both topographical and oceanic influences.

Precipitation events and precipitation yields will be examined with particular reference to the synoptic environment with which they are associated. Probability maps will be generated from the computer datasets which will be at a scale suitable for use by European countries in national and regional forecasts.

Precipitation thresholds for the onset of particular hazards are likely to vary considerably within Europe depending on the surface conditions which influence water storage characteristics. The study will therefore examine the responses of regional water budgets to particular synoptic sequences with a view to ascertaining the rainfall inputs over specific time periods associated with hazards of particular magnitudes for agriculture and water resource management.

The long term changes of particular synoptic situations will then be used to derive projections for changes in total and seasonal income of precipitation for each area.

II Genesis of clay and carbonate enriched subsolum horizons in podzolic cleys in Ireland - an indicator of a drier pedoclimate?

Dr. J.F. Collins, University College, Dublin, and Dr. R.F.Hammond,Teagasc

It is proposed to study the morphology and composition of a variety of soils with simultaneous silicate clay and carbonate enrichment in their lower sola with a view to establishing their genesis. It is planned to compare such soils with topographically-related counterparts that have either clay alone or carbonate alone enrichment and with associated soils showing enrichment in neither of these constituents. Intensive large scale mapping of small areas in Co. Kildare will be supported by physical, chemical and mineralogical analysis. The hypothesis being tested is that these soils developed under a drier climate during which clay was mobilized and that during subsequent wetter conditions carbonates were deposited from carbonate-enriched and rising groundwaters, changing podzolic conditions to those of gleying and water saturation.

III Reconstruction of climatic fluctuations and environmental change in the period 14000 - 8000 BP based on multidisciplinary investigations of lake sediments from western Ireland

Dr. M. O'Connell, University College, Galway

The end of the last Ice Age (c. 14000 to 9500 B.P.) is characterized by a complex series of climatic oscillations which were confirmed in their effects to the eastern North Atlantic and the N.W. European landmass. This, as it were, "false-start" to the present warm post-glacial stage is unknown from elsewhere in the Northern Hemisphere and, apparently, has no counterpart at the boundary of earlier glacial/interglacial cycles (Watts, 1980). This project attempts to document the effects of temperature oscillations in the North Atlantic on the terrestrial environment in western Ireland, where can be expected to be best expressed.

A number of suitable sites with thick late-glacial deposits, which should facilitate fine scale resolution of vegetational and climatological change, have already been identified in Connemara.

It is now proposed to undertake a further coring programme to:

(1) Establish stratigraphical variation at the know sites;

(2) Locate further potentially suitable sites for detailed investigation; and

(3) Locate suitable deposits containing autogenic carbonate in Caroniferous limestone areas adjoining Connemara.

It is proposed to carry out multidisciplinary investigations on selected cores from a number of representative sites including:

(a) Radiocarbon dating of non-calcareous sediments, with a view to establishing as precise a time-scale as this method allows;

(b) Paleomagnetic studies. Inclination and declination features will facilitate time correlation between sites and enable a time-scale to be attached to calcareous sediments which cannot be satisfactorily dated by the radiocarbon method;

(c) Pollen and macrofossil analyses which will enable precise reconstruction of vegetation development;

(d) Independent evidence of variation in climatic conditions which will be provided by oxygen isotope analysis of sediments with authigenic carbonate.

The above studies, details of which are at present being negotiated, will involve cooperation between the following institutions:

Department of Botany, University College, Galway (Dr. M. O'Connell) School of Cosmic Physics, Dublin Institute for Advanced Studies (Dr. P.W. Readman)
Instituut voor Aardwetenschappen, Vrije Universiteit, Amsterdam (Dr. S. Bohncke)
Physikalisches Institut, Unversität Bern (Dr. u. Siegenthaler)

IV Sea-level changes and research in Ireland

Dr. R.W.G. Carter, University of Ulster, Coleraine
Dr. J.D. Orford, Queen's University, Belfast, and
Dr. R.J.N. Devoy, University College, Cork

It is envisaged that world sea-levels will rise in the next century as a result of global warming, due to the 'Greenhouse Effect'. Temperature rises of between 1 and 2 C could cause sea-level rises in the order of 0.3 to 1.5 meters. However, some scenarios suggest that the rise may be higher, resulting from the melting of the west Antarctic ice shelf. Notwithstanding, Ireland faces rates of sea-level change up to 10 mm/year, far in excess of any recent rates, but not unusual in the context of geological time.

In order to understand the nature and impact of sea-level change on the Irish coastal environments, it will be necessary to:

(a) Expand our knowledge or recent coastal environmental change, through the analysis of shoreline and shelf deposits; and

(b) To model the impact of sea-level rise on our coastal environments.

Ireland possesses a wide range of coastal environments, often within very small areas. In some cases, these environments are among the best and most accessible in the world offering great potential to compile and test models of shoreline change, which are distinct from the current paradigms (mostly U.S. in origin).

There is a sound base for such studies, with three universities actively engaged in sea-level research (Queen's Belfast, University College Cork and the University of Ulster). Workers in these universities have already received funding for projects on sea-level change, both for work in Ireland and elsewhere, including England, France, Holland, Canada, the U.S.A and Australia.

At present several major projects are underway. Devoy (Cork) has EC funds for studies of sea-level change in the southwest. Carte (UUC) and Orford (QUB) have grants from the Royal Society, London, and the Canadian Government to continue collaborative research with the Canadian Geological Survey on shoreline response to sea-level rise. Carter also is completing a project on shoreline erosion in northeast Ireland for the Department of the Environment and has accepted a Leverhulme grant to look at gravel shorelines and sea-level change in western France. There are about eight research workers in Ireland at various stages of project.

It is hoped to extend research on to the Irish continental shelf, as well as embarking on research in west central Ireland (an area totally unstudied) and, in addition, to consolidate the work on late-Holocene relative sea-levels especially in resolving the problems of estuary infill.

V Understanding the role of marine eco-systems, and response of coastal zones to Global Change

Professor M. Orren, University College, Galway

The Department of Oceanography at University College, Galway, can make contributions to two of the identified subject areas, namely:

(1) Understanding the role of marine ecosystems;
(2) Response of coastal zones to global change.

Geographically, Ireland is ideally situated for marine research in the North Atlantic. The North Atlantic Drift first encounters the European continental shelf west of Ireland and, more important, the Irish coast is, with some exceptions, largely unperturbed by man when compared with continental Europe. The Department is already investigating the interaction between physical, chemical and biological processes in the eutrophic zone through analyses of water, sediments and biological organisms for particularly important trace metals such as since, cadmium, copper, lead and molybdenum, while satellite imagery obtained from the University of Dundee is being used to identify the complex frontal systems off the west coast of Ireland and the dispersion of the Shannon river plume.

This project aims to describe the processes of trace metal cycling through the geosphere, hydrosphere and biosphere in the Shannon estuary and in the Galway Bay region, and, when sufficient quantitative data is available, the processes will be modelled with the ultimate goal of achieving a predictive model of coastal responses to change. Quantitative studies of specific organic compounds in the ocean, commencing with marine pigments, amino acids and other defined groups of organic compounds will yield valuable information on the mixing of terrestrial and ocean waters. These in-depth studies of organic compounds in the ocean will greatly improve our currently inadequate knowledge of organic cycling in the coastal zone and will obviously provide an important input for coastal zone management when organic waste disposal is considered.

The physical/chemical baseline achieved by the preceding project will enable us to describe in quantitative terms the long term response of the coastal zone to global change. Standardized and internationally preferred methodology will be used so that the results may be compared with those from other coastal zones.

The essential back-up for the physical and chemical studies will be provided by the links existing between the Department of Oceanography and the Departments of Zoology (Benthos Group), Geoscience (sediment/water interactions, natural weathering) and Physics (meteorology/air-sea interaction). International links are still being established but cooperative work is already underway with marine scientists in Southampton, and links are being established with the Woods Hole Oceanographic Institute (U.S.A.), Old Dominion University (U.S.A), Edinburgh University and the Roskilde Group in Denmark.

VI Monitoring of a forest ecosystem in a region of low-level anthropogenic emissions

E.P. Farrell, J.F. Collins, G.W. Smillie, A.J. Scott, R.G. McCarthy, Forest Service, Bray, Co. Wicklow Univeristy College, Dublin
G.J. Mullen, Thomond College, Limerick
K. Kreutzer, R. Schierl, University of Munich

The overall objective of this project is to improve understanding of the effects of atmospheric pollution of forest ecosystems.

Since the early 1980s, symptoms of forest decline have been observed on a very large scale, over a wide area of Europe. The cause of the problem has not been determined with any degree of certainty, but most experts agree that atmospheric pollution is at least a contributing factor to many of the several distinct diseases which have been observed.

Laboratory controlled environment chamber and open top chamber studies can give valuable information helpful to the understanding of pollution influences. Ecosystem studies are also of importance and studies have been instigated in several countries both in Europe and in North America. Most of these studies are located in regions where symptoms of forest decline have become apparent. In many cases the atmosphere is heavily polluted with a range of potentially toxic gases and levels of acid deposition are often high.

The study site, which is located in County Cork in the south of Ireland, has been chosen with two specific attributes in mind. Firstly, it is situated in a region which experiences very low levels of atmospheric pollution and, secondly, the forest stand is very similar, with respect to structure and soil conditions, to a stand which is the subject of a similar study in Germany, namely, the Hoglwäld experimental site in Bavaria. At that site, the effects of atmospheric inputs on a forest ecosystem are monitored as part of a larger study involving the experimental manipulation of the ecosystem.

Ireland, by virtue of its position, low population density and relatively low level of heavy industrial development, escapes the worst of the pollution which affects nearly all of the European mainland. The site selected is distant from known point sources of atmospheric emissions. Annual proton deposition measured at a site about 10 km from the study area is in a range 0.01 to 0.09 kg and collection equipment will be transferred to an open area immediately adjacent to the site for this project.

The site in County Cork was selected in close cooperation with collaborators from Lehrstuhl für Bodenkunde, University of Munich. Ireland is probably unique in Europe in having, in an unpolluted environment, forest stands similar in species and structure to those occurring under conditions of significant atmospheric pollution on the European mainland. The stand at the selected site has the same species, Norway spruce, and structure, as at the Höglwald, and soil characteristics, particularly morphological and chemical, are broadly comparable.

The specific objectives of the project are to measure:

(a) Atmospheric concentrations of gaseous pollutants in the region;

(b) Bulk pollutant deposition;

(c) The quantity and chemical composition of throughfall under the forest canopy; and

(d) The impact of pollutants on the forest soil.

Atmospheric concentrations of pollutants will be measured using a High Efficiency Annular Denuder. A platform for this equipment' will be built adjacent to the site and the equipment will be transported to the site an installed there at regular intervals (6 times per year approximately), at which time collections will be made over periods of one to several days. The equipment is under the control of the Department of Physics. University College, Dublin, at whose laboratories the analyses will be carried out.

Bulk pollutant deposition will be collected at the same site or close to it. Open collectors will be installed on a platform and collection vessels will be serviced at weekly intervals.

Throughfall will also be collected in gutter and pot collectors at weekly intervals by Forest Service or University personnel. Bulk deposition and throughfall material will be analyzed at the laboratories of the Department of Agricultural Chemistry and Soil Science of University College, Dublin.

The impact of pollutants on the soil will be measured under the forest canopy by analysis of samples obtained using litter traps, humus lysimeters and soil solution suction cups and by analysis of soil samples collected at intervals throughout the study period. Lehrstuhl für Bodenkunde personnel will participate in the installation of humus lysimeters, section cups and tensiometer. The tensiometer. will be used for calibration during the suction cup sampling operations. The operation of suction cups and tensiometer will be under the control of Thomond College. Analysis of samples will be conducted at the Department of Agricultural Chemistry and Soil Science, University College, Dublin, Lehrstuhl für Bodenkunde will have primary responsibility for monitoring changes in the chemical status of aluminum, heavy metals and nitrogen in the soil. They will also be involved in the comparison of results between the Irish and German sites which forms an important part of the project.

VII Sulphur emissions from peatland ecosystems

E.P. Farrell, J.F. Collins, G.W. Smillie, University College, Dublin
M.O. Andreae, Biogeochemistry Department, Max Planch Institut für Chemie, Mainz, Germany

Since January 1986, Soil Science personnel at University College, Dublin, have, in cooperation with the Irish Forest Service, operated a rainwater collection station at Glenturk in north County Mayo.

The measurement station is situated 11 km from Broad Haven Bay to the north and 23 km from the Atlantic Ocean to the west. The major soil type in the Atlantic Ocean to the west. The major soil type in the region is ombrotrophic blanket peat, with very low non-capillary porosity and saturated hydraulic conductivity. Average rainfall in the area is 1400 mm per annum distributed over 270 days. Under these conditions, the soil is saturated to within 3 cm of the surface for most of the year.

Peatlands cover 1.34 million hectares, 16.2 per cent of Ireland. With 212,000 hectares (40 per cent of the land area), County Mayo has the greatest area of peatland of any Irish county. Of the total, 128 hectares are unmodified and experience anaerobic conditions close to the surface for much of the year.

A rainwater collection station is located on an undrained bog, regarded as representative of this kind of soil and landscape. Samples are collected monthly and analyzed for major cations and anions. Excess sulphate deposition for a twelve-month period totalled 56 kg sulphate per hectare. This is regarded as high, considering the relatively remote situation. Possible natural contributions include the ocean (principally as dimethyl sulphide), hydrogen sulphide of biogenic origin and lithological /groundwater sources from weathering pre-Cambrian rocks. Pre-Cambrian formations rich in sulphur are known to occur in the region.

It is proposed to investigate sulphur fluxes in a blanket peatland ecosystem using a combination of approaches including gas concentration measurement in chambers and vertical concentration gradients in the atmosphere. Sulphate deposition will also be measured. Wind speed and direction data will be analyzed, and cation and anion concentrations in precipitation determined. Analysis of specific compounds such as methane sulphonic acid will be used to attempt to identify the fraction of deposited sulphate attributable to different sources.

VIII Working Group on geo-biosphere observatories; outline proposal

The following comments are based upon views expressed by individuals in University College, Dublin, Queen's University Belfast, University of Ulster, Bord na Móna, An Foras Forbartha, Teagasc, ERA Ltd.

Within the context of the International Geosphere-Biosphere Programme and this Working Group, and using criteria of uniqueness, global significance and accumulated research, Irish involvement is suggested in geo-biosphere observatory work in the study of:

1. Peat/bog ecosystems, especially of the 'Extreme oceanic ecosystem type' of which Ireland is the major representative;

2. Lacustrine 'ecosystems', including their linkages with agro-economic ecosystems;

3. Agro-economic productive systems, particularly grassland and forest ecosystems;

4. Hydrological and clastic sedimentary cycling in Sahelian/arid and Equatorial rain forest 'ecosystems' in Africa and S.E. Asia.

Within scientific institutions in Ireland collectively there exists equipment and expertise in satellite and airborne remote sensing image analysis, in sensor design and construction and in modelling relationships between ground and remotely sensed data. These have been applied to each of the four 'areas' listed above.

1. Lakes in Ireland occur in a wide range of geo-biosphere environments undergoing varying degrees of anthropic modification, providing ideal situations for controlled studies. Monitoring of lake water quality, hydrology and sedimentation by ground sampling and remote sensing is proceeding and databases are being created by U.C.D. with An Foras Forbartha and by the Northern Ireland Department of the Environment with Queen's University, Belfast and University of Ulster. Several lakes have been selected for baseline studies in connection with European Acid Rain research. There is immense potential for building on this work.

3. There are several different types of peatland and bog ecosystems in Ireland similarly experiencing varying degrees of anthropic modification. They are widely regarded as representative systems and could provide baseline studies within the IGBP. Although there is considerable knowledge about Irish peatbog systems there are few comprehensive monitoring programmes and little is known in detail regarding their hydrological and geochemical behavior. Studies involving remote sensing within a monitoring framework are beginning particularly in Northern Ireland. There is, as with lacustrine studies, clear potential for building upon and developing these studies. Radar imagery will be useful for monitoring moisture content and plant growth, multispectral imagery is already used for baseline mapping, classification and monitoring change.

4. Considerable research effort is being put into the analysis and monitoring of agro-economic ecosystems by individuals, groups and institutions. Particular mention should be made of grassland and forest ecosystems. Long term data sets (unfortunately not yet sufficiently broad based or integrated) are being generated, airborne and satellite remote sensing and ground truthing, controlled experimentation and model validation are proceeding in a variety of locations and situations.

5. Hydrological resources in the Sahelian/arid zones of Niger, Algeria and Mali and sediment cascades in the rain forest zones of Sierra Leone and of Indonesia are being studied by individuals and small groups, mostly on a contractual basis. Remotely sensed and ground data collection is involved, but monitoring is limited. The future involvement of Irish environmental scientists in studying the general problem of desertification in fragile ecoystems in Africa is envisaged.

In terms of the IGBP the deployment of such expertise and commitments might perhaps be considered within the framework of observatories being planned by other national or international groups in those countries with which Ireland has bilateral aid arrangement and/or cultural links.

Two final cautionary points must be made:

1. Within Ireland, continuous collection of geo-biosphere data, unlike meteorological and hydrological, in an integrated, comprehensive and systematic manner is limited. Geochemical and sedimentary flux measurements are virtually non-existent. Although there are no observatories dedicated to such monitoring, sites, locations, structures do exist, however, which could be developed into such observatories.

2. The regular monitoring of Irish ground conditions by satellite and airborne multi-spectral sensor is severely limited by cloudiness. The advent of the European satellite ERS-1 in 1990 carrying imaging radar sensors will partly circumvent this problem.

IX Kinetics and mechanisms for the reaction of hydroxyl radicals with alkyl and peroxyacyl nitrates

Dr. O.J. Nielsen, Riso National Laboratory, Roskilde, Denmark,
Dr. H.W. Sidebottom and Dr. J. Treacy, University College, Dublin

Alkyl and acyl peroxid radicals are important intermediates involved in the oxidation of volatile organic compounds emitted into the atmosphere.

The purpose of this work is to determine absolute rate data for the reaction of HO radicals with alkyl and peroxyacyl nitrates and to identify the transient and end products of the ractions under atmospheric conditions, particularly with respect to the eventual oxidation products of the nitrogen containing species.

Initial studies at Riso National Laboratory, Denmark, will be concerned with the determination of absolute rate data for HO reactions with a variety of alkyl and peroxyacyl nitrates using pulsed radiolysis combined with kinetic spectroscopy. It is hoped that further work will lead to identification and kinetic information on the transient intermediates involved in these reactions.

Product analysis studies of the reaction of the nitrates will be carried out at University College, Dublin, using a smog chamber facility having FTIR and GLC mass spectrometry detection techniques.

Project starting date: January 1987, to run for three years.

X Bio-geochemical cycles - atmospheric segment - gases, aerosols and precipitation analysis, Microphysics of clouds, and Natural and anthropogenic sources of air pollutants

T.C. O'Connor, S.G. Jennings and A.F. Roddy,
Department of Physics, University College, Galway

The Department of Physics, University College, Galway, would be very interested in participating in the International Geosphere-Biosphere Programme in view of the research in progress or planned in the Department and at its field station on Mace Head near Carna, Co. Galway. The above are the general areas of research.

Current activities

1. AEROCE - an NSF funded programme involving about 20 universities and agencies in the US investigating biogeochemical fluxes in and out of the North Atlantic - have chosen Mace Head as their primary station in the Eastern Atlantic and are in the process of setting up the station. U.C.G. will contribute to this (T.C. O'Connor).

2. Noctilucent clouds and CO_2 increase (A.F. Roddy) Transmission of EM radiation through clouds and remote sensing techniques (S.G. Jennings) CCN counter (M.O. Andreae, Mainz)

3. Monitoring ozone and CFC concentrations as the European station for GAGE (Global Atmospheric GAses Experiment) since January 1987;
Projected station for EUROTRAC TOR (Tropospheric Ozone Research) project (T.C. O'Connor)

   Monitoring of background aerosol size and mass distributions and studie sof background maritime aerosol hygroscopicity and volatility (S.G. Jennings)

Geo-Biosphere Observatory

In view of the extensive atmospheric monitoring at Mace Head, and the interest of the Department of Oceanography, U.C.G., in water quality and the biological work of the U.C.G. Marine Research Laboratory at Carna, and the extensive work by other groups in Connemara, one should consider seriously the development of the Geo-Biosphere Observatory at Carna for maritime, littoral and atmospheric studies and the environmental aspects of intensive aquaculture.

T.C. O'Connor, Department of Physics, U.C.G., is the EUROTRAC contact point and coordinator in Ireland. This research programme will contribute to the International Aerosol Climatology Project and the International Global Atmosphere Chemistry Programme of LANAP.

XI Impact of elevated carbon dioxide levels on European ecosystems

Dr. M.B. Jones, Dr. D.L. Kelly, Trinity College, Dublin, and Dr. J. Burke, Oak Park Research Center, Carlow.

The rising levels of carbon dioxide in the atmosphere will have both direct effects on plants by increasing photosynthesis and indirect effects through changes in climate. Although much research has been directed at the effects of elevated CO_2 levels on crop plants very little attention has been paid to natural vegetation. One of the more subtle but important effects on natural vegetation may be to enhance or reduce the component plants' competitive ability. Such changes may reflect the ability of certain plants in the community to take advantage of the enhanced carbon dioxide levels while for others there may be no advantage. In the medium or long term even small responses could lead to changes in community structure that could result in the disappearance of rare species.

The Botany Department at Trinity College and the Scientists at the Oak Park Research Center, Carlow have considerable expertise in studying the physiological responses of whole plants to elevated carbon dioxide levels. Jointly, we have established Ireland's only open top chamber set-up which is currently being used to investigate the effects of ambient air pollution levels on crop-loss as part of the European open-top chamber network. These chambers can be used to expose plants to elevated CO_2 levels. In addition we have considerable expertise in studying plants communities and community change, especially in woodland within Ireland.

We propose to combine these two areas of expertise into a study of the effects of elevated carbon dioxide on the components of the deciduous woodland ecosystem in

Ireland. Collaborating laboratories in other EEC countries might well make comparative measurements for forest ecosystems in other locations. Our proposed study would involve a combination of field observation, growth chamber and laboratory studies as well as involvement of the open-top chamber set-up at Carlow. In the latter instance we would plan to supplement some of the chambers with carbon dioxide whole others and the open plots would be subject to the prevailing levels of carbon dioxide. Important species of the natural woodland community in Ireland would be established in open-top chambers at Oak Park. The vegetation in the natural site, and in the chambers (with and without added carbon dioxide) would be subjected to detailed study. The physiological responses which regulate growth of the individual species would be examined as well as any changes in abundance, fecundity or competitive ability.

Little work has been carried out to assess the impact of rising carbon dioxide levels on species in natural plant communities which make up a major component of plant cover in Europe. We know that such plants will be subject to significantly enhanced carbon dioxide levels in the very near future and the importance of this to the survival of particular species should be investigated. The International Geosphere-Biosphere programme would be an appropriate framework for such a study.

ISRAEL

Introduction

In July 1985 an ad-hoc Committee for the IGBP was established in Israel by the Academy and, after reviewing the IGBP draft proposal, the past and ongoing research and monitoring activities in Israel relevant to an IGBP, as well as the potential contribution by Israeli scientists to the latter, expressed its unanimous support for such program.

The ad-hoc committee prepared a Memorandum outlining the particular significance of Israel as a model-area for different investigations, emphasized the exceptionally well-documented record of past natural and man-made environmental changes in this area on scales ranging from millions of years to tens of years, the inter-disciplinary nature of the research, as well as the environmental monitoring activities carried out in Israel over the last few decades.

A copy of this memorandum was submitted on 1 August 1986.

In April 1988, an Israel National Committee for the IGBP was established. Its members (see below) studied the reports distributed by the IGBP forums and contacted scientists and scientific organizations in Israel in order to gather relevant information for planning Israel's contributions to the IGBP.

It is deemed opportune to list at this stage a number of ongoing research efforts in Israel, definitely relevant to the IGBP and some of the experimental research sites and monitoring organizations, which could serve the purposes of the international IGBP community.

The draft IGBP programme

The Israel NC-IGBP considers the IGBP planning as expressed in the documents distributed until now as reflecting the needs of this comprehensive programme. It is hoped that at the Stockholm meeting a more definite framework will be proposed, in order to facilitate coordination and integration of efforts on national and international levels.

The Israel NC-IGBP considers the problems connected with origin, transport and deposition of desert and industrial dust as deserving particular attention, especially if the large-scale deforestation of jungle areas (South America) and increasing desertification (North Africa) are taken into account. The Israel NC-IGBP would be ready to organize in Israel an IGBP - sponsored workshop on these topics which have been intensively studied here over the last decades.

National priorities

The situation of Israel between the Mediterranean and the extreme desertic climatic belts, on the shores of the most oligotrophic sea in the world (the Levantine Mediterranean) and the moderately oligotrophic Gulf of Aqaba, in an area with a rapid development over four decades of intensive agriculture based largely on ground water and lately even saline water-supported, of afforestation and of large-scale intervention in water resources, with a rapidly growing industrialization and mostly oil-based means of transportation inter alia, it is difficult to indicate a major point of concern with regard to the potential impact of - even small-scale - natural or man-made environmental changes, regional or global. For this reason, a great variety of research programs on a wide spectrum of topics is being carried out. The intensive research and monitoring efforts, as well as the long-range and short-range documentation of environmental changes extant in Israel represent a potentially important contribution to the IGBP. As indicated before, there, is

little doubt that for certain IGBP investigations and long-range experiments Israel represents an ideal model-area.

The Israel NC-IGBP suggests to consider some of the Israeli installations as international IGBP long-range observatories. These installations are excellently equipped and some of them unique in the whole region, i.e.:

- The Interuniversity Institute for Marine Sciences in Eilat (Red Sea);
- The National Oceanographic Institute of the Israel Oceanographic and Limnological Res. Corp., Haifa;
- The Lake Kinneret Laboratory of the IOLR, Tabkha;
- The Sde Boqer-Hatzeva and Nizzana (Negev) Experimental Research Stations of the Hebrew University's Arid Ecosystem Research Center.

National Committee members

Prof. Z. Reiss, Chairman
Dr. U. Marinov
Dr. A. Nissenbaum
Prof. M. Shilo
Prof. E. Tchernov
Prof. D. Yaalon

JAPAN

Introduction

The Japanese Committee for IGBP was established in Science Council of Japan on August 27, 1987.

The committee is chaired by Professor Yasuyuki Oshima. 11 scientists initially joined the committee and 4 executive members appointed. Later the committee and executive memberships were enlarged to 26 and 5 members. The committee meetings were held 10 times by now and the executive members met 5 times. The major topics of the meeting were

- Exchange of information on IGBP,
- Collaboration among scientists in various fields in Japan,
- Relationship to other on-going and planned ICSU programs,
- Japanese own programs under the IGBP umbrella.

The committee organized a meeting in March 1988 to discuss the relationship to other related programs with scientists from various research categories. Also it organized the first symposium for IGBP in July 1988.

The committee has been planning to publish Newsletter of IGBP-Japan in three times a year and the first number will issue on early November.

Research themes of Japan-IGBP in the first period (1991-1994)

(1) Elucidation of Exchanges of Gases and Aerosols in Lithosphere-Hydrosphere-Atmosphere Systems

- Aeronautical observation of long-distance transport of gases and aerosols between continents and oceans;
- Gas-exchanges between ocean and atmosphere;
- Determination of greenhouse effect gases (CO_2, CH_4, N_2O) fluxes from fields;
- Estimation of aerosol-transport from continents to ocean surfaces;
- Mass-transport in hydrosphere and atmosphere.

(2) Energy and Mass Exchanges between Terrestrial Ecosystems and Atmosphere

- Elucidation of mass and energy exchanges in subtropical and tropical terrestrial ecosystems,
- Elucidation of mass and energy exchanges in temperate terrestrial ecosystems;

(3) Minerals Cycles and Productivity of Marine Biosphere:

- Marine biosphere productivity and minerals cycles
- Biota-environment interaction in boundary zones between continents and oceans

(4) Elucidation and Modeling of Chemistry Interaction in Geosphere-Biosphere-Atmosphere Systems:

- Elucidation and modeling of chemistry interaction in geosphere-biosphere-atmosphere systems;

- Elucidation and modeling of anthropogenic climatic changes

(5) Large-scale Monitoring of Environmental Changes

- Time-spatial changes in vegetation distribution and productivity
- Time-spatial changes in ice and snow covers
- Long-distance transport of dust from continents
- Time-spatial changes in soil moisture
- Time-spatial changes in marine biosphere productivity

(6) Reconstruction of Paleoenvironment

- Reconstruction of paleoenvironment using sedimentation data
- Reconstruction of paleoenvironment using ice core data
- Reconstruction of paleoenvironment using biological data

(7) Elucidation of Climatic Changes due to Great Rare Events

- Effects of great eruptions of Volcanos on climate
- Effects of big forests fires on climate

THE NETHERLANDS

The Royal Netherlands Academy of Arts and Sciences established its IGBP Committee at the end of 1987. The committee was added to the combined committee for the MAB programme of UNESCO and the SCOPE programme of ICSU. The board of the IGBP Committee is formed by: Prof. H. Postma (chairman), Prof. J.W.M. La Riviére, Dr. G.P. Hekstra, Prof. G.J. Vervelde and Dr. H.M. van Emden (secretary).

Joint Global Ocean Flux Study

Dr. Ir. Hein de Baar

JGOFS now being planned for the next decade (1989-1999) will combine efforts of biologists, chemists, physical oceanographers and geologists from several countries in a concerted effort:

> "To 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."

The contribution from The Netherlands will be a series of four expeditions. In the fall of 1989 two cruises will focus on biology/chemistry in the surface ocean and processes on the sea floor /benthic) respectively. Two similar cruises will be executed in the spring of 1990. Otherwise the overall JGOFS is an explicitly open organization and involvement of scientists from countries (e.g. China, Iceland, Japan, Sweden) other than those providing ships for the Pilot Study id actively encouraged or already implemented.

Netherlands contribution to the World Ocean Circulation Experiment (WOCE)

W. Otto and W.P.M. de Ruyter

As the central oceanographic component of the World Climate Research Programme (WCRP), the World Ocean Circulation Experiment (WOCE) is of much interest for physical oceanographers in the Netherlands. The importance of the issue of climatic change for a country like the Netherlands makes a significant contribution to WOCE highly desirable. In the following a summary is given of the various activities and plans in this connection. As there are relations between WOCE and the Joint Global Ocean Flux Study (JGOFS) and various satellite programmes (ERS-1, TOPEX/POSEIDON) and as there are connections with the TOGA (Tropical Ocean, Global Atmosphere) programme, the WOCE plans are being developed in connection with these activities.

There is a Netherlands WOCE working group constituted that will work within the Netherlands Foundation for Sea Research ("Stichting Onderzoek der Zee", SOZ). The institutes participating:

Royal Netherlands Meteorological Institute (KNMI).

Institute of Meteorology and Oceanography (IMO), University of Utrecht.

Netherlands Institute of Sea research (NIOZ).

Technical University, Delft.

EUROTRAC

S. Zwerver

Eurotrac means "European experiment on transport and transformation of environmentally relevant trace constituents in the troposphere over Europe".

EUROTRAC covers three main areas:

- The chemistry and transport of ozone in the troposphere on a regional and a hemispheric scale;
- The processes which lead to the formation of acidity in the atmosphere, particularly those involving the presence of aerosols and clouds;
- The studies on the uptake and release of atmospheric trace substances by the biosphere.

The projects will cover one of the following five activities:

- Determination of the distribution of primary and secondary pollutants;
- Studies of the processes involved in gas and droplet phase;
- The development of fast, sensitive and selective instruments;
- Quantitative evaluation of gas deposition and collection of cloud droplets by vegetation;
- Development of models.

International Satellite Land Surface Climatology Project (ISLSP), field experiment in desertification-threatened areas

H.A.R. de Bruin

Background

In many European countries meteorological satellite data are used for applications over land-surfaces: Albedo, net radiation flux and vegetation index are frequently determined by different groups and the Italian Meteorological Service plans to introduce evapotranspiration maps as an operational product. With, maybe, the exception of the global radiation flux, none of these products are currently sufficiently validated to be used with the necessary reliability in studies of land-surface processes.

On the other hand the transformation of land-surfaces has a long history in Europe and gets a new accent in view of the possible climate changes predicted by global models. Though all of total 5 models for the European African segment show approximately the same general trend, they differ considerably with respect to the prediction of regional changes. The reason for theses differences are believed to be caused by insufficient parametrization of ocean as well as land-surface processes. Studies of Mintz (1984), Warrilow (1986) and Rowmtree (1988) underline the importance of land-surface processes in climate modelling.

A complex problem is therefore faced in this important research area:

First, land-surface processes are in itself not fully understood, especially the interaction of vegetation with at the one side the soil and at the other side the atmosphere needs much more clarification.

Second, with increasing knowledge about the interaction between soil, vegetation and the atmosphere, it will become necessary and feasible to improve successively the parametrization of land-surface processes in climate models in order to enhance their predictive capability.

Third it is necessary to collect data which are needed to study land-surface - atmosphere - vegetation interaction processes (LAVIP) and to feed global models. Since a quasi global scale is involved, there are great expectations that measurement made from satellites may help to bridge the present gaps of observations.

Fourth it is necessary to develop the tools to translate the outcome of climate model predictions ("scenarios") into information about regional impacts.

Goals of a Land-Surface Processes Experiment in Europe

The goal of land-surface experiment in Europe are:

- Study of land-surface processes in an area which is threatened by desertification and will first be affected, if climate changes. The processes to be studied include the interaction of soil, vegetation and atmosphere with respect to radiation, momentum, heat and mass transfer (especially but not exclusively water).

- Acquisition of experimental data needed to improve the parametrization and simulation of land-surface processes in detailed one-dimensional models.

- Investigation of the causes that lead to desertification, and, if possible, modelling of this process.

- Validation of information, which can be inferred from measurements made by satellites to study changes of land surface characteristics on a global scale and which may ultimately provide global data sets needed for climate modelling. The planned experiment will specifically address the problem to obtain reliable information in sparsely vegetated areas.

- Development of methods for determining land-surface parameters averaged over areas of the grid size of climate models - up to 250 x 250 km^2 - that are required to improve the parametrization of land-surface processes in climate models. This does not necessarily imply that the experiment must cover an area of this size. It is rather thought of an experiment at the scale of the U.S FIFE experiment, but it is hoped that an area will be found, where the results obtained at the surface in an area of, say, 25 x 25 km^2 may be representative for or can be extrapolated by means of aircraft or satellite measurements to an area that is useful for an intercomparison with a global model.

Approach

To meet the goals of the experiment it is imperative to determine the energy and water fluxes between the soil, the vegetation and the atmosphere, their dependance on climate as well as on environmental parameters, and their relation to the radiances observed from space.

Area averaged energy and water fluxes, and the parameters that determine these fluxes, can only be measured at or near the ground. Therefore adequate simultaneous ground measurements of all important parameters in the soil and the Planetary Boundary Layer as well as of the vegetation is required. In order to relate these necessarily point site measurements to each other and to area values aircraft measurements of fluxes are essential.

To solve the scaling problem between the point measurements at the surface, the pixel scale measurements from satellites and the grid size of climate models intermediate steps are essential: detailed remote sensing methods applied from aircraft, high spatial resolution satellite data of the LANDSAT and SPOT type, and finally meteorological-climatological satellites data (NOAA, MOS, ERS-1, and METEOSAT).

In order to perform an experiment of such complexity one has in the beginning to exclude additional complications that may arise from a topography structured at a scale comparable with the size of the area covered by the number of satellite image pixels needed to infer reliable information. Accordingly it is planned to start with an area is homogenous as can be found in Europe in accordance with the goals outlined above. After an informative visit in Spain and study of informations obtained from Greece it was concluded that the most favorable conditions for such an experiment can be found in Spain.

Because the number of stations which can be installed at the ground is limited, the sites of these stations have to be selected carefully to match the sampling requirements. The principle often applied is to construct a wide-mesh network with a few observation masts (about 25 m high or at least 15 m above the vegetation) and soil hydrology stations together with denser clusters of stations in a few critical or typical areas within the wide mesh area. The details of the necessary networks have to be determined for the finally selected area.

Modelling the water balance of the forested land surface

A.W.L Veen

This activity is concerned with physically based, time-dependent modelling of the water balance of the forested land surface, recognizing evapotranspiration as the main problem area. Research is directed at the parametrization of forest as a source of water vapor and of the lower atmosphere as a sink. Special attention is given to the applicability of standard meteorological data for reliably simulating the forest water balance.

General Information

Phase 1: One-dimensional models

Phase 1 of the activity (1978-1986) started at the University of Groningen (The Netherlands) and was implemented increasingly in cooperation with the Institute of Hydrology, Wallingford, U.K. This first phase resulted in physically based, time-dependent models of interception and transpiration for coniferous and deciduous forest. These one-dimensional models, based on the confiferous and deciduous forest. These one-dimensional models, based on the big leaf approach (Penman-Monteith formula) have been tested against data on forest evapotranspiration in the Netherlands (Castricum forest lysimeters; cooperation Provincial Water Supply Company North-Holland), England (Thetford Forest; cooperation Institute of Hydrology) and the Federal Republic of Germany (Lange Brahmke Forest; cooperation Technische Universität Braunschweig).

Judging from the results it has been concluded that parametrization of the forest in physical terms (a.o. aerodynamic conductance of the canopy by (aeroplane displacement and roughness length, canopy storage capacity, surface conductance as controlled by specific humidity deficit, air temperature, total solar radiation and soil moisture deficit) does indeed lead to satisfactory predictions of forest evapotranspiration. It has also been shown that direct measurements of stomatal conductance, integrated over the canopy, shows promise as a research tool for the analysis of the relationship of surface and stomatal conductance in homogeneous vegetation. Apparently, also the Penman-Monteith parametrization of evaporative fluxes as related to atmospheric conditions works quite well. In one of the interception models the rainfall regime has been integrated explicitly.

Phase 2: Regionalization

In phase 2 of the Groningen University activity (1986-1994) the regionalization problem is tackled.

In an exploratory study, commissioned by the national research programme Study Committee on Water Management of Nature, Forest and Landscape the models, developed in phase 1 of the programme, have been applied to simulate representative values for evaporative losses of a range of forest types under varying climatological and soil conditions in the Netherlands.

However, regionalization of models for the evapotranspiration process requires (at least) evaluation of horizontal transfer of heat and water vapor (advection) and of effects at step changes in aerodynamic and surface conductance.

With support of the Study Committee Water Management programme mentioned above, and in the framework of the national Hydrological Study Area Sleen, a project has been started to develop available micrometeorological approaches into a model for evapotranspiration around a change in surface roughness. At a grass-forest transition meteorological conditions and evaporative fluxes will be monitored simultaneously over both the grassland and the (mixed deciduous) forest. The expected change of evaporative flux with height over the forest near the edge will be registered and linked to boundary layer conditions. A 36 m tower and a 6 m mast have been fitted with two automatic weather stations, and two sets of eddy correlation equipment (sonic anemometers, Krypton hygrometers, fast response thermo-couples, Gill propeller anemometers). In the course of 1989 data sets on non-foliated and foliated conditions will become available.

One spin-off of this project will be data to test schemes for the modelling of the differences in boundary layer conditions above forest and grass land. A well-tested scheme of that kind could be applied for transforming meteorological data - collected as they are above the standard grass cover of meteo stations - to actual conditions over the forest canopy. Obviously, this could be very useful in remote sensing.

Two pilot projects on interception and infiltration in tropical rain forest have been finished. Within the framework of the Tropenbos programme, plans are being finalized in cooperation with the Agricultural University Wageningen to follow up with a project in Central African rain forest (Gabon). This project is concerned with measuring and modelling the water budget of virgin rain forest and secondary vegetation in controlled deforestation plot trials.

Place in IGBP

As to its scientific content, the research activity is related to the IGBP component: "Biospheric aspects of the hydrological cycle". It encompasses Field experiments (i.e. single parameter experiments on a small scale, completed experiments on pixel-array to sub-grid scale), analysis of physical and physiological characteristics (i.e. stomatal conductance, aerodynamic conductance, interception) as described in section 5.3.3 of the IGBP report no. 4, prepared for the first meeting of the SAC-IGBP, 24-28 October 1988 in Stockholm.

The structure of input data, and the parametrization in the models provide opportunities for exploring the response of forest evapotranspiration to climate change as predicted by GCM's. Indeed, a pilot project of this kind has recently been started.

Data can be supplied for ground truth requirements in remote sensing experiments and in grid scale experiments as indicated in the report (p. 54-55). The research Facilities at the Sleen project site (The Netherlands) and at the Monts de Cristal site (Gabon) are in principle capable of being extended in time so as to become useful in the GBO network (report p.27).

Ground water resources in selected Atlantic Islands

J.H. Stock

Introduction

Groundwater resources are of tremendous importance to our human society, both for direct use (drinking water supply) and for indirect use (industrial and agricultural applications).

In many areas of the world, groundwater resources are under pressure, due to increased demand, not in the least through development of tourist industry. This pressure often results in:
(a) over-use (wells drying up):
(b) increasing salinities (the equilibrium between freshwater infiltration and seawater pressure disturbed);
(c) pollution (failures in filtration and purification capacity of aquiferous substrate, or penetration of unfiltered surface waters or sewage).

Since many wells, in particular in countries of volcanic nature, have been dug to a phreatic level corresponding with the actual sea-level, it is predicted that factor (b) of the above list, increasing salinity, will have a great negative influence in the near future, due to the expected rise of the sea-level.

Deforestation of areas with a positive precipitation/evaporation balance, will lead to increased surface run-off, and a reduced infiltration rate. These factors will negatively influence factor (a), the deficit between influx and use of groundwater resources.

Factor (c), pollution is playing an important role, partially because of rapid urbanization of virgin areas (tourism:), without sufficient potentials for sewage treatment. On the other hand, in zones suffering from torrential rains (and reduced holding capacity of soils due to deforestation), large areas will be inundated and groundwater resources will be polluted. In karstic areas in particular, soil pollution can influence large drainage areas.

Sectors (a), (b) and (c) mentioned above are right in focus actually, because of threatening changes on a large scale.

Proposal

The partners in this programme have a 15-years's experience in biological groundwater studies, in particular in semi-arid areas of insular regions in the warm-temperate and tropical Atlantic.

We propose

(a) To document the actual situation by surveying groundwater resources in a number of selected Atlantic islands;

(b) To compare the actual data with the data accumulated in the past 15 years;

(c) To check biological indicators (mostly macro-invertebrates) against physico-chemical and bacteriological parameters, in order to install a monitoring system, in particular in potentially endangered areas;

(d) To issue predictions about the expected quality of groundwater resources especially as to expected changes due to general (global) processes;

(e) To train local students on-the-spot in the methodology;

(f) If financial conditions allow, to repeat a through e on a number of selected islands in the tropical Indo-Pacific, where catastrophic developments have assumed a somewhat slower pace than in the Atlantic.

Soils and the greenhouse effect

W.G. Sombroek

The present status and future trends concerning the effect of soils and their cover on the fluxes of 'greenhouse gases', the surface energy balance and the water balance.

Topics

The following are the main subjects of the Conference:

- Introduction to geospheric-biospheric-atmospheric interrelational processes with special reference to the role of soils and land cover in these processes.
- Quantification of the global spatial distribution of soils and their cover.
- Quantification of the fluxes of 'greenhouse gases' evaporation and albedo for the world soils and their land cover types.
- Mechanisms, modelling and quantification (with case studies) of:
  the exchange of greenhouse gases between the atmosphere and soils and their cover in relation to soil and water management.
  the evaporation from soils and land cover.
  the reflection characteristics (albedo).
- Global trends in the spatial distribution of land cover types.
- Qualification of the effect of soil and land cover changes on the emissions of 'greenhouse gases', evaporation and albedo.
- Remote sensing techniques for the monitoring of land cover and related emission patterns.
- Identification of research gaps (also spatially) concerning the above topics.
- The value and future utilization of soil related studies in interdisciplinary research programmes for geosphere-biosphere-atmosphere research programmes.

Landscape-ecological impact of climate change

C.W. Stortenbeker

Assessing the potential effects of a climatic change on terrestrial ecosystems and landscapes in Europe

Themes

- Sensitivity assessment of specific environments and processes for climatic change in Europe (based on case studies 1 - 6)
- Climate scenarios and models, with special reference to their regional applications in Europe

- Assessment of general environmental changes in response to climatic change in Europe, a.o.:

  changes in major vegetation patterns

  changes in biological diversity

  changes in sediment/solute transport, erosion and landform development

  changes in hydrology (e.g. evapotranspiration, runoff)

  changes in soil properties (structure, organic matter, chemistry, soil water regime, salinity)

  accelerated coastal erosion and its consequences

  change in land use/socio-economic implications

International Geosphere-Biosphere Programme

(Contribution of the Netherlands)

T. van der Hammen

The Dynamic of Quaternary Geo- and Ecosystems

The major part of this project fits in key area 4: "Effects of climatic change on terrestrial ecosystems". Sub-projects in Europe and in South America, referring to the dynamic relation of bio-communities and their environment. Both the present-day ecosystems and their history are being studied, using vegetation sciences, actio-ecology, paleo-ecology, palynology, paleobotany, soil sciences, Quaternary geology etc.

Important are the following /sub) projects:

Peatbog ecosystems in Europe,
in relation to climate and climatic history, human influence etc. Living peatbogs in Ireland; models of peatbog functioning and peat formation, in relation to rainfall variations etc.

High resolution in time (5-10 years), detailed dating, stable isotopes as temperature indicators, chemical study in relation to aerosol in peat. Reconstruction of rainfall and temperature for the last thousands of years.

Study of birch-care ecosystem: several years monitoring and construction of model, relating climate with production, tree rings, etc.

Ecoandes-project
Study of tropical Andean Ecosystems. Study of climate, vegetation and soils along transects through the three Cordilleras of the Northern tropical Andes. (Satellite projects in Costa Rica and Mexico, in collaboration with local institutes). Models of quantitative relation of vegetation and climate (vertical zonation and horizontal variation). Study of vegetational and climatic history of the last thousands of years (and on a larger scale of the last few million years), with high resolution in time. Collaboration with several Colombian institutes.

Tropenbos-Colombia-project
Study of vegetation, soil, climate and human impact in the Colombian Amazonas (part of a waster programme in three continents, sponsored by the Dutch Government). Mapping of vegetation and soils and study of climatic-vegetational history. Study of ecological processes, functioning of ecosystems, in relation to climate and human

influence. Collaboration with many Colombian institutes. Centered in Araracuara, which may be an ideal site for Geosphere-Biosphere observatory.

Related projects, with which we collaborated, collaborate or will collaborate:

CLIMAP
IGCP-programme: Paleohydrology of the Northern Hemisphere.
E.S.F. Scientific programme: The European Paleoclimate and men since the last glaciation (EPC).

The role of earth-sciences within the Global Change programme

B.P. Hageman

1) A vital potential of geosciences with respect to global changes is the production of records of past changes far back in time. Not only can such changes be put in a right order but as dating methods are so well developed by now that absolute dating along several methods is approaching to perfect, especially regarding events during the last few millions of years.

2) Sedimentology has developed tremendously in many respect because of the needs of the exploration for oil, gas and other geobound resources. This knowledge of the sediments enables revealing conclusions on the earth modelling processes over well defined periods, sometimes even in conjunction with year cycles.

3) Such records not only produce a possibility to depict artists view reconstructions of some lost paradise. The modern investigation methods, often using stable isotopes, assemblages of pollen and micro-organisms etc. in many cases enable us to conclude on quantified parameters such as temperature, precipitation groundwater and surface conditions and also in the responding elements such as vegetation cover, animal life, erosion conditions etc.

4) These earth-scientific abilities enable to reconstruct former processes in nature in particular with respect to the effects of interactions, trigger mechanisms and self enforcing processes and they often can give an answer to the crucial question of origin and effect.

5) Special earth-scientific studies have been focussed in the last two million years of the earth history, the Quaternary. During this period the development of the face of the earth was almost exclusively dominated by the rhythmic glacial cycles under which regime the earth is still being carved. These studies have produced rather clear and over the latest cycles very well dated climatic records related to the different latitudes.

6) Within these earth-scientific studies special attention was paid to the interactions between the agent "climate" and the responder "earth surface" and to their mutual influencing. In these mechanisms delinear relations in the form of triggering and self enforcing processes were concluded from what was carved into and read from the Quaternary sediments. The most revealing record on the relations we are searching for today.

7) Scenarios on future natural development and on the effect of changing natural parameters by means of the impacts of human activities, have to be elaborated at the hand of mathematical models. The only way to calibrate these models in a trustworthy way is to let them work "backward" thus "predicting" the past which we know with amply sufficient accuracy. A model that fails in this respect is definitely wrong and has to be reorganized till sufficient agreement with the well known records has been attained.

8) Dates collected over periods of a human lifetime as a rule are inaccurate with respect to the reconstruction of the dominant global processes. In general noise, subordinate short cycles and measure failures in the magnitude of the effect quantity we like to register are fighting for preference to destroy the picture. A fragmentary series of even less accurate dates however collected over a timespan of 10.3 till 10.4 that length produces a curve in which the vector at each point is of orders higher accuracy, especially in the case of big amplitudes characteristic for this geological period dominated by the glacial cycles.

9) The latter is not only true for the most important and steering agent expressed in the temperature graph, but also for all "responding" graphs such as ocean-level curves, vegetation curves, precipitation, erosion and denudation graphs etc.

10) The conclusion therefore must be that a programme on Global Change without taking full notice of the geological records and earth-scientific capabilities is something like writing a look on human nature only at the hand of today's morning paper.

NEW ZEALAND

Introduction

New Zealand's knowledge of an involvement in the IGBP to date has evolved through the Royal Society of New Zealand and its affiliation to ICSU.

The International Geosphere Biosphere Programme is of interest to a wide group of scientists and scientific societies affiliated to the Royal Society of New Zealand as well as its National Committees whose role is to be a channel of communication with international unions and scientific committees of ICSU and to coordinate New Zealand activities in relation to them.

On the initiative of the National Committee for Geodesy and Geophysics an interim sub-committee of NCGG was established to act as a clearing house for IGBP information and to make recommendations to the Royal Society's International Secretary about the best way of dealing with IGBP matters in the future. Dr David Wratt, NZ Meteorological Service, Wellington, and New Zealand Correspondent on the International Association of Meteorology and Atmospheric Physics (IAMAP), was appointed convener and other members of the interim sub-committee are:

Dr D. Hollinger, Forest Research Institute, Christchurch
Dr B.Fitzharris, Geography Department, University of Otago, Dunedin
Dr G. Betteridge, Physics and Engineering Laboratory, DSIR, Lower Hutt
Dr B. Stanton , Division of Water Science, DSIR, Wellington
plus a representative from the SCOPE (Problems of the Environment) National Committee.

A National contribution to IGBP for 1988 has recently been made by RSNZ Council formalizing New Zealand's participation in the Programme.

In March this year the Society hosted a symposium on Climate Change where speakers discussed different aspects of climate and its variability ranging from the long term history of climate variation to the modelling of climate change. This topic, of interest to many RSNZ members, provided a welcome opportunity for wide ranging discussion and debate.

The Royal Society has also established a Standing Committee of its Council, the New Zealand Climate Committee to coordinate science activities in the climate change area on a continuing basis and to produce a report for Council in May 1989 on the scientific basis for climate change predictions.

Following a seminar on climate change coordinated by the New Zealand Government's Ministry for the Environment, also held in March, initiatives led to the setting up of a programme to coordinate New Zealand's response to climate change. Three Working Groups were established and the Society's Climate Committee has been accredited by Government as the Facts Working Group of the New Zealand Climate Change Programme. The two other groups are the interpretation Working Group and the Implementation Working Group.

Members of the RSNZ Climate Committee are:
Mr J.S. Hickman, Convener , NZ Meteorological Service, Wellington
Dr G. Betteridge, Physics and Engineering Laboratory, DSIR Lower Hutt
Dr B. Fitzharris, Dept of Geography, University of Otago
Dr J. Hannah, Dept of Survey and Land Information, Wellington
Dr R. Heath , Division of Water Science, DSIR Wellington
Dr M. McGlone, Botany Division, DSIR, Christchurch
Dr M. Manning, Institute of Nuclear Sciences, DSIR Lower Hutt
Dr J.T. Steiner, NZ Meteorological Service, Wellington
Dr W. Williams, Grasslands Division, DSIR, Palmerston North
Dr J. Kidson, NZ Meteorological Service, Wellington

The Royal Society has established contact and dialogue with the Australian Academy of Science on the IGBP. Closer collaboration on IGBP matters between the two countries has been accepted positively and the Academy has invited New Zealand, where appropriate, to send an observer to its meetings. Dr Wratt attended an Australian IGBP meeting in August.

Liaison with other countries in the Pacific may be developed. New Zealand will have two representatives at the IGBP Southern Hemisphere Workshop on Climate Change and its Consequences to be held in Swaziland in December.

The draft IGBP programme

IGBP Report No 4 (the draft plan) has not yet been received in New Zealand. The following comments are based on IGBP reports 2 and 3.

In general, the proposed plans and working arrangements set out in reports 2 and 3 look very sensible to the interested New Zealand scientists who have seen them. Two particular comments on the plans are:

(a) The discussion of possible funding is vague, especially for activities which might involve several countries with different sizes and resources. This could be particularly important for Geosphere-Biosphere Observatories where the network might include transects across several countries or observations at remote island which are expensive to service. It is suggested that further consideration be given to mechanisms for funding such work.

(b) The areas which the Special Committee on the IGBP felt deserved special priority are indicated by the topics for the working groups and coordinating panels. While the topics chosen are all important ones there is perhaps insufficient emphasis placed on human interaction, social dynamics and the biosphere. For example the links between population pressure, deforestation, changes in land use, and resultant changes in the biosphere are important in many parts of the world.

Comments on IGBP Coordinating Panel Reports:

(a) Terrestrial Biosphere-Atmospheric Chemistry Interactions:

A physiognomic approach (characterizing the responses of vegetation types rather than different specific communities) may prove to be the most efficient.

The methodologies to be employed are a bit vague but might include the eddy correlation technique for trace gas flux measurements. This will require close partnerships between ecologists and micrometeorologists.

Factors affecting the extent and composition of communities (e.g. land-use changes, species invasions) must be considered as well as how these factors may change with climate change.

(b) Biospheric Aspects of the Hydrological Cycle:

The characteristics of the vegetation in controlling water vapor fluxes should perhaps receive additional emphasis. Canopy architecture, for example, strongly affects the interception of water vapor and radiation. An additional example is the action of stomata in regulating transpiration and how this action may change with a changing climate or atmospheric composition.

(c) Effects of Climate Change on Terrestrial Ecosystems:

Biotic effects such as changing competition or the invasion of new species associated with climate change should perhaps receive additional emphasis along with variation in physical resources. In some environments and over the near-term, these biological agents may predominate.

Potential Problems:

Such an enormous and ambititious programme will require the close coordination of modelling and experimentation. Because of the very limited data that exist in many areas (e.g. vegetation or marine-atmosphere interactions, effects of climate change on vegetation) there exists the very real possibility of a "fact gap" developing. To make efficient use of the modelling resource, modelers need to know what factors and interactions are of critical biological and physical relevance. Conversely, experimenters must be aware of the requirements of modelers to provide the necessary data in a timely manner. Special working groups or journals may aid in this coordination.

Much thought will be needed to scale flux estimates of water vapor, CO_2 and trace gases correctly over a hierarchy of levels. Models that scale must be experimentally verified as far as possible to assess whether unforeseen properties emerge at higher levels.

Additional suggestions

Geo-Biosphere Observatories:

Proposed transects along which Geo-Biosphere Observatories could be located are described in "Geosphere Biosphere Observatories: Their Definition and Design for Studying Global Change". (Special Issue 16, Biology International). It is apparent to the Interim New Zealand Committee that proposed observatory transects are principally across continents and do not include the South Pacific. A transect to cover this area could pass from Scott Base in the Antarctic, through the Sub-Antarctic islands and New Zealand, and then trough sub-tropical and tropical islands to the equator. This transect would include (through the Sub-Antarctic islands) high latitude locations where temperature changes due to the greenhouse effect are predicted to be relatively large, and where global change might significantly affect ecosystems. The transect could also include observations of the area of Antarctic sea ice and its variability, monitoring at a sensitive mountain location in New Zealand, and the monitoring of sea level changes and their impact on Pacific atolls. Meteorological measurements and some other observations are already made at remote sites such as Scott Base, Campbell Island and Raoul Island, and Geo-Biosphere observations could perhaps make use of the infrastructure already set up to support these activities.

These suggestions are in line with the idea that studies should concentrate on sensitive areas of the natural environment where global change effects are likely to have a major impact. However it must be stressed they are put up as tentative ideas at this stage as there have been no formal scientific meetings to discuss research and funding for IGBP matters in New Zealand yet.

National priorities

Because planning for IGBP is at such an early stage in New Zealand, it is not possible to give a definitive list of national priorities. Areas of particular interest and research activity in New Zealand at present are predicted climatic change and its impact on ecosystems and human activities, and stratospheric ozone reduction and the Antarctic ozone hole.

Because of geographical and historical isolation, native ecosystems in New Zealand are highly susceptible to invasion by exotic plants and animals. Exotic species have already profoundly affected the structure and function of numerous ecosystems. A changing environment will provide opportunities for additional invasions. Experience shows that the effects of exotic species can be dramatic and precipitous, suggesting that exotic species may provide a greater near-term threat than the direct effects of climate change. Continued study of the biology, ecological effects, and control of exotic species must remain a priority.

Additional Areas of Expertise and Research Activity in New Zealand Relevant to the IGBP:

(a) Scaling of evaporation from leaf to region and surface parameterization of global climate models.

(b) Long-term catchment hydrology including data on dissolved organic carbon loadings.

(c) Direct measurement of water vapor, heat and CO_2 fluxes between vegetation and the atmosphere. Forest carbon balance studies.

(d) As a consequence of its remote location and low pollution, New Zealand possesses unusually clear skies and may be well suited for calibrating or ground truth satellite sensors.

(e) New Zealand has escaped the effects of many pollutants and may be usable as a "clean laboratory" for ecosystem level experiments.

POLAND

After the preliminary discussion in the Polish scientific milieu, we are particularly interested in participating in the following global projects:

- Extracting Environmental Data of the Past
- Development of Geosphere-Biosphere Observatories
- The Role of Antarctica in Global Change /Poland has long tradition in the research in the polar regions/
- Climate change and Water Resources

In all these areas Polish Universities and research centers possess an adequate experience and the results of the research done up to now. Representatives of Poland at the Scientific Advisory Council, Professor A. Breymeyer and Professor L. Starkel will be able to present more detailed information on the possibilities of participation of the Polish research centers in these research.

SOUTH AFRICA

Introduction

In 1986 the South African National Committee for ICSU approved the appointment of a Special Committee to develop South Africa's contribution to the IGBP. The Special Committee, under the chairmanship of Prof P D Tyson, Vice-Principal, University of the Witwatersrand, has met twice, in March 1987 and March 1988.

In order to assist the Special Committee, the following five Coordinating Panels have been appointed:

- Atmosphere-Geosphere Interactions
  (Convener: Prof T C Partridge, University of Witwatersrand)

- Atmosphere-Terrestrial Ecosystem Interactions and Change
  (Convener: Dr F J Kruger, Department of Environment Affairs)

- Marine Biosphere-Hydrosphere-Atmosphere Interactions
  (Convener: Dr L V Shannon, Sea Fisheries Research Institute)

- Terrestrial Biosphere-Hydrosphere-Atmosphere Interactions
  (Convener: Prof R E Schulze, University of Natal)

- Anthropogenic-Environmental Interactions
  (Convener: Mr T Hart, Human Science Research Council)

In addition to the five Panels, Working Group on Data and Data Handling has been appointed, under the leadership of Prof F E Steffens (University of South Africa).

Draft IGBP programme

The South African Special Committee commends the IGBP on the leadership given to the programme as reflected in IGBP Reports no 1 to 3. These reports have been examined by South African scientists and will form the basis on which national activities are build. Report no 4 has only recently been received and comments on this document will be submitted to the IGBP as soon as possible.

At a meeting of the Management Committee for the South African IGBP held on 23 September 1988 the following specific observations regarding the international programme were made:

1. It was recommended that greater balance between the physical and biological disciplines should be sought in the development of the programme which currently places greatest emphasis on biological facets of global change.

2. It was felt that greater emphasis could be placed on hydrological processes in the arid lands of the Southern Hemisphere, which differ in important ways from conditions pertaining in the Northern Hemisphere.

3. It was noted that there is only one Southern Hemisphere scientist on the International Committee. A greater north/south balance should be sought.

4. Evidence indicates that the earth may be entering a phase of reversal of the dipole component of the geomagnetic field during the 21st or 22nd century. this geophysical development is expected to bring about striking changes in all phenomena affected by the solar wind. The extent to which climates are affected by solar wind perturbations is not sufficiently well understood; the International Association of Geomagnetism and Aeronomy (IAGA) Executive has expressed concern and urged careful monitoring of all related parameters.

5. In view of southern Africa's relatively stable coastline, the region would offer ideal conditions for the study of sea-level change.

IGBP programme - national priorities

Based on the International model, the South African IGBP will be carried out in two phases:

- The first phase (1987-1990) will develop a review of what relevant work has been done on environmental changes on time scales from years to decades to centuries in the southern African region, and will plan South Africa's contribution to the second phase.

- The second phase (1991-2000) will provide for the execution of the South African plan, possibly including new research into the causes and consequences of environmental change in South Africa.

The South African programme diverges somewhat from the international model, focusing on those issues on which the local scientific community has greatest interest and expertise, and will not attempt to cover all facets of the final IGBP programme. Furthermore, the South African programme is somewhat less strongly biologically orientated. This is reflected in the setting up of an additional Coordinating Panel on Atmosphere-Geosphere Interactions. In addition, specific attention is being given to anthropogenic influences on environmental change per se.

The south African Special Committee has already convened a number of workshops and conferences towards achieving its goals for Phase I.

From 12 to 14 October 1987 a National Conference on Long-term Data Series relating to Southern Africa's renewable natural resources was held in Pretoria, as a first contribution to the IGBP. The proceedings are in press.

A workshop will be convened from 29 to 30 November at Gobabeb, Namibia, to review understanding of the marine/terrestrial atmospheric interactions between the Benguela upwelling system and the Namib desert environment. It will address issues within a hierarchy of spatial and temporal scales, ranging from the evolution of the major forcing factors to current patterns of community structure and function.

An advanced course in time series analysis was convened from 4 to 6 June 1988 in Cape Town, and in response to the great interest shown, two additional courses are planned for the near future.

A Paleoclimatic Workshop, organized under the auspices of the National Programme for Weather, Climate and Atmosphere Research, was held from 9 to 10 September 1988 in Stellenbosh.

The first phase of the South African IGBP will culminate in a National Conference on Geosphere-Biosphere Change in Southern Africa, which will be held from 4 to 8 December 1989 in Cape Town. The aims of the Conference are:

1. To review available knowledge on global and regional change phenomena within southern African marine, terrestrial atmospheric and hydrospheric systems.

2. to present interdisciplinary syntheses, within the framework currently being developed for the international programme, of the interactive processes involved in global and regional change.

3. To evaluate the state of knowledge and predictive power of information on global and regional change phenomena affecting southern Africa in order to identify research needs, directions and priorities.

4. to encourage the participation of as many interested scientists as possible in the South Africa IGBP.

Workshops have been convened by the various Coordinating Panels to plan review and synthesis inputs to the National Conference. Over 60 scientists and engineers are actively engaged in this process.

List of national IGBP Committee members

Prof P D Tyson, chairman
Prof H J Deacon
Prof J G Field
Dr S C J Joubert
Dr F J Kruger
Mr I A W Macdonald
Dr O G Malan
Prof T C Partridge
Prof R E Schulze
Dr L V Shannon
Prof W R Siegfried
Prof J E Steffens
Mrs E P du Plessis
Mr B J Huntley
Dr C W Louw
Mr O A van der Westhuysen

SWEDEN

The Swedish national report consists of reports from a series of workshops on projects essential to the IGBP.

Exchange of trace gases between soil/vegetation and the atmosphere

Convenors: Henning Rodhe (chairman), Stockholm and Bo Svensson, Uppsala.

Possible future Swedish research (new or extension of ongoing projects) within the area:

i) Comparisons of different methods for measurements of deposition, primarily No_x, SO_2 and O_3: box gradient, eddy correlation etc. Such a study is planned within the EUROTRAC programme (BIATEX), where SU and IVL take part. A campaign on NO concerning this issue will occur in Jädraås 1992.

ii) The scaling from point measurements to larger areas is of great importance. For gases of which the uptake or the emissions are dependent on the activity of the leaf stomata of plants (NO_2, SO_2, O_3) evapotranspiration ought to be a possible way for describing effective areal surface resistances. Expertise within this sector is available in Sweden (SMHI, SLU, MISU, GU). A substantial contribution should therefore be possible.

iii) CH_4-emissions from wetlands, especially in Northern Scandinavia: Methane is a very important trace gas in atmosphere chemistry as well as affecting the global climate (greenhouse effect). It is therefore important to establish a good budget for methane in the atmosphere. CH_4-emissions from wetlands especially at high latitudes have been shown to be important. It is therefore suggested to measure emissions of this gas over a south/north gradient in wetlands and landfills, which are the sources to suspect. The more than ten year old measurements made at Abisko by SLU ought to be repeated and extended.

iv) Regulation of N_2O-fluxes to the atmosphere: The ongoing research at SLU should be continued and extended, preferably in collaboration with LinU and SU. Especially the mechanisms of regulation and the influence of plants should be emphasized. Later a systematic survey of different soil should be undertaken.

v) Interpretation of throughfall measurements, especially for sulphur: Today it is not at all clear, if it is possible to use throughfall data in order to calculate dry deposition to forest canopies. An estimate of the amounts recirculated form the soil via tree trunks is necessary. Field experiments with S-35 is desired. (SLU, IVL, SU)

vi) NO-emission from different soils of the globe: The experience and equipment available at SU should be taken advantage of in surveying different ecosystems. Emphasis should be put on dry areas, where surprisingly high emissions have been discovered.

vii) Development of methods for mapping of vegetation in connection with the interpretation and extrapolation flow measurements: Factors such as LAI, degree of areal cover etc. are of importance. All flow measurements ought to be accompanied by such measurements. How are they obtained from satellite? (SLU).

viii) The remarkably low deposition velocities of NO_2 obtained at SU should be verified by further measurements. Such measurements are planned within the BIATEX programme.

ix) The potential of terpene emissions as important factor in the ozone balance in the atmosphere: Measurements are lacking from several areas among others boreal forests (SU, SLU, IVL).

Climate related environmental changes in global and scandinavian perspective

Convenors: Björn E Berglund (chairman), Lund: Nils Malmer, Lund; Anders Rapp, Lund; and Åke Sundborg, Uppsala.

Conclusions and recommendations

Data character:

- Time span of interest: 0-20 000 BP, that means the last glacial-interglacial cycle;
- Climate related data emphasized, but also including consequences of human impact like deforestation, hydrological changes, etc;
- Events as well as long-term trends are important;
- Improved global and regional documentation aiming at a global synthesis;
- Optimal time control needed for understanding interacting factors;
- Biological-geological response to modern climatic fluctuations important.

Methods:

- Standard methods but improved for quantification;
- Develop data bases for palaeoclimate, palaeohydrology and palaeoecolgy.

General Strategy:

- Complete data bases by extended documentation on hydrological, biotic, carbon storage, human impact, etc. changes. Quantify data;
- When new information needed, select sites/areas with and without human impact for future correlation in time and space of natural systems with human-influenced systems;
- Regional studies important for areas and time periods when time control is particularly good, e g 12-10 000 BP and last 1 000 years;
- Data model comparisons by testing palaeodata against climatic, hydrological, vegetation models.

Organization:

- Most of the presented international projects have relevance for IGBP. It is important that Swedish scientists are involved in this international collaboration. Their research results will be useful for IGBP. The exact strategy for the collaboration between IGBP and other projects has to be solved by the IGBP Council.

Proposed research project with Swedish participation

Several projects of interest to Swedish scientists were proposed. Most of these proposals are highly relevant for the IGBP program according to the research proposal presented by the working group on "Techniques for Extracting Environmental Data from the Past" (July 1988, to be published as IGBP Report 6). In the following summary we refer to this report and our Appendix with seminar summaries.

1. Annual decadal resolution climatic changes during the last 1 000 years - studies based on different records: historical archives, tree rings, lake sediments, especially laminated ones, peat stratigraphy, ice cores, etc. Optimal geographical coverage. Cross-checking different analytical methods. Test against climatic models. - IGBP Report pp 10-14. Swedish seminar, see Wigley, Karlén Dahlström, Bartholin, Kullman, Rehnberg.

2. Arid region paleoclimate and vegetation change tested against climate models for continents and oceans. - IGBP Report pp 15-19. Swedish seminar, see Rapp & Sundborg, Harrison.

3. CO_2 variations, biomass changes, carbon storage and human impact during Holocene. Also including a quantification of organic carbon in vegetation, soils, peat, etc. Improved carbon cycle models. - IGBP Report pp 10-20. Swedish seminar, see Malmer, Prentice, Berglund.

4. Global environmental changes during Holocene, natural systems compared with human-disturbed, including biotic, hydrological pedological etc changes at all latitudes. Interaction between different systems, rate of change, etc. Response to future potential climate change. Testing field data against regional and global models. - IGBP Report pp 21-26. Swedish seminar, see Berglund, Jacobsson, Rapp & Sundborg, Prentice, Harrison, Kullman, Hjort.

5. Global changes through one glacial-interglacial cycle, a 150 000 years perspective. Comparisons between beginning and termination of a glacial. Rate of change problem. - IGBP Report pp 27-34. Swedish seminar, see Lundqvist, Björck, Harrison.

6. Modelling palaeo data for better understanding of physical, chemical and biological processes on a global scale. - IGBP Report pp 37-39. Swedish seminar, see Prentice, Harrison.

Finally, we would support the proposal from this IGBP working group that palaeo data research is given a higher status within the Global Change Program - there is a need for a Coordinating Panel or Steering Committee on "Global Changes in the Past".

Effects of Climatic Changes on Terrestrial Ecosystems

Convenors: Sune Linder and Bengt Torsell, Swedish University of Agricultural Science (SUAS), Uppsala

Summary and conclusions

The main conclusions drawn at the symposium, complied with some post symposium considerations are:

1. Models and competence to simulate carbon/nutrient cycling and ley crop production in relation to weather fluctuations and long term climatic changes are presently available in Sweden (Papers 1, 2, 5).

2. Principles for climatic influences on some insect pests and plant diseases have been applied in predicting crop damages (Paper 4). This experience is useful in the IGBP context. There are also some successful efforts in coupling crop and disease models.

3. Methods for handling agrometeorological information in grid systems on a national scale have been developed and tested. Such capabilities are prerequisites for using crop models to predict production changes on continental scales.

4. Experience in linking models for nutrient cycling, crop production, pest and disease development is poor in Scandinavia. However, successful conceptual considerations of these matters in relation to managed forest production were displayed (Paper 2).

Recommendation on some immediate Swedish IGBP research priorities

1. Parameter estimation and calibration of existing crop models for application on Scandinavian-European scales.

2. Further development of coupled crop-pest models. Work with at least seven plant diseases and pests are required.

3. The Swedish weather grid information system should be linked with identical grids existing over Scandinavia (Europe).

4. Further development of coupling of physical based models with biological growth models. These should be valid for both agricultural and forest crops.

5. Further development of process-based models of forest growth, which over a rotation can take into account the effects of within and between year variations in climatic variables.

Swedish research capabilities in relation to global research tasks

The IGBP program is global in its scope. Swedish research efforts on terrestrial, agricultural and forest ecosystems should therefore eventually employ system models working on continental scales. There is some considerable competence in this particular field at a handful of research centers in the world.

We recommend that efforts are made to attract scientist with this particular competence to the IGBP program and that Scandinavian agricultural and forest research is oriented within this framework. It is evident that such joint global research efforts require careful planning and adequate resources.

The role of the sea in the global geochemical cycle

Convenors: Bengt-Owe Jansson, Stockholm, and Anders Stigebrandt, Göteborg

Main conclusions:

A. General

1. The importance of producing quantitative data was stressed.

2. Qualitative changes in a system in a long time scale are mostly overlooked. This large scale effect of quality should be more looked into.

3. The importance of coastal areas as a whole as sink and source for global fluxes must be considered.

B. Tools and methods

1. Models both of regional (Baltic) and global (greenhouse gases) scale are well underway in Swedish research teams.

2. The importance of biogenic feedback mechanisms (such as rate of production of dissolved organic matter, DOM) on system properties in the long time scale has been largely overlooked.

3. Sedimentation of organic material in the sea has a crucial role in the recycling of many elements. Better equipment has to be developed for use in offshore areas.

SWITZERLAND

Introduction

A national committee ("Landeskomitee") for IGBP was set up in May 1987 under the auspices of the Swiss Academy of Sciences. This committee has identified as its task the promotion of the planning and implementation of national and international research projects of Swiss scientists that are relevant to the study of global change, as stated in the IGBP Reports No. 1 and 2. The Swiss National Committee, for the IGBP is realizing this mandate by promoting the exchange of information between research groups within and outside Switzerland and with the various bodies of the IGBP. This is accomplished through direct mailings of relevant information, through the publication of information in a national bulletin ("Oceanographie-CH") and through the planning and organization of national and international workshops and symposia.

Draft IGBP programme and additional suggestions

The Swiss IGBP Committee fully supports the goals of the IGBP as outlined in IGBP Reports No. 2-4. However, on several occasions scientists in Switzerland have expressed their belief that much may be learned from studies of past sudden changes of the global biosphere, such as: (a) major extinction events (e.g. K/T-boundary); (b) geologically documented disturbances of the global carbon cycle (e.g. mid-Cretaceous anoxic events); (c) layers of nearly monospecific marine plankton skeletons (e.g. Upper Jurassic, Oligocene, Pleistocene); (d) quantification of the rate of environmental change and its relation to diversity and biomass changes (e.g. last deglaciation). Initiatives have therefore been taken towards the establishment of an IGBP related programme concerned with the study of "Past Global Change" under the auspices of the IUGS.

National priorities

Current and planned activities by Swiss scientists, considered to be relevant to the goals of IGBP include the following:

Project EUROCORE

Purpose: This European ice-core programme on atmospheric chemistry and climate will drill ice cores in Greenland and analyze then for reconstructions of climate and atmospheric history.

Participants: Geophysical Institute, University of Copenhagen, Denmark
Laboratoire de Glaciologie et Geophysique de l'Environnement, Centre National de la Recherche Scientifique, Grenoble, France
Physics Institute, University of Bern, Switzerland

Duration: 1989 - 1993

Sponsor: European Science Foundation ("Additional Activity")

Project CLIMATE ACROSS EUROPE SINCE THE LAST GLACIATION

Purpose: This European paleoclimate programme encourages, coordinates and supports state of the art research on physical, chemical and biological parameters recorded in continental natural archives and attempts to synthesize a consistent picture of the evolution of climate and environment in Europe during the last 15 thousand years.

Participants: Numerous research institutions in EC and non-EC countries.

Duration: 1989 - (?)

Sponsor: European Science Foundation ("Associated Program")

Project PROCLIM

Purpose: This "Swiss Climate Research Program" is currently planned to focus on: (a) an improvement of the monitoring of regional climate data and the development of climate models; (b) reconstruction from proxy data and modelling of past climates on various special and temporal scales (little ice age to last interglacial); (c) paleoclimatic traverse across the Alps (coordinated with the project "Climate across Europe since the last glaciation").

Participants: Numerous research institutions in Switzerland. International collaboration with related projects is planned.

Duration: >10 years, starting in 1989

Sponsor: Swiss National Science Foundation and possibly other agencies of the Swiss Federal Government.

GBO: Geosphere-Biosphere Observatory

The possible establishment of an IGBP-GBO in Switzerland, or in Ivory Coast at the Centre Suisse de Recherches Scientifiques en Cote d'Ivoire (CSRS), is currently being discussed and tentatively proposed to IGBP. Scientific research at the CSRS has been conducted since 1951 and has included botany, mycology, phytosociology, malacology, zoology (amphibians, reptiles, mammals), parasitology, and soil sciences.

UNITED KINGDOM

Report of the British National Committee for the International Geosphere Biosphere Programme to the Scientific Advisory Council for the IGBP, Stockholm, 24-28 October 1988.

Introduction

In September 1986 the Royal Society submitted a paper to the ICSU General Assembly in Berne, Switzerland, entitled the "International Geosphere Biosphere Programme - A Royal Society View". The paper set out preliminary UK proposals for the IGBP and advocated ICSU commissioning a series of feasibility studies to draw up guidelines for the programme and individual components and to identify existing, overlapping or complementary projects. It was intended that these studies should lay the groundwork for the effective implementation of the programme.

Following the decision of the ICSU General Assembly to establish the International Geosphere Biosphere Programme, the Council of the Royal Society approved the setting up of the British National Committee (BNC) for the IGBP, under the chairmanship of Professor W.G. Chaloner, FRS with the following terms of reference:

(i) To correspond with the Special Committee for the Geosphere-Biosphere (SCGB), the terms of reference of which are "to provide for the development and correlation of the scientific programme, to describe and understand the interactive, physical, chemical and biological processes that regulate the total Earth system (the unique environment that provides for life), the changes occurring in this system and the manner in which they are influenced by human actions, with a view to allowing the commencement of the operational phases in the early 1990s"; and

(ii) To report to the Council of the Royal Society.

The BNC has met twice and the results of its discussions are given below.

The draft IGBP programme

The British National Committee for the IGBP welcomed the decision of the Special Committee for the Geosphere Biosphere (SCGB) to establish four Coordinating Panels (CPs) and four Working Groups (WGs). At its meeting on 23 February 1988, the BNC considered the priority research fields selected by the SCGB, paying particular attention to the significance and suitability of the scientific research topics identified by the Coordinating Panels and Working Groups and the degree and character of UK interest in those topics. The BNC also discussed a variety of other research topics which it considered to be particularly relevant to the IGBP, and agreed to recommend the inclusion of a number of these in the international programme. A synopsis of the UK proposals is given below:

Coordinating Panel on Terrestrial Biosphere-Atmospheric Chemistry Interactions

Having examined the brief of the CP as laid out in IGBP Report No. 2, the BNC expressed concern that CO_2 had not been included among the list of important gases identified by the CP as being worthy of examination, and also suggested that a greater emphasis should be placed upon the study of the terrestrial biosphere and specifically terrestrial sources and sinks. In the light of these comments the Committee welcomed the revised brief of the CP as set out in IGBP Report No. 3 and notably the inclusion of CO_2 in the list of key biogenic gases.

It is also important that, having recognized that several ICSU bodies are currently planning research projects in this field, for example the International Global Atmospheric Chemistry (IGAC) Programme being planned under the auspices of IAMAP, the Coordinating Panel should link its schedule of work with these other projects to avoid unnecessary duplication and to ensure that its research goals are met.

Coordinating Panel on Marine Biosphere-Atmosphere Interactions

The marine biosphere plays a central role in the global carbon cycle and will have to be included explicitly in prognostic models of global CO_2 change. However, the marine biosphere interacts with the atmosphere not only through the CO_2 flux but also through the flux of dimethyl sulphide (DMS) which has been studied by Professor J.E. Lovelock, who suggests it may control the number of cloud condensation nuclei and therefore the albedo of clouds over the ocean. The BNC suggested that the CP might therefore consider widening its scientific remit beyond the CO_2 problem to include a study of the broader global sulphur cycle and biogenic gases in general.

However, the BNC also recognized that several programmes of study are currently being planned to investigate this problem, for example the US Global Ocean Flux Study (GOFS), the UK Ocean Flux Study (BOFS) and the International Joint Global Ocean Flux Study (JGOFS) which is coordinated by ICSU's Scientific Committee on Oceanic Research (SCOR). Clearly, the key issue to be resolved is the coordination of work being carried by the IGBP and JGOFS although as JGOFS emphasizes field studies, the IGBP could concentrate upon complimentary theoretical modelling work, as suggested in IGBP Report No. 3.

Coordinating Panel on Biospheric Aspects of the Hydrological Cycle

In IGBP Report No. 2, it was felt that the brief of the CP had identified the main elements required in this area. Transformations of the near earth surface and the surface itself by agriculture and forestry as well as urban development have had significant on-site and off-site hydrological impacts. However, the BNC agreed that the following points were also relevant:

i) In addition to being very important to Global Circulation Models (GCMs) the transformations have great significance for terrestrial hydrologically related processes such as groundwater movement and pollution, and water resources for human consumption. The CP's concern for providing inputs for GCM's should not override the equally important hydrological effects at ground level.

ii) The report made no specific reference to soil erosion in relation to both hydrology and vegetation cover. In semi-arid and arid environments there are critical interactions between vegetation cover, soil hydrology and soil erosion. Over large parts of the Earth it is the loss of soil, with its extremely slow replacement time compared with the vegetation cover, which is more critical, both from a hydrological and an atmospheric-vegetation point of view. Whereas in temperate environments hydrological relationships are limited by climatic energetics, in drier environments the soil characteristics have a major role to play. There is now a significant amount of national and international effort being made on soil-plant interactions in a erosional context which could be of benefit to and benefit from coordination in such an interdisciplinary programme.

iii) The Committee felt the CP should establish an appropriate spatial scale for the studies outlined. Although it was difficult to envisage how the micro-scale of root characteristics might fit into the global model it was suggested that a series of sub-models might be required to interleave with the macro-scale, global model.

Coordinating Panel on Effects of Climate Change on Terrestrial Ecosystems

In considering the CP's remit, as set out in IGBP Report No. 2, the BNC agreed that too great an emphasis had been put upon ecosystem processes as such and suggested that a link needed to be made between biological studies and physical and chemical studies in his context; similarly it was felt that the effects of climatic change on the genotypes of species had generally been overlooked. It is now widely recognized that duplication of effort when planning research projects needs to be avoided and the Panel's recognition of the work being carried out by SCOPE on ecotones is welcomed. However, the BNC agreed that the extensive database, describing changes in the vegetation of North Europe and the USA (and built up by phytogeographers over the past century), should be recognized and, if possible, utilized by the Panel.

Working Group on Global Geosphere-Biosphere Modelling

The BNC recognized that the problem confronting IGBP modelers is the identification of the class of environmental issues that might be addressed by global models, including not only the physics if the atmosphere (treated in GARP) and the broader planetary system (being examined by the WCRP), but also some key chemical processes. The modelers have to assume that, eventually (perhaps by the early decades of the next century), the power of super-computers will become sufficient to integrate the highly complex equations of global physical-chemical systems. Currently, however, they have to limit their ambitions to those aspects of global chemistry for which there us a reasonable chance of deriving prognostic equations, with adequate recognition being given to those processes which remain unresolved. There are some problems in global chemistry, for example those relating to the seasonal hole in the ozone layer above the Antarctic, that can be treated as a physical problem, but it is not expected that the SCGB will be content to limit the IGBP to those problems. Indeed the WGs intention to address other issues, such as the effects of carbon dioxide in climate change, that involve biology as well as physics, is welcomed. As models should include plants, because of their crucial importance as sources and sinks for individual substances, the WG is encouraged to widen its remit to include the effects of plant biota. However, the WG should not tackle aspects of global change that are intractable, i.e.: those for which there is little prospect of their simulation in prognostic models.

Working Group on Data and Information Systems

In considering IGBP Report No. 2, the BNC considered that although the WG's remit placed a heavy emphasis on the collection and dissemination of remote sensing data sets, the service (as summarized in the document) that was envisaged would be inadequate to cope with the overall requirements of the IGBP. Utilization of alternative (and complimentary) data sources, of data organization, integration, and data-sensitive analytical methodologies will be essential; the WG must avoid simply creating new data-warehouses. The greatest emphasis needs to be placed on the methodological problems associated with the establishment of global databases, having first verified the necessity of specific databases.

The BNC felt that the remit of the WG might be expanded to incorporate the prediction of hazards such as flash floods, tsunamis and earthquakes. The rationale for this is that the role of metropolitan populations, both as initiators of environmental change and as the victims of catastrophic change, can be thought of in environmental terms. Indeed a reasonable database of population distribution throughout the world would be helpful and pertinent, particularly now that the Human Response to Global Change (HRGC) programme has got underway. If undertaken. the WG should coordinate its activity with the agencies such as UNESCO and UNDRO that will be responsible for the International Decade of National Disaster Reduction, and also with the International Geographical Union (IGU) Global Databases Planning Project.

Working Group for Extracting Environmental Data of the Past

The field covered by this WG was perceived to be one of the central pillars of the work of the IGBP as a whole, but it should avoid embarking on further reviews of techniques available for reconstructing past environments. The WG must adopt an appropriate time scale: although significant changes in the environment have taken place over the past 10 000 years, the examination of changes occurring over a longer time scale will help understanding of the causality and nature of short-term changes.

Working Group on Geo-Biosphere Observatories

In relation to the general objectives of IGBP and to the specific subjects of three of the CPs, (namely those on Terrestrial Biosphere-Atmosphere Chemistry Interactions, Biospheric Aspects of the Hydrological Cycle, and Effects of Climate Change on Terrestrial Ecosystems), it is clear that a range of Geo-Biosphere Observatories (GBOs) which can be controlled (at least in terms of the human activities upon them), instrumented and observed will be required. Consequently, the establishment of a Working Group on Geo-Biosphere Observatories seems sensible and the issues outlined in IGBP Report No. 2 seem appropriate. Until the WG has a clearer identification of the objectives of the several parts of IGBP and of the measurements and observations required, it is not so clear that the comments about the two kinds of sites envisaged (i.e.: biosphere reserves and regions where rapid change is expected) are apposite.

The SCOPE/MAB Biosphere Reserves were selected primarily as areas for conservation and landscape interest and it is not obvious that they are necessarily the most appropriate choice for IGBP research. For instance, IGBP is not solely concerned with ecosystems with little direct human activity and therefore the choice of sites should remain open at this stage.

As judged from IGBP Report No. 3, the WG clearly recognizes that the establishment of a network of GBOs needs to be coordinated with other international organizations and not least of all with ICSU itself. The US National Committee for SCOPE, for example, was intending to propose to the SCOPE General Assembly in June 1988 that a workshop should be held in Europe in autumn 1988 to address the subject of Long Term Ecological Research. As this workshop was intended to discuss many aspects of long term ecological research sites, this may represent an area of contact with the objectives of the WG on Geo-Biosphere Observatories.

Additional suggestions

Modus operandi

It was noted from IGBP Report No. 3 that the first meeting of the Scientific Advisory Council (SAC-IGBP) would consider a draft report from the SC-IGBP outlining a framework for, and preliminary contents of, the IGBP. The BNC has discussed a possible project-based modus operandi which it is understood the SCGB is considering for the IGBP. The Royal Society's experience of the IGCP, which is project-orientated, is that there are considerable advantages in international cooperative programmes that are so organized. The studies that are launched within the IGCP framework are those which stem from the interests of the working scientists (rather than by decree from above) and only those which can readily demonstrate a wide measure of support internationally are approved, proposals being made within the boundaries of broadly-stated programme guidelines. Secondly, central approval is accompanied by annual seed funding (averaging ca. $3 000 pa.) to facilitate international planning, progress reviewing and final presentation of results, most projects being strictly limited in time (about 5 years) to allow new projects to be initiated. The project-basis of the IGCP has enabled the UK at least to fund UK participation in the administration and guidance of those projects in which the UK is interested, so it is feasible to measure value for money (which is much more difficult with unfocused broad-spectrum research for which countries simply pay an annual subscription). Of course, funding for the research studies that contribute to the selected projects must be secured from the usual funding bodies but, in the UK at least, the selection of discrete projects does enable British scientists to participate in the international programme (and this may be true of other countries which are not able to earmark large sums of research monies for international programmes).

Man's reaction to global changes

It is clear that the socio-economic effects of environmental changes are not addressed by the IGBP and yet are critical for the survival of organized society. Countless examples illustrate that, however good our capacity to understand the global dynamic system, these efforts count for little unless the social, political and economic dimensions of the problems generated by changes in the environment are identified and studied. Of course to incorporate these into the IGBP would be extremely difficult yet not to do so would be blind to reality. However, it may transpire that the HRGC Programme will address these issues and so complement the purely scientific IGBP.

National priorities

The British National Committee has identified the following as being possible UK contributions to the IGBP:

Coordinating Panel on Terrestrial Biosphere-Atmosphere Chemistry Interactions

There is considerable UK expertise in tropospheric chemistry and dynamics particularly in the processes of photoionization, dissociation, ionic scavenging, parameterization of natural

processes and global modelling. Some work has been done on emissions from specific (albeit agricultural) ecosystems.

In consequence, the UK would hope to contribute to the research topics identified by this CP, though, as much of the research is long term, it may be difficult to attract funding.

Coordinating Panel on Marine Biosphere-Atmosphere Interactions

The UK Biogeochemical Ocean Flux Study (BOFS), sponsored by NERC, is directly addressing this subject and is related to JGOFS. Professor J.E. Lovelock and his co-workers have a world reputation in this field.

Coordinating Panel on Biospheric Aspects of the Hydrological Cycle

British groups with particular interests in plant-water interactions are at the Institute of Hydrology (Wallingford), Imperial College London, and Nottingham University. On the interactions of plant-hydrology-soil erosion, the main interests are at Leeds University and at Bristol University where a group is working on non-linear dynamic models of erosion and their field validation and calibration. Work relevant to the impact of parameterization of surface change in relation to GCMs is being carried out at the Universities of Liverpool and Leeds, and in the Meteorological Office. There is a large amount of work in the UK on short-range, intermediate and long-range climatic changes, most of which is well known. Perhaps less well known is the work by karst geomorphologists using speleothems dated by uranium series methods, such as that at Bristol University. The use of palaeomagnetic techniques to detect man's impact on soil erosion rates was pioneered at Liverpool University.

Coordinating Panel on Effects of Climate Change on Terrestrial Ecosystems

In the UK a considerable amount of work has been done on the investigation of the effects of past climatic change on vegetation and whole ecosystems. There is considerable expertise, particularly at the Universities of Oxford, Birmingham and East Anglia, relating to the Holocene, during which ecosystems have been affected both by climatic change and man's activity, but also in studying climatic changes during earlier epochs when man's activity was probably much less significant. By incorporating these studies into the IGBP, it should be possible to promote substantive interaction between a global network of palaeoclimatologists and atmospheric modelers thereby relating observed changes to past climates and enhancing the scientific value of current research in this area.

Working Group on Geosphere-Biosphere Modelling

The UK has played a prominent role in global modelling of the atmosphere for both GARP and the WCRP, thanks largely to the expertise of the Meteorological Office and university scientists working in conjunction with the Office and with the adjacent European Centre for Medium Range Weather Forecasting. In recent years, UK ocean modelers have embarked on large-scale circulation modelling, and coupled ocean-atmosphere modelling. There is considerable UK interest in atmospheric chemistry related to essentially physical aspects (ozone, tropospheric pollution, mesosphere trace gases, etc). The NERC is considering establishing a University Research Centre to accelerate such research, with special emphasis on the modelling of those features of the atmosphere for which dynamic physics and chemistry are equally important. There is little experience in the UK related to the modelling of the global environment with equations that explicitly include changes in the biosphere and geosphere, nor is there much experience elsewhere. Nevertheless, there is interest in the UK in modelling the individual processes that will eventually have to be represented in such large scale models, notably marine primary production, and land surface processes including hydrology.

Working Group on Data and Information Systems

The UK has a considerable reservoir of skills in this area and relevant work is currently being undertaken by several organizations including NERC (in the Marine Information and Advisory Service (MAIS) and the NERC Unit for Thematic Information Systems (NUTIS)) and Birkbeck College, London where an environmental database for the entire EEC is being compiled. The UK can, therefore, make a significant contribution in this area.

Working Group on Techniques for Extracting Environmental Data from the Past

Within the UK there is considerable interest, particularly amongst Quaternary scientists, in movements of sea level in the British Isles, and especially in the post-glacial period much of which was deployed during the spans of Holocene sea levels (IGCP Projects 61, 200 and 274). Interest in Pleistocene sea-level movements is more restricted. These interests should grow as dating methods improve in terms if the range of materials (and amounts of materials) that can be dated. There is a little interest among British sedimentologists in the analysis of tidal signals in sediments. This work could be further developed, with help from Dutch investigators who lead the field, to allow for the identification of climate-related storm-induced 'noise'. There is scattered interest among UK palaeontologists in the analysis of annual growth patterns in invertebrates. As attention has so far been concentrated on just a few groups (e.g.: on corals at the University of Newcastle upon Tyne) there is considerable scope for UK contributions in this area. There is scattered interest in the sequential analysis of floras and vertebrate faunas in the Quaternary and, to a sequential analysis of floras and vertebrate faunas in the Quaternary and, to a lesser extent (floras mainly), in the Cenozoic, from which UK contributions may be drawn.

However, in addition to the above, it is important to note that the UK has world leaders in some important technique areas such as reconstructing the hydrological balance from lake-level information, the quantitative interpretation of coleopteran assemblages in terms of past climate (Department of Geology, University of Birmingham; and University of East Anglia), and reconstructing global ice volume and atmospheric carbon dioxide levels from deep sea sediment data (e.g.: at Oxford, the Robert Hooke Institute for Cooperative Atmospheric, Oceanic and Planetary Research; and the Subdepartment of Quaternary Research at Cambridge). Reconstruction of past climates from historic data is a specialization of the Climate Research Unit at the University of East Anglia.

At the University of Bristol, the organic geochemistry unit has been developing molecular stratigraphy in relation to past climate history: quantitative study of molecular biomakers is providing new insights concerning sedimentary input from the marine biosphere, especially in relation to photic zone water temperatures.

Working Group on Geo-Biosphere Observatories

The UK, as a geographical area probably has little bearing on global fluxes, or as a sink or source, there is no need to include the UK among sites represented in IGBP. However, the UK has a number of sites, for example the Plyolimnon water catchment, Rothamsted Experimental Station and the Monkswood Experimental Station, where there is already a significant long-term record of relevant observations and which could, with a little extra investment, contribute to IGBP. UK research organizations also have sites overseas, particularly in Antarctica (Signby Island) and Malaysia (Danum Valley) where relevant observations have been and are being made. Professor Lovelock has established 10-year measurement sites at Macehead, Republic of Ireland; Cape Grimm, Tasmania; Cape Meares, Oregon; Ragged Point, Barbados; and in American Samoa. The Department of Biology, King's College, London and the University of Essex have collected baseline data on bioproductivity from five tropical grassland sites as a UNEP project. Support of such sites could actively involve scientists both from the UK and developing countries.

The objectives of the IGBP are pertinent to important strategic research interests in the UK which include the effect of atmospheric pollution on climate, the effect of vegetation and land use change on the hydrological cycle and on water quantity and potability. UK involvement in IGBP can probably be achieved at marginal additional cost to existing and planned UK research programmes. The benefits of involvement will relate to maintaining a skill and knowledge base in the UK to timely and full appreciation and utilization of international datasets, and assessing the contributions from UK environmental research including possible UK-based or promoted Geo-Biosphere Observatories in relation to internationally-promoted research on the global environment.

List of members of the British National Committee for the IGBP

(The British National Committee for the IGBP was set up by Council of the Royal Society in November 1986 and Dr P.T. Warren (Executive Secretary) is the dejure Secretary).

Professor W.G. Chaloner, F.R.S., Chairman
Professor J.R.L. Allen
Dr J.C. Bowman, C.B.E.
Professor A.D. Bradshaw
Professor G. Eglinton, F.R.S.
Professor J.L. Harper, F.R.S.
Professor D.O. Hall
Professor J.E. Lovelock, F.R.S.
Sir John Mason, C.B., F.R.S.
Professor D.W. Rhind
Dr N.J. Shackleton, F.R.S.
Professor J.K. Syers
Dr J.D. Woods
Dr B.L. Bayne

UNITED STATES OF AMERICA

Summary of recommendations

Human activities are currently leading to changes in the global environment at virtually unprecedented rates, with potentially severe consequences for our future welfare. Increases in carbon dioxide and other greenhouse gases, concerns for climate change, the appearance of the antarctic ozone hole and worldwide depletion of the ozone shield, tropical deforestation, and a host of other changes in our environment have captures the attention of scientists, the public, and policymakers. The problem of global environmental change is crucial and urgent.

For scientists, understanding the changes now in progress - both natural and anthropogenic - and predicting their future course are unprecedented challenges. New capabilities for observing the earth and new understanding of natural processes have led to a new conception of the earth as an integrated whole and to the development of evolving, extremely broad research programs on global change. Such programs must draw upon the capabilities of scientists in many disciplines and many nations and must build upon the foundation provided by many ongoing national and international programs.

In the United States, the program on global change includes the study of biogeochemical dynamics, ecological systems and dynamics, climatic and hydrologic systems, human interactions, earth system history, solid-earth processes, and solar influences. The fundamental paradigm is that the prediction and ultimate management of environmental problems inescapably require development of a new earth system science aimed to improve understanding of the earth as an integrated whole.

In the international scientific community, the International Council of Scientific Unions has organized the International Geosphere-Biosphere Program (IGBP) to address the problems of global change. The objective of the 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".

The IGBP is currently in its preparatory phase, during which the program's goals and research components are slowly evolving and coming into focus.

In this report, a limited number of high-priority research initiatives are recommended for early implementation as part of the U.S. contribution to the preparatory phase of the IGBP. The recommendations are based on the committee's analysis of the most critical gaps, not being addressed by existing programs, in the scientific knowledge needed to understand the changes that are occurring in the earth system on time scales of decades to centuries. These initiatives will build upon the capabilities of the U.S. program in global change.

With this framework in mind, the committee recommends the following:

1. **Research initiatives**

The committee recommends that the early U.S. contributions to the IGBP should focus on the following five research initiatives that address key relationships in the earth system:

- **Water-energy-vegetation** interactions to develop global models of the response of terrestrial ecosystems to changes in climate, land and water use, and related factors, and to determine the reciprocal effect of such changes in terrestrial ecosystems on the climate system on regional and global scales. This research initiative requires an integrated approach of observations, experiments, and model development.

- **Fluxes of materials between terrestrial ecosystems and the atmosphere and ocean** to (1) improve understanding of ecosystem processes most important for determining fluxes of radiactively active gases between the land and atmosphere, in order to predict how changes in climate and land use alter gas emissions, and (2) improve understanding of the effects of land use changes on nutrient transfer to river, estuarine, and ocean systems, especially to understand consequent feedbacks to climate through, for example, long-term changes in ocean productivity.

- **Biogeochemical dynamics of ocean interactions with climate** in order to predict effects of climate change on ocean biogeochemical cycles and the interactions of such cycles with climate via release and absorption of radiatively active gases. The ocean's capacity to sequester or release such gases - for example, carbon dioxide or organic sulfur species - is directly and indirectly influenced by climate.

- **Earth system history and modeling** to document changes in atmospheric composition, climate, and human activities to improve and validate models of global change. A focus on periods of rapid rates of change will provide insights into those changes that can be expected to occur with rates predicted for the future.

- **Human interactions with global change** to analyze changes in human land use, energy use, and industrial processes that drive changes in the earth system. Documentation of changes in such human activities over the last several hundred years and construction of future scenarios of human activities that contribute to global change will be part of the effort.

Steering groups of experts should be formed to develop detailed research plans for each of the five initiatives proposed above, with the committee assuring coordination and integration.

2. Supporting research

The U.S. component of the IGBP should serve to strengthen, coordinate, and enhance support for ongoing supportive activities in the earth sciences such as the World Climate Research Program, the Global Tropospheric Chemistry Program, the Joint Global Oceanic Flux Study, and related discipline-oriented research.

3. Long-term measurements

In order to document global change and provide a basis for the IGBP research program as a whole, a long-term commitment from all relevant agencies for sustained long-term measurements of key variables is required. An important element is an integrated Earth Observing System program to coordinate space-based observations.

4. Data and information systems

All components of the IGBP, both U.S. and international, will require effective data and information systems, capable of making available to research investigators contemporary space- and ground-based data from observations and experiments as well as historical data sets. Establishing and maintaining an effective system for the diverse types of data that will be generated by the IGBP require an innovative, flexible, and carefully conceived approach. A Global Information System Test should be implemented to test the end-to-end performance of the information system.

5. International Geosphere-Biosphere Research and Training Centers

A limited number of International Geosphere-Biosphere Research and Training Centers should be established around the world as major foci for international cooperation in research and training for the study of global change. The centers would serve as appropriate to provide bases for large-scale manipulative experiments, to establish links with other international and national research and observational networks, and to serve as central repositories for observational and experimental results.

6. Interagency coordination

Interagency coordination between the relevant U.S. agencies for implementation of the U.S. component of the IGBP is essential to the effective management of the complex program. Existing mechanisms for such coordination under the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET) Committee on Earth Sciences should continue to be strengthened, and the adequacy of this mechanism to the task at hand should be periodically reviewed.

7. Coordination of international activities

Innovative mechanisms should be developed for coordination of related activities of international, intergovernmental and nongovernmental organizations, and many national groups of all kinds, with the IGBP. The International Council of Scientific Unions should urgently address the international institutional arrangements for the IGBP.

Introduction

Rapidly evolving changes in the global environment have captured the attention of scientists, policymakers, and citizens around the world: the increase of atmospheric greenhouse gases such as carbon dioxide, methane, and the chlorofluorocarbons; the expected consequent changes in global climate and sea level; global depletion of stratospheric ozone and the observed "antarctic ozone hole"; widespread desertification in many parts of the developing world; massive tropical deforestation and reduction in the diversity of plant and animal species; extensive damage to mid-latitude forests; and acidification of lakes and soils in many regions. At the least, these changes have far-reaching and potentially disruptive implications for the world's natural resources. In the worst case, the changes collectively threaten the life-support system of the earth. The problem of global environmental change is crucial and urgent.

The scientific community is thus urgently challenged with providing to decision makers the best possible assessments of the future course of the global environment, assessments on which policies to mitigate and adapt to these changes can be based. Over the past decade, efforts to translate the agenda of environmental problems perceived by the public into a scientific agenda of clearly posed, tractable, and prioritized research problems have led to a unifying seminal insight: We cannot hope to understand fully or to predict meaningfully the course of any single long-term environmental change without understanding the earth system as an integrated whole, the changes in the system over the earth's history, and the ways in which anthropogenic activities interact with the system.

Contemporary advances in technology, such as the ability to observe the earth from space and the rapidly accelerating capabilities for data handling, numerical modeling, and telecommunications, make such an ambitious venture possible at this time. Historically, revolutionary scientific advances follow the development of each new instrument that extends our vision of the real world. Invention of the telescope opened our understanding of the universe. The microscope led to revolutions in biology and medicine. Today, satellite-borne sensors, worldwide communications systems, and supercomputers permit us to see our planet for the first time as an integrated whole. Disciplinary advances that have led to current understanding of the components of the earth system provide a launching point from which an integrated view of the system can proceed. Thus, because of these advances in science and technology, understanding global environmental change is not only urgent; it is now possible.

U.S. program for the study of global change

Long-term changes in the earth have been addressed in a number of national and international programs (e.g., the Global Atmospheric Research Program, its successor World Climate Research Program, and UNESCO'S Man and the Biosphere Program) that provide a strong foundation for continued progress. Most recently, an extremely broad U.S. national effort in the study of global change has evolved based on the conceptual foundation of earth system science. This conceptual framework was developed in a multidisciplinary study by the Earth Systems Science Committee of the National Aeronautics and Space Administration and has been used

extensively by the National Science Foundation and the National Oceanic and Atmospheric Administration in planning their research programs on global change (ESSC, 1988). The goal of earth system science is to obtain a scientific understanding of the entire earth system on a global scale by describing how its component parts and their interactions have evolved over the earth's history, how they function, and how they may be expected to continue to evolve. Because of the increasing evidence of potentially significant human influences on the earth system, the U.S. program focuses on the research necessary to predict those changes that will occur in the decades to centuries, both naturally and through interactions with human activities.

Currently, the U. S. program on global change centers on the study of the following seven elements identified by the Federal Coordinating Council for Science, Engineering, and Technology's Committee on Earth Sciences (Committee on Earth Sciences, 1988):

- **Biogeochemical dynamics** to study the sources, sinks, fluxes, and interactions between mobile biogeochemical constituents within the earth system, with a particular focus on water, oxygen, carbon, nitrogen, sulfur, phosphorus, and the halogens.

- **Ecological systems and dynamics** to study the responses of ecological systems, both marine and terrestrial, to changes in global environmental conditions and the influence of biological communities on the atmospheric, climatic, and oceanic systems.

- **Climatic and hydrologic systems** to study the physical processes that govern the climate and hydrological system - comprising the atmosphere, hydrosphere (oceans, surface and ground water, and so on), cryosphere, land surface, and biosphere.

- **Human interactions** to study (1) the impact of human activities on the global environment, including releases of nutrients, toxins, chemicals, and trace gases and changes in the use and cover of the land, such as desertification, and (2) the impact of changing global conditions on human activities.

- **Earth system history** to uncover the natural record of environmental change contained in rocks, terrestrial and marine sediments, glaciers and ground ice, tree rings, geomorphic features, and other direct or proxy documentation of past environmental conditions.

- **Solid-earth processes** to study those processes affecting the life-supporting characteristics of the global environment, especially those processes that take place at the interfaces between the earth's surface and the atmosphere, hydrosphere, cryosphere, and biosphere.

- **The solar influence**, including studies of the atmospheric response to changes in solar trends including variations in solar output and the earth's orbital elements.

The International Geosphere-Biosphere Programme

Internationally, a new interdisciplinary program in which scientists from many nations and diverse disciplines can work together to understand the earth as an integrated whole is being planned to augment the ongoing efforts dealing with individual components of the earth system. The internationally defined objective of the International Geosphere-Biosphere Program (IGBP) - A Study of Global Change, launched in 1986 by the International Council of Scientific Unions (ICSU, 1986), 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 influenced by human activities".

Priority in the IGBP falls on

> "those areas of each of the fields involved that deal with the key interactions and significant change on time scales of decades to centuries, that most affect the biosphere, that are most susceptible to human perturbation, and that most likely lead to predictive capability".

Implementation of the IGBP clearly calls for interdisciplinary, international research on an unprecedented scale. The success of the program will depend on the ability to document global change through long-term and sustained measurements of key variables in the earth system through an expanded space- and ground-based composite observing system. Modeling global change, a critical element of the program, calls for extended research by interdisciplinary teams employing advanced computational capabilities. Thus implementation of the program requires a long-term political commitment to develop the scientific basis upon which policy decisions can be made.

The operational framework for the IGBP must include investigation and understanding of phenomena of time scales both shorter and much longer than the decades to centuries scale for which predictive capability is needed. Studies under the World Climate Research Program of the response to the short-term phenomena of El Nino, for example, provide information about the modes and rates of response of the biota to changing environmental conditions. Long-term phenomena revealed in the record of the past provide essential background against which these more immediate changes can be evaluated. Similarly, although the focus of the program is on global scales, it must include those regional-scale studies that are needed both to understand the whole-earth system and to anticipate significant regional impacts of global change.

The international scientific community is currently engaged in the preparatory phase of the IGBP under the guidance of the ICSU Special Committee for the IGBP. During this period, the program's goals and research components will evolve and come into focus. Some operational elements of the IGBP have already been initiated, and others will be implemented as planning is completed and funding becomes available. The program is expected to be fully operational in 1992. The U.S. initial contributions to the IGBP, discussed in this report, together with U.S. contributions to related ongoing programs, will form part of this evolving international effort.

Objectives and organization of this report

This report specifically proposes a limited number of early U.S. initiatives, based on the internationally defined goals for the IGBP, that will contribute significantly both to our national interests and to the IGBP. The proposed initiatives build on the several ongoing national and international programs addressing problems of global change relevant to the IGBP, notably the projects organized under the World Climate Research Program and the U.S. National Climate Program. The proposed initiatives are designed to supplement such existing efforts, not to supplant them.

In formulating its recommendations, the committee had no intention of constraining either the IGBP or the broad U.S. program of research in the area of global change to only these specific early initiatives. These areas for initial focus are intended to provide a framework for early U.S. contributions to the IGBP rather than to include all research that will ultimately need to be carried out under the IGBP. The appropriate content and priorities of the broad U.S. effort on global change and the specific U.S. contributions to the IGBP will continue to be the subject of review and assessment by the committee.

The specific purposes of this report are as follows:

- To articulate a number of important key issues and interactions that characterize global change in the geosphere-biosphere system on time scales of decades to centuries;

- To identify the knowledge that is the most urgently needed to improve understanding of those issues and interactions; and

- To formulate initial priorities for initial U.S. contributions to the IGBP, recognizing the contributions of other ongoing and proposed programs.

Part I of the complete report constitutes the committee's findings, while Part II (not presented here) presents a group of background papers developed by working groups under the coordination of members of the committee. These papers were prepared in workshops and consultations organized by the committee, and they discuss research needs from five perspectives on the earth system: climatic and hydrological systems, biogeochemical dynamics, ecological systems and dynamics, human dimensions of global change, and earth system history

and modeling. These papers provide a more complete indication of the range of issues considered by the committee in reaching its conclusions.

Initial research priorities for U.S. participation in the IGBP

In this chapter, the committee identifies a number of the most critical gaps in our understanding of global change that most urgently need to be addressed in the initial U.S. contribution to the IGBP. The several research initiatives that are recommended in this chapter provide a framework for U.S. contributions to the IGBP in the current planning stage of the program's development. These recommendations are not intended to emphasize those issues not being addressed by ongoing programs.

The committee adopted the following criteria for selecting these initial research initiatives:

- The issue must be global in nature, and research conducted on the topic must be expected to lead rapidly to a greater understanding of global environmental change.
- The magnitude and breadth of the issue must transcend the boundaries of existing research programs and discipline-oriented endeavors, making it unlikely that it can be addressed within traditional disciplinary studies.
- The issue must be amenable to research, with significant progress expected in a period of a few to 10 years or with immediate initiation required in order to build the long-term monitoring and research base needed for sustained progress in understanding global change.

The research initiatives are recommended on the basis of the committee's systematic review of the current state of knowledge from five perspectives on the earth system: climatic and hydrologic systems, ecological systems and dynamics, biogeochemical dynamics, the human dimension of global change, and earth system history (see the background papers in Part II for detailed discussions). From these analyses - particularly from analysis of the interactions among these five components of the earth system - and from a review of related ongoing programs, the committee identified a number of questions about key relationships that are currently insufficiently understood but essential to improving scientific abilities to predict global change, for example:

- How is the climate system coupled to the dynamics of terrestrial ecosystems, and, specifically, what are the feedbacks between ecosystem dynamics and the hydrologic component of the climate system?
- What factors control fluxes of radiatively active gases between the land and atmosphere and fluxes of biologically important elements from land to aquatic systems? What are the feedbacks between climate change and fluxes of these materials?
- What are the fluxes of biogenic substances from the upper ocean to both the atmosphere and the deep ocean? How do these fluxes affect climate, and how does climate change affect these flux rates?
- How is the coupling of human and environmental systems altered by long-term global trends in social, economic, and technological development? How is the coupling altered by environmental change itself?

Research initiatives for early implementation

Answering these key questions about the earth system demands improved understanding of the influences of terrestrial and oceanic biota on the climate system, and the interactions with the hydrologic cycle, nutrient supply and transport, and surface climate conditions. Answers also depend on an understanding of how anthropogenic activities generate trace gases through changing land use, energy production, and industrial processes.

The committee recommends that these gaps be addressed through major research initiatives on each of the following topics:

- **Water-energy-vegetation interactions** - the coupling between the climate system, especially its hydrological processes, and the dynamics of terrestrial vegetation.
- **Fluxes of radiatively active trace gases and nutrients** to and from the terrestrial biosphere.
- **Biogeochemical dynamics in the ocean** that regulate formation and influence the ocean's capacity to sequester or release radiatively active gases, such as carbon dioxide and organic sulfur species, and their interactions with climate.
- **Earth system history and modeling** to reconstruct the record of the past preserved in ice cores, sediment deposits, and other proxy indicators of change.
- **Human interactions with the global environment** to document and analyze land use changes and changes in industrial production and consumption over the past several hundred years, and to create useful scenarios of future changes in the processes that drive global change.

Issues that need to be addressed in each of these initiatives are discussed below. These discussions, however, only outline the broad initiatives that should be pursued and illustrate the types of experiments, modeling efforts, and observations that will be required. Detailed research plans and schedules must be formulated by groups of experts engaged in the relevant research disciplines.

Water-Energy-Vegetation Interactions

The committee recommends an observational and research project - a water-energy-vegetation experiment - to study the coupling between the climate system, especially its hydrological processes, and the dynamics of terrestrial vegetation. The initiative has two objectives: (1) to develop validated global models of the response of terrestrial ecosystems to climate, water and land use change, atmospheric chemistry, and other global- or regional-scale stress factors such as changing atmospheric composition, fires, herbivore, and disease; and (2) to determine how ecosystem structure and function affect evapotranspiration, soil moisture, and surface runoff on regional and global scales. The project would in essence be the biological complement to the Global Energy and Water Cycle Experiment (GEWEX), whose planning is just now beginning under the WCRP.

This research initiatives will require field and laboratory experiments, modeling efforts, and observations to address the response of ecosystems to climate changes, as well as the response of climate to ecosystem change. Included would be the following:

- Experiments on whole ecosystems in order to quantify effects of climate change and other stress factors.
- Studies to scale up information on nutrient cycling and plant physiological processes to the level of the whole ecosystem, taking into account the dynamics of key species.
- Recovery of records of past vegetation cover and other indicators suitable for validating the long-term hydrological response of climate models to global change.
- Development of models of global and regional climate that emphasize hydrological and land surface processes (using parameterizations derived and validated by field data and process studies) and that can be used to study the sensitivity of climate processes to vegetation changes.
- Analysis of the human causes and effects of changes in the hydrological cycle, including documenting past and projecting future human activities important for the hydrologic cycle; defining those aspects of hydrologic change most important for human activities;

and developing frameworks for application of hydrologic projections to environmental assessment and management.

- Observations at a global scale of seasonal and interannual variations in vegetation cover and evapotranspiration.

A regional focus to study the coupling between vegetation and the hydrologic cycle in particularly important or sensitive geographic regions such as the Amazon Basin, the taiga-tundra transition zone, and the western United States is an important component of this initiative. Such a focus includes projections of the impacts of changes in terrestrial hydrologic processes on ecosystem composition and functioning in specific regions.

The initiative also requires strong input from other international research programs, such as GEWEX and the International Satellite Land-Surface Climatology Project (ISLSCP), to address the questions of global distributions of rainfall over land and atmospheric properties important surface evapotranspiration.

Fluxes of Radiatively Active Trace Gases and Nutrients to and from the Terrestrial Biosphere

The committee proposes a research initiative focused on the fluxes of materials such as (1) radiatively active trace gases to and from the terrestrial biosphere, and (2) nutrients from land to aquatic and marine ecosystems.

The objective of a research focus on radiatively active trace gas exchange between the terrestrial biosphere and the atmosphere is to improve understanding of those basic ecosystem processes that determine gas fluxes. This understanding is needed to construct functional models that can be used to predict how climate and land use change will alter emissions and absorption of radiatively active trace gases from the biosphere and, in turn, feed back to further changes in climate. The research should emphasize methane, carbon dioxide, and nitrous oxide, but other significant constituents, e.g., ammonia and organic compounds, are also concern.

The initiative will require the following:

- Experiments involving plants, soils, and peats to improve understanding of processes affecting gas exchange between them and the atmosphere, such as changes in carbon storage; the influence of nutrient availability; the influence of population dynamics through nitrogen fixation, and microbial processes; hydrological influences on partitioning between production of carbon dioxide and methane and between nitrogen and nitrous oxide; and the influence of the chemistry of precipitation on such processes. Experiments on intact ecosystems that include the biota and soils will also be needed to measure the effect of environmental changes on the complex, interacting processes of vegetation change, nutrient cycling, and gas fluxes. Larger scale ecosystem experiments can involve, for example, manipulations of entire watersheds or can use natural or inadvertent anthropogenically induced perturbations for experiments.

- Investigations at local or regional scales, particularly in ecosystems such as the Arctic and the tropics that play significant roles in global change. A local and regional focus, including comparative studies along environmental gradients, is needed in order to extrapolate predictions of gas emissions to the global scale after a mechanistic understanding of gas emissions is achieved.

- Models that combine descriptions of the functioning of whole ecosystems (process-functional approach) with descriptions of changes in populations and communities within ecosystems (population-community approach), in order to predict the changing patterns of fluxes from ecosystems subjected to rapid change. Because this new generation of models will be mechanistic, they could be used to extrapolate beyond existing or past conditions, and to predict gas emissions from new combinations of vegetation, soils, climate, land use, and atmospheric processed.

- Increased attention to documentation of past ecosystems from the record of the past, in order to understand better the range of ecosystem form and function that could develop in the future in response to global change.

- Documentation on a global scale of the history of land uses believed to be sources of methane and other trace gases, and assessments of future changes in human activities that can result in changes in emissions. Similarly, prehistoric and historic activities that have affected carbon storage in vegetation and soils should be documented on a global scale.

The component of this research initiative focused on fluxes of nutrients from terrestrial to aquatic systems will, in addition to studying nutrient transfers in natural ecosystems, emphasize the effects of land use change on the amount and pathways of nutrient losses from terrestrial ecosystems. The objective is to broaden the initiative on trace gas emissions to include analysis of how global changes now under way will effect the transfer of nutrients to riverine, estuarine, and ultimately, ocean systems, As discussed in the following section, changes in ocean productivity have important long-term implications for climate. Thus nutrient transfers from the terrestrial to marine systems could have important feedback effects.

Transfers of materials across ecosystem boundaries will be strongly affected by various aspects of global change. Large scale experiments, involving manipulations of entire watersheds or intact ecosystems, are needed to assess the effects on nutrient losses of floods, increased fire frequency, loss of species, and other events related to global change. Rising sea level will also affect nutrient cycling and transfer to the ocean. Superimposed on these effects, and in some systems overwhelming them, are massive changes in land use, especially in the tropics, where the human population and activity are growing rapidly. Deforestation and increased intensity of agriculture in dry and humid tropical regions are affecting nutrient availability in soils and transfers to other systems via dust and runoff.

Understanding the processes underlying nutrient losses from terrestrial systems will require monitored watersheds. Once baseline data are established, experiments with different kinds of land use can be carried out, with paired watersheds left unchanged as controls. These experiments will separate human effects from other aspects of global change. Long-term observations are necessary, as some effects are cumulative and others have long response times. Long-term studies will also increase the opportunity to observe and hence understand unusual climatic events that stress the system.

The important requirements are as follows:

- Experimental manipulations of drainage basins to increase understanding of the mechanism controlling nutrient transfer via water or air from the land to streams, lakes, rivers, and eventually, the ocean.

- Examinations of systems along a gradient, e.g., from savanna to dry forest to rain forest, in order to quantify fluxes as a function of ecosystem type.

- Research to follow the fate of nutrients after they are lost from terrestrial ecosystems in rivers, lakes, groundwater, the ocean, and the atmosphere. Studies of estuarine processing of nutrients loaded into rivers should be emphasized.

- Analysis of the patterns and causes of anthropogenic land use change, including documenting past and projecting future human activities important for terrestrial nutrient fluxes, and defining those aspects of nutrient flux most important for human activities.

- Particular emphasis on phosphorus in nutrient balance studies. While phosphorus is less mobile and dynamic than carbon, nitrogen, and sulfur, it exerts a strong control on productivity both on land and in aquatic systems.

Some approaches appear promising in the context of this research focus. For example, stable isotope signatures of carbon, nitrogen, and sulfur as tracers of element movement and as integrated reflections of the processes controlling element transformation and loss will provide important information. While this approach is relatively well worked out for carbon, considerable development of research techniques is necessary before it can be applied to

nitrogen and sulfur. Better measurements of both historic and current rates and types of land conversion also need to be developed and applied.

Collaboration with the research component on fluxes of radiatively active gas, discussed above, is needed to understand, model, and predict biosphere-atmosphere interaction following land clearing. Additionally, interaction with ongoing programs such as the International Union of Biological Science's Tropical Biology and Fertility Program and the International Atomic Energy Association-Centro Energia Nuclear na Agricultura (IAEA-CENA) Amazonia I Project will be needed for the research focus discussed here.

The overall initiative should be linked with activities of experts concerned with land use change as a primary driving force in species extinctions worldwide (see "Human Interactions" initiative below). Both the information on rates of land use change and the measurements of the fate of nutrients once they are lost from cleared land are fundamental to these efforts, and knowledge of the functional significance of particular species in local areas is fundamental to this initiative.

Biogeochemical Dynamics in the Ocean

The committee recommends a research initiative to understand and predict the effects of climate change on ocean biogeochemical cycles and their corresponding feedback to climate. The objective of this effort is to develop the capability to predict the effect of projected global climate change on the ocean's physical/chemical and biogeochemical processes, especially as they feed back to climate via the release or adsorption of radiatively important gases such as carbon dioxide and organic sulfur species.

Changes in climate over the ocean will alter the physical conditions of the upper ocean. Incident irradiation, evaporation/precipitation, and wind shears on the ocean surface help to define the mixing state, and hence the nutrient supply and residence time for plankton, Nutrient supply and re-suspension properties are important factors in determining the nature of the planktonic food web. Greater rates of nutrient supply, and higher mixing rates, for example, promote the growth of large diatoms. These two different types of plankton sustain markedly different food webs and have significantly different consequences for the residence time of photosynthetically fixed carbon in the ocean. In addition, different plankton groups have different physiologies related to sulfur metabolism and play considerably different roles in the evolution of organic sulfur species, which have climatic implications when liberated to the atmosphere.

This effort will require a global-scale assessment of the processes governing the rates of primary production and determining the fate of biogenic materials in the sea. A major international program, the Joint Global Ocean Flux Study (JGOFS) is now being defined in this area. It will consist of global observations, regional process, studies, costal ocean studies, and modeling. Some of the recommendations below will probably be included in JGOFS, some should be initiated as soon as possible, while other activities, especially those related to the biogeochemical implications of the anticipated climate change, may require results of JGOFS and other ocean programs such as the World Ocean Circulation Experiment before they can be initiated.

A U.S. contribution in this area should include the following:

- Helping to establish the global remote sensing capability and appropriate sea surface verification necessary to assess temporal and spatial patterns in plankton distribution.

- Studying the processes responsible for the initiation of plankton blooms (including dependence on temperature, mixing state, and nutrient supply) and their roles in (1) the flux of organic material and calcium carbonate to the deep sea and (2) the production of organic sulfur compounds, which, when liberated to the atmosphere, have implications for climate.

- Developing modeling and scaling techniques to generalize the results of intensive local studies of plankton blooms to characteristic regional and basin scales.

- Placing emphasis on those high-latitude ocean regions where vertical fluxes of carbon to the deep sea and vertical fluxes of nutrients to the surface waters give these regions disproportionality large global significance.

- Investigating the biogeochemical processes responsible for forming, transporting, and preserving in ocean sediments the hard parts of plankton used in studies of past climates.

- Initiating large-scale models of upper ocean physical and biogeochemical processes that have potential to feed back to climate via the regulation of radiatively active trace gas release from the ocean.

Human Interactions with Global Change

This research initiative would focus on the relatively short-term record of the period of intensive human activities that have affected the global environment. Anthropogenic changes in the earth system need to be systematically documented over the past several hundred years and analyzed as a basis for developing useful reference scenarios of future change. In particular, two aspects of human activity are especially relevant to global change: land use changes, which influence both physical (e.g., albedo, evapotranspiration, and trace gas flux) and biological (e.g., vegetative cover and biodiversity) variables; and the industrial metabolism that transforms resources into emissions that must be absorbed and processed by the environment.

Investigation of global land use patterns would involve the following:

- Construction of a core conceptual model or theory of the causal relations underlying changes in culture (e.g., population, development values) on one hand and changes in environment on the other hand, to human choices that affect long-term, large-scale patterns in the use of land.

- Documentation of how key variables of land use, population, agricultural prices, and so on, identified in the conceptual model have changed throughout the world over the last several hundred years.

- In-depth regional case studies of the general relationships suggested in the conceptual and historical work.

- Construction of future scenarios of global land use change, and exploration of alternative human choices regarding global change could alter those scenarios.

Parallel to the study of global land use change, a similar approach to the study of industrial metabolism would involve the following:

- Construction of a conceptual model linking demographic, economic, and institutional factors with the evolution of material and energy uses, and human consumption processes relevant to global change.

- Documentation of how particular material and energy resources have been metabolized through human production and consumption processes over periods of decades to centuries.

- In-depth regional case studies of the general relationships developed in the conceptual and historical work.

- Construction of future scenarios of industrial metabolism and associated materials and energy exchanges with the environment.

Earth System History and Modeling

The initiative on earth system history and modeling is concerned with documenting and understanding overall patterns of global change. The initiative would focus on reconstructing the

past over tens of thousands of years to provide a data base for validating global change models. The history of atmospheric composition and climate, and of the spatial distribution of climate, vegetation, and ocean circulation, would be developed. Special attention is needed on period of rapid change to provide insight into poorly understood system processes.

A research focus on the long-term record requires the following:

- Data from polar and temperate latitude ice cores, ocean sediments and corals with 10- to 100-year temporal resolution, and various kinds of physical and biological terrestrial records.

- Theoretical studies and modeling to establish quantitative relationships between measured parameters and physical processes, in order to better interpret the record of the past.

- Sensitivity studies with global models to define the spatial and temporal resolution needed in the study of the record of the past and to suggest which types of data should be collected.

- Development and improvement of global change models based on observations from the record of the past. Models can use information from the past record such as climate and vegetation and indirect measures of the carbon cycle. Past abundance of carbon dioxide, methane, carbon-13 and other stable isotopes, and other chemical species accessible from the record can be used for model validation. Data on the history of human interactions with the earth system, as developed in the previous initiative, will also be useful. Close collaboration between observational and modeling activities is essential.

Development of research initiatives

Two streams of activity are required to develop the research initiatives for the U.S. contribution to the IGBP into detailed plans for research programs: (1) involvement of scientists with particular expertise to develop the research plans, and (2) support of those related activities essential to the success of the IGBP.

Steering groups should be established on each of the five research initiatives proposed above as research foci for the initial contribution to the IGBP. These groups should be closely coordinated with other relevant activities in the National Research Council. These steering groups, operating under the Committee on Global Change over approximately the next two years, would engage scientists with the relevant expertise to further define programs of coordinated research in the respective area. The Committee on Global Change would ensure that the research plans developed by each group are coordinated into an overall plan for the U.S. contribution to the IGBP.

Support for existing programs related to the goals for the IGBP is also an integral part of the U.S. effort. Three categories of support can be identified:

1. As noted above, U.S. contributions to the IGBP are drawn from the broad suite of U.S. observational and research programs that have been described as the U.S. effort on global change. The U.S. program is based on the concept developed in the report of the NASA-sponsored Earth System Sciences Committee that study of the earth as an integrated system is an important and timely paradigm for the earth sciences. Strong support for such a broad national effort in the study of the earth is an essential foundation for the focused programs addressed in this report.

2. A number of existing, ongoing programs have objectives and well-developed plans that clearly fall entirely or partly within the scope of the IGBP or the broader U.S. global change efforts. Among these are UNESCO's Man and the Biosphere Program, the several projects of ICSU's Scientific Committee on Problems of the Environmental Monitoring System (GEMS). Particularly relevant and essential are the components of the World Climate Program. One of these, the World Climate Research Program, organized under the World Meteorological Organization (WMO) and ICSU, focuses on dynamic and hydrological processes in the climate system and has in planning or in progress a number

of well-conceived projects (e.g., Global Energy and Water Cycle Experiment, World Ocean Circulation Experiment, Tropical Ocean/Global Atmosphere Program, International Satellite Cloud Climatology Project, and International Satellite Land-Surface Climatology Project) that promise to contribute greatly to the goals of the IGBP. The contributions of the Data, Applications, and Impacts components of the World Climate Program should also be emphasized. The IGBP and these existing activities are highly complementary and mutually supportive.

The challenge is to harmonize and coordinate the practical work of the various planning bodies so that each activity can be effectively focused on appropriate objectives. Such an approach was successfully employed in the Global Atmospheric Research Program (GARP), where the WMO/ICSU Joint Organizing Committee, the ICSU Committee on Space Research, the International Association of Meteorology and Atmosphere Physics' (IAMAP) Radiation Commission, and other bodies pursued closely coordinated programs. Interaction within this family of closely related activities in the earth sciences should be strengthened, coordinated, and enhanced.

3. Support for discipline-oriented research related to the goals of the IGBP is needed to bolster the scientific foundations of the program. For research centered on the atmospheric and oceanic components, a long and mature history of previous studies and an array of coordinated research programs provide good foundations for contributions to the understanding of global change, the existing research program is less well developed. The relevant research communities should be encouraged to develop their own internally justified research priorities relevant to global change. An aggressive program to support research in these as well as other related disciplines is needed.

For instance, a number of areas of needed research are highlighted in the background paper on ecological systems and dynamics (see especially the section on principal issues and research challenges). These include (1) research on physiological responses of plants and animals to the environment, especially to multiple stresses; patterns of genetic variability, including the development of theory regarding evolutionary responses to rapid environmental change; direct effects of elevated carbon dioxide concentrations on intact ecosystems; and characteristics that allow some species to adjust geographical ranges rapidly in the face of change while others become extinct; (2) monitoring of ongoing changes in distributions that may record the incipient effects of global change and of ongoing changes in land use; and (3) development of more complete paleorecords, particularly from little-explored parts of the earth.

The existing research program on the human components of global change is also inadequately developed, as discussed in the background paper on the human dimension. Efforts to bring together natural, social, behavioral, and engineering scientists to examine in-depth the research required on the human dimension of global change should be supported. Several research areas identified in the background paper - integrated methods to assess the risk and implications of long-term environmental change for resource availability at the regional scale; ways that knowledge, perceptions, and values related to global change can be more effectively brought to bear on human choices that affect global change; and evaluation and design of institutional mechanism for better management of global change - require further development in close collaboration with those relevant scientific communities in the social, behavioral, and engineering sciences that were not adequately represented in current planning activities.

Supporting needs for program development

Planning of the IGBP will have to be responsive to a number of challenges that transcend previous experience with collaborative scientific programs. These challenges are presented by the exceedingly broad scope of the program, the need to blend new technology with traditional observational techniques on a worldwide scale, the need to plan and sustain a coordinated research and documentation effort over many decades, and the need to present to the public and policymakers in a timely and comprehensible manner the conclusions on complex issues of substantial and growing public concern.

A number of common themes should guide the development of specific plans for research and observations to be carried out as part of the IGBP:

- **Documentation of significant contemporary changes in the global environment requires establishment and maintenance of long-term observations.** Long-term-series measurements of key variables, such as global trends of trace gases and global changes in land use, are needed to detect global changes. Monitoring of sensitive ecosystems for critical parameters, such as productivity and species loss, can provide early warning signals of global change. In addition, such long-term records often provide unanticipated insights into system dynamics. The careful design, implementation, and application of long-term observations and associated information management systems will be a critical element in global change research.

- **The need for recognition of the significance of discontinuous and extreme events in the earth system** (e.g., periods of extreme temperature, drought, hurricanes and flash floods, and plankton blooms). The research and observational programs should include the capacity to act rapidly to investigate the response of the system to any such events. The program should also be designed to recognize that changes in the frequencies of extreme events might indicate the occurrence of fundamental changes in the earth system.

- **The identification and investigation of particular ecosystems** that are most subject to change and/or that have particularly strong potential for feedbacks to the physical climate system. For example, global warming may increase dramatically rates of metabolism in arctic tundra, with currently unpredictable consequences for release of methane from thawing permafrost. The high biodiversity in the tropics and the significant role that the tropics play in the earth system make these areas important for global change research. In addition, ecosystems receiving high anthropogenic inputs of nutrients, arid zones, agricultural systems, and ecotones or transition zones that are anticipated to be sensitive indicators of global environmental change are areas deserving intensive investigation. A focus in the IGBP on such geographic areas would provide a focus for research and would permit efficiency in collection data.

Documenting global change

At the core of the IGBP must be a systematic effort to document the significant changes on a global scale over the coming decades. This effort overlaps, but is distinct from, research initiatives aimed at elucidating key processes involved in such changes and efforts to examine the record of the past. All these activities are necessary to develop and test quantitative models of how the entire earth system functions on time scales of decades to centuries. The program structure and institutional arrangements must be appropriate in order to (1) obtain the necessary observations and calibrations, (2) process and analyze them to extract the required information, and (3) assemble this information and make it accessible to scientists and policymakers worldwide and to future generations.

The Role of Models

Because of the complexity of the interactions between different parts of the earth system, a central goal is to codify understanding of specific processes and measurements of large scale changes in terms of quantitative models. To the extent that credible models based upon established principles can be developed and verified against an adequate base of observations, they can then serve as testbeds for evaluating hypotheses about cause-and-effect relationships and for development of efficient observational strategies, and for deriving predictions about future trends. Models are discussed in more detail in the background papers in Part II of the complete report and in the report of NASA's Earth System Sciences Committee (1988). Here it suffices to abstract some general concepts.

Comprehensive quantitative models of the earth system are formulated in terms of a set of state variables, such as the temperature distribution in the ocean or the concentration of nitrous oxide in the atmosphere. These state variables are on a global scale and are inevitably simplified idealizations of reality. The development with time is defined by predictive equations or algorithms that codify our understanding of the specific processes that connect them. Enhanced

understanding resulting from process studies becomes reflected in improved algorithms in such models. Documentation of global change, on the other hand, implies determination of the time history of the state variables themselves. Establishing confidence in a model requires a rigorous process both of assessment of its basic principles in the light of accumulated understanding of the processes involved, and of testing its parts and the entire model against measurements of the state variables. Because of the empirical idealizations involved in constructing a practical model, substantial redundancy is required in such tests. In general, the greater the ability of the model to simulate observed behaviors on increasingly longer time scales or changes that are independent of the information invoked in its development, the greater the confidence in its predictive capability.

Thus research and measurement strategy aimed at using models as the primary integrating tool would concentrate on two rather distinct activities: (1) focused studies enhancing understanding of selected processes and (2) long-term global measurements of key state variables.

Process Studies

Scientific research organized into process studies need not necessarily be global and should normally be of limited duration, resulting in improved algorithms through which their conclusions are applied on a global scale. The emphasis is likely to be simultaneous intensive observation and measurement of a wide variety of variables in a few case studies, using any available techniques including experimental ones. The choice of variables and techniques will derive from the specific experimental design for each study and may change with increasing understanding of the process. Diverse analysis procedures will be used by individual scientists to contribute to a collective understanding that is then distilled into algorithmic form.

Long-term Measurements

Long-term measurements of state variables, on the other hand, must be global and sustained at acceptable quality for many decades. The observation and analysis techniques must be standardized and applied systematically and cost effectively in a manner that is frequently described as routine or operational. It should be noted that the term "measurement" is used to include here all aspects of the inferential chain from the original observations to global analyzed products, and it is essential to consider the entire system. Many factors affect the end-to-end performance of this system, including the calibration of the original sensors and other data sources and the coverage in space and time. Validation of the inferential process connecting the sensor output with the variable being analyzed and the algorithm being used to implement that connection also affects the end-to-end performance. Procedures for quality control and editing of the data for global analyses, and the availability of independent measurements that can be used, at least on a spot basis, to compare with the routine output cannot be overlooked. A final factor critically important to global change is the documentation of all these items in a manner that will enable scientists 20 years from now to determine whether observed changes are real or merely artifacts of the way the measurements were made or interpreted.

Difficult though it may be sustain such measurements, documenting global change requires that they be sufficiently comprehensive both to enable the causes of observed changes to be inferred from model simulations and to use available models to test alternative hypotheses for the causes of observed changes. To the extent that established models exist, the required set of ongoing measurements can be reduced somewhat by utilizing implied relationships between state variables (for example, the geostrophic relation between wind and pressure in the extratropical atmosphere). For some variables, such as the solar irradiance or the concentration of carbon dioxide in the atmosphere, the small spatial variability is such that a few sustained measurements of high quality suffice for the most important information on a global scale. For other variables, such as temperature, we must rely on an extensive network of observations and international data exchange maintained for other purposes. For yet others, such as precipitation or subsurface ocean circulation, acceptable techniques applicable routinely on a global scale do not yet exist, and a research and development effort is called for to enable the most critically important gaps to be filled. For still others, a network of surface observations such as the proposed International Geosphere-Biosphere Research and Training Centers discussed below would seem most appropriate at this time.

It must be recognized that documenting global change through long-term measurements presents an organizational, managerial, and technical challenge and political commitment of profound importance. Resource limitations will certainly require full collaboration with existing organizations collecting relevant data for other purposes (such as weather prediction). New mechanisms will have to be established to identify cost-effective ways to supplement these systems to make them useful for long-term measurements. Remote sensing from space is a powerful tool for obtaining global observations, but in most cases the data must be combined with in situ measurements from other sources in a composite observing system for a fully satisfactory analysis. Mechanisms must be established to review the end-to-end performance of such composite systems and to make necessary adjustments (see the discussion on information systems below). In some areas, pioneered by the weather services of the world and the World Climate Research Program, observational networks of considerable maturity are in routine operation. In most areas, however, the infrastructure for coordinated planning of in situ and remote observations, international data exchange, analyses, and validation of end-to-end performance will need significant strengthening.

Data from the Past

Because the time scale for global change is comparable to the time over which research in the IGBP will be conducted, concentrating on the present and future behavior of the system is insufficient. It is necessary to seek independent data sets for model testing and evaluation in the record of the past, in spite of the loss of precision that may accompany the use of proxy data or incomplete records. Emphasis should be placed on circumstances most likely to yield relatively complete data sets useful for testing at least some aspects of quantitative models, or on determining the natural variability of individual key state variables. Because only part of the desirable information is available, in some cases only in principle, choices in research strategy derive primarily from the development and application of techniques to infer global-scale variables from limited, often indirect, data. Because knowledgeable judgments are required at so many stages, reconstructions of past states of the earth system will never become routine inferences from a predefined observation system. The research and information management structures in IGBP should reflect the inherent characteristics of pre-instrumental data.

Additional Comments

The conceptual distinctions made above between process studies, ongoing measurements, and earth history provide broad indications of the range of IGBP activities and as such may assist in defining programmatic structure for a measurement strategy, but they should not be regarded as rigid prescriptions. For example, the first three of the initial foci recommended in earlier involve a mix of process studies and activities aimed at developing the capability for long-term measurements, and studies of the human dimension, aspects of which may defy simple algorithmic treatment.

Furthermore, the status of our comprehensive models is such that they are currently at best only partially useful for setting requirements for long-term observation and analysis systems. Indeed, there is no accepted model in existence that covers the full range of interactions between the physical, chemical, biological, and human subsystems of concern to IGBP. In some areas of concern, such as terrestrial ecosystem dynamics, there is inadequate understanding of the basic principles for constructing a model to operate on a regional scale, and hence no consensus on what the principal state variables should be, let alone consensus on the algorithms connecting them. Almost all our current models are vulnerable to the total omission of processes that may turn out to be of major importance. For example, recent discoveries suggest that heterogeneous chemistry in ice clouds is central to the control of ozone in the antarctic stratosphere, although previous models were restricted to gas phase interactions. Thus, as our understanding of the interactions within the earth system improves, perceptions of the relative importance of different state variables as key indicators of global change are likely to be adjusted also. Meanwhile, our best judgment must be the basis for action in obtaining at least a minimal set of such indicators.

Measurement strategy

Implementation of Long-term Space-based and In Situ Measurements

The list of potentially important long-term global measurements is long and has not yet been reviewed in detail by this committee. Careful consideration will have to be given to the selection of the most critical variables for special attention, particularly in relation to the end-to-end performance attainable by augmenting existing data gathering and analysis activities, both remote sensing and in situ, and in relation to the potential for development of new techniques suitable for global deployment.

Both satellite- and ground-based measurements will provide essential information for the IGBP, and the measurement strategy needs to be designed so that one complements the strengths and weaknesses of the other. Satellites provide global coverage and frequent and long-term observations, but currently provide only qualitative information. Several parameters important to the IGBP cannot, with current technology, be measured from space (e.g., precipitation, soil moisture, gas fluxes, winds, and tropospheric chemistry). In situ measurements, on the other hand, provide potentially accurate measurements of many variables important to the IGBP and are essential to validation of space-based observations. Clearly, however, surface networks cannot realistically provide global coverage on a long-term basis.

Meanwhile, it is clear that the capability for long-term measurements can be developed most effectively in the context of specific research foci that need them, at least in the short term. In this context, programs such as the Tropical Ocean and Global Atmosphere program, the World Ocean Circulation Experiment, and the Global Energy and Water Cycle Experiment of the World Climate Research Program are not only essential process studies, but also critically important environments for the evolution of our ability to document global change. Satellite missions approved for deployment in the near future, such as UARS, ERS-1, TOPEX/Poseidon, and Sea-WIFS aboard Landsat-6 will each contribute major new types of measurement on a global scale, from which could evolve an effective long-term capability for very important global state variables. New applications of existing data streams, such as the Vegetation Index recently developed from the AVHRR sensors aboard NOAA polar orbiters, can be highly effective although relatively inexpensive.

The committee recommends the planning continue vigorously for the deployment in the mid-1990s of a more comprehensive long-term interagency and international Earth Observing System, with major components aboard a number of polar-orbiting platforms, supplemented by particular instruments in tropical and geostationary orbits, and building upon existing, ongoing research and operational observing programs. Special attention should be given to the integration of the space-derived data from EOS with complementary in situ data and validation studies to derive long-term analyzed global products containing documented information. Specific sites for validation studies need to be established.

International Geosphere-Biosphere Research and Training Centers

The committee recommends that a limited number of International Geosphere-Biosphere Research and Training Centers be established to provide bases for research and observations of global change. Many of the planning reports for the IGBP have recommended the establishment of geo-biosphere observatories, which would serve many important functions related to global change research. Observatories have been recommended as sites for long-term observations, process studies including large-scale manipulations of ecosystems, training, ground truth validation for remote sensing missions, model validation, and other purposes. The multiple utility of observatories is compelling, and research related to long time series of observations would benefit from institutional mechanisms to coordinate observatories.

A hierarchical approach to the concept of biosphere observatories should be employed. At the base of the hierarchy would be the extensive, existing net of specialized monitoring and field stations, supplemented where necessary by new installations in sparsely represented areas. At the middle of the hierarchy would be sites already established for long-term research, such as biosphere reserves of UNESCO's Man and the Biosphere Program and the U.S. Long-Term, Ecological Research sites maintained by the National Science Foundation. Again, this mid-level could be strengthened where appropriate with new facilities. At the top of the hierarchy would

be a limited number - perhaps half a dozen - of new International Geosphere-Biosphere Research and Training Centers established to realize the goals of the IGBP.

Possible research foci for these centers are the roles of tundra, tropical, semiarid, temperate forest, and high-latitude ocean systems in global change. Sites for the centers would be selected on the basis of ecological characteristics, geomorphology, human factors, and potential for climate change.

The primary purpose of the centers would be to serve as major foci for international cooperation in research and training by (1) providing a base for large-scale manipulative experiments designed to understand linkages between ecosystems and climate change, (2) developing efficient hierarchical networking with other international and national research and observational programs and organizations, such as designated ecological research sites and reserves, (3) orchestrating the development of facilities for smaller scale and more transient observational and process studies, (4) serving as a central repository for detailed observational and experimental results on the systems represented by the respective center, and (5) constituting a tangible international commitment to continuing cooperative efforts to understand global change.

To be successful, the centers would have to be developed in accord with the ICSU practices for full access for scientists from all nations. It would be essential that leading scientists spend significant blocks of time in residence in order to facilitate training of students and young scientists in global change research. Moreover, the success of this effort would require commitment of funds from all nations, regardless of the suitability of their own territories for the siting of a center.

Information systems

Global change must be documented consistently over many decades, across disciplinary and international boundaries, through evolving perceptions of what is most important, and under pressure from governments and citizens to provide as soon as possible reliable information about what are expected to be ever increasing concerns to the peoples of the world. The system by which irreplaceable data are made accessible to all who need them and are preserved for future generations is the foundation on which the enterprise must be built. It is also the component of the program that experience shows is most likely to founder through ineptitude or neglect.

Perhaps even more important than the primary data is the distillation into derived products or analyses of lower volume but greater information density, which in turn are used as data for model development or cross-disciplinary studies that yield information about the functioning of the earth system. It is thus essential to extend traditional concepts of data management to include the recapture and preservation of these derived products and the means to make them accessible to a group of users who may not be familiar on a day-to-day basis with all the details of the original data stream. The sheer volume and complexity of primary data relevant to global change enforce utilization wherever possible of higher level syntheses or abstractions that have already been made by some other competent user. In other words, the data management system must become a complete information service.

These requirements pose major technical, institutional, and managerial challenges to our existing structures. For example, an unfortunate byproduct of the explosion over recent decades of digital data and techniques for handling them has often been the separation of the data themselves from metadata, or information about the data. This is because metadata are generally in text or graphical format that does not easily fit into efficient database management structures or standardized tape formats. Yet information about the algorithms used for a derived product, the quality control procedures, comparisons with independent measurements, reviews by expert outsiders, and so on, is what enables the user to judge the reliability or value of the product for a particular application, and should therefore be an inseparable part of the data set. The same is also true for original data in terms of calibrations, quality control flags, and so on. With more powerful computers and software systems the storage of metadata should not be a fundamental limitation. However, a major effort is needed to develop standards for the exchange of entire data sets including metadata between data centers. A similar effort is needed to enable electronic distribution of catalog and directory information. Other issues arise from the diverse and

untraditional sources of derived products, and the need for mechanisms to select the most significant products. However, new opportunities are also provided by technological developments such as the advent of digital publishing on CD-ROM and similar media.

The IGBP can draw upon a number of existing institutional mechanisms for data exchange between nations. The World Data Centers were established during the IGY as central repositories from which contributed scientific data could be made available to participating nations. Frequently co-located with a national data center in the host country, WDCs have proved a valuable mechanism for international data exchange within a number of the disciplines involved in the IGBP. However, the volume and complexity of even present conventional data streams from in situ sensors are severely taxing the available capabilities, and major upgrades will be necessary to meet the information needs of the coming decades.

In addition to the WDCs, there are operational exchange mechanisms in disciplinary areas for specific purposes that overlap with IGBP requirements, for example, the real-time exchange of meteorological and ocean surface layer data over the WMO Global Telecommunications System for use in weather prediction. The distribution channels for satellite data have evolved along separate lines, partially conditioned by the large data volumes typically involved and the need for timeliness. Under the open skies policy enunciated by the United States, image data from U.S. weather and Landsat satellites are directly available to any nation installing the necessary ground receiving equipment. However, with the more specialized, high-data-rate instruments of the future, the raw data are best processed in one location, and rebroadcast of results of analyses is a more complex operation. In addition, an ever-increasing number of nations or space agencies are now operating or plan to operate satellites that can potentially make important contributions to IGBP, but not all of these have made clear commitments to an open skies policy. For research satellites, premature dissemination of the data is clearly inappropriate, and access is usually initially limited to specific investigator teams. Subsequent access by scientists from other countries has tended to be ad hoc, on the basis of bilateral arrangements.

These considerations require that urgent attention be given to identifying criteria that separate bona fide applications of satellite and relevant in situ data to the study of global change from uses with commercial, national security, or proprietary interests. Effective mechanisms for truly international exchange of such data need to be established, at least for the purposes of IGBP. Ill-considered proliferation of ad hoc bilateral arrangements risks dividing the scientists of the world into those in nations that have access to essential global data sets and those who have to be content with secondary sources of unverifiable quality, with serious consequences for international collaboration and the credibility of research results from the program.

The evolution of a practical and effective information system will be facilitated by a combination of a top-down and bottom-up approach. A top-down consideration of the entire system should include the end-to-end performance requirements for long-term measurements. The special needs of data from process studies at specific sites and investigations of global history, as well as possible institutional arrangements for international exchange of all types of data, need to be considered. A bottom-up approach aims at establishing on an experimental basis role models of effective solutions to a much more restricted set of problems.

In the latter context, **the committee recommends that a Global Information System Test be implemented to test the end-to-end performance of an early prototype of an information system for the IGBP**. This test would be implemented in 1992 or soon thereafter, possibly in association with the International Space Year. Its objectives would be to make selected satellite and related data sets accessible to an international group of scientists and to document the information content of associated derived products. This end-to-end test would be conducted in the context of recognized research foci within the IGBP or in the WCRP that would serve as a prototype. A limited number of variables would be selected on the basis of scientific need, the availability of the necessary data, the effort required, the potential to test significant aspects of the data and information system, and the availability of a group of scientists and data professionals committed to making it a success. Such a test could be an important learning experience for the implementation of the Earth Observing System and related activities later in the decade.

Management of the IGBP

The scale and number of interested parties in IGBP focus attention on the effectiveness of existing institutional structures at both the national and the international levels. These structures include nongovernmental scientific organizations like ICSU and COSPAR; intergovernmental organizations like WMO, UNEP and IOC; individual universities; consortia of universities; and federal laboratories. The structure in place have proven partially successful for the focused programs of the past, but are untested for the broad and multidisciplinary programs of the future. It is not clear that entirely new structures will be required; however, success for the IGBP demands at the very least much stronger coordination among existing organizations and mechanisms.

The program, if successful, will be complex, will cross most national boundaries, will involve many disciplines including the social sciences and engineering, will require a blending of high technology with traditional techniques, and will develop a new kind of real-time information system linking research and operations. Implementation of these plans will require a high order of management skills and mechanisms. Formulation of public policy will be a logical complement to the science aspects of the program, and care must be taken to assure that the two aspects freely trade information.

A Brief History

The International Geophysical Year, Global Atmospheric Research program (GARP), and World Climate Research Program (WCRP) are often cited as models of institutional arrangements that give guidance to the IGBP. Each of these has laid groundwork for the next. IGY, essentially the aggregate of research by individual investigators and national teams, provided international access to data through the innovative concept of World Data Centers. Coordination was accomplished through a small committee of ICSU augmented by an advisory council of designated representatives from participating countries. The satellite programs were national contributions (Bullis, 1973). World Data Centers in the context of new technology will be an important aspect of the IGBP.

The Global Atmospheric Research Program was more complex. An intergovernmental mechanism already in place was used to coordinate meteorological satellites. A formal treaty was drawn up between ICSU and the World Meteorological Organization to ensure strong scientific guidance and participation together with the management capability of an operational agency. These are the kinds of linkages that will be required, but on a much larger scale for the successful operation of an IGBP.

The World Climate Research Program involves atmospheric science, oceanography, and land surface processes. here the WMO/ICSU links have been augmented by new arrangements between the ICSU Scientific Committee on Oceanic Research and the Intergovernmental Oceanographic Commission. The International Association of Meteorology and Atmospheric Physics (IAMAP) and International Association of Hydrological Sciences (IAHS) have been involved in land surface studies. UN agencies such as United Nations Environment Program (UNEP) are involved in the program as well. The inclusion of a larger number of agencies and links than was the case for GARP has been necessary for the program; however, at the same time the management has become more cumbersome.

An Emerging Concern

The need for examination of existing international institutional arrangements does not derive solely from the IGBP, but rather has been a concern for several years. In 1985, two meetings were held on this subject. Both existing and new models for facilitating international cooperation were considered (Kendrew et al., 1986; Kohn et al., 1987).

The U.S. House of Representatives (Fuqua, 1986) concluded that science could be used to move nations beyond the realization of individual national goal to the next level of global needs. The report noted the need for an international cooperative science decision-making mechanisms beyond what now exists. The International Institute for Environment and the World Resources Institute (1987) observed that an understanding of global change is driven by forces that call for a reorganization of science to study the earth as a planet.

The World Commission on Environment and Development (1987) concluded that global environmental and developmental problems are inseparable and that they must be approached in a holistic manner. The commission believed that the actions required for success are beyond the research of present decision-making structures and institutional arrangements, both national and international.

The Need for Reexamination

The IGBP creates a specific and clear need for a careful examination of our existing national and international mechanisms and arrangements. In arrangements need to be reexamined:

1. IGBP will be global and multidisciplinary. On the nongovernmental side, ICSU is also global and multidisciplinary. Therefore ICSU is the proper international scientific organization for scientific guidance of IGBP. On the governmental side. there is no one agency that has the capacity to mobilize the operational capability for observations and data management, to cover all relevant disciplines, and to represent all nations. A coalition of operational agencies will be required.

2. The space component of the global observing system will be more cost-effective and better able to distribute data widely if it is fully internationalized. There are existing groups, but they need closer coordination. These include the International Polar-Orbiting Meteorological Satellite (IPOMS) Group, the Coordination of Geostationary Meteorological Satellites (CGMS Group, the Committee on Earth Observations Satellites (CEOS), the International Forum on Earth Observations using Space Station Elements (IFEOS), and the Coordination Group of Space Station Partners on the use of Polar Platforms for Earth Observations. These are all groups that offer opportunity for international dialogue among representatives of earth observation agencies. Regional groups of other countries, such as the Society of Latin American Specialists in Remote Sensing and the Asian Society for Remote Sensing, also exist. On the nongovernmental side, we can look to COSPAR for coordination and guidance.

3. An information system that would provide all researchers with access to data on the time scales required for both operations and research clearly requires close communications, and technology has outstripped current international institutional capability. We must preserve the archiving and access availability, especially for developing countries, to data about the earth, while at the same time using the latest technology to make the data system effective and comprehensive.

The urgency of establishing a program does not mean that every detail must be put into place at once. The immediate need is to ensure that the international structure is adequate to cope with the broad issues of multidisciplinary science using high-technology observational and modeling instrumentation and computers.

It is clear that international institutional arrangements for IGBP need to be addressed soon, so that any proposed changes in existing structures can be fully examined by all the relevant and interested parties. It is also clear that the developing history of the study of the earth has given the scientific community both significant experience in learning how to work together in an interdisciplinary mode and a rich "bag of tools" for management and administration.

Although the structures in place are untested for the broad and multidisciplinary programs of the future, it is not clear that entirely new structures will be required for the IGBP. However, success for the IGBP demands at the very least much stronger coordination among and strengthening of existing organizations and mechanisms. The preferable mode of management is one that requires the least change or addition to existing mechanisms, but the need for new institutional structures should not be ruled out, provided that the necessary coordination and guidance are made available.

The committee recommends that ICSU convene an impartial group of experts in the near future to develop specific recommendations to the international community on organization and management of the IGBP. This group should include representatives from the existing large programs such as UNESCO's Man and the Biosphere Program and WCRP, as well as from the program areas to be emphasized in IGBP.

National Organization

At the national level, there is a need for fostering interdisciplinary programs on global change in universities and in federal laboratories. A number of these are already in place, and it may well be that there is an important role for activities sponsored by university consortia. Universities make up the most central, pervasive, and stable infrastructure to provide the needed knowledge base, to develop the global model components, and of course, to educate an appropriate and adequate talent base to pursue the quest of understanding the earth system in the coming decades.

The specific activities to be undertaken will depend on scientific priorities, which in turn will come from the scientific communities involved. The federal laboratories constitute a major national resource for global change research. Particularly, these laboratories are often the managers of and participants in large-scale, complex research programs involving ships, aircraft, rockets, spacecraft, ground-based research facilities, and global-scale measurements networks. They are also frequently among the first recipients of advanced computers, and thus, in many research fields, have forefront and extensive computational capabilities. Several federal laboratories are leaders in the development of global models for atmospheric, oceanic, and land processes, and are repositories for global-scale data bases. The federal laboratories are encouraged to strengthen their interdisciplinary and interagency programs in global change research, and to increase their interactions with university researchers and students to enhance effective use of these extensive national resources for research on global environmental change.

It is clear that the breadth and scope of the IGBP necessarily involve the efforts on many federal agencies with diverse missions, capabilities, and constituencies. Harmonious working relationships and effective coordination will be essential to optimize U.S. contributions. Coordination at the agency level is already being addresses through the FCCSET Committee on Earth Sciences (CES).

The Committee on Earth Sciences effectively represents the federal agencies with major interest in global change and has proved to be a useful forum for airing planning issues. The full cooperation of the agencies involved in CES will be important for the success of the U.S. contribution to the IGBP. It will also be essential that CES work closely with the Office of Management and Budget since the recommendations will cut across many agencies and will have budgetary implications for all agencies.

Committee on Global Change (U.S. National Committee for the IGBP)
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USSR

The below enumeration of the major trends of the USSR participation in IGBP is based on the approved concept of the programme and on the scheme of research worked out by the Special Committee of ICSU on IGBP with a number of suggestions taken into account that have been submitted by Soviet research institutions.

Interaction of atmosphere, land, ocean and biota.

A. Formation and dynamics, chemical transformations and runoff of CO_2, ozone, trace gases and aerosol admixtures in atmosphere and their relation with biosphere and impact on the climate.

B. Matter flows between ocean, atmosphere and land.

C. Processes of the transfer of biogenic elements of the ocean, the change of contents and dynamics of admixtures in the ocean.

D. Geochemical and biochemical cycles and their changes.

E. Interaction of climate, ocean and glaciation.

F. The global energy and its impact on meteorological and biogeochemical processes (including global electric circuit).

The global hydrological cycle.

A. The flows of water between ocean, atmosphere and land.

B. Planetary water exchange, including redistribution of moisture between the depths of the Earth, ocean, land, atmosphere and outer space.

C. Dynamics of ecosystems in relation to the changes of hydrological regime.

D. The impact of anthropogenic changes of hydrological regime on the cycle of biogenic elements.

Terrestrial ecosystems.

A. Dynamics of the biocenotic cover and sustainability of biosphere on regional and global levels.

B. Natural and anthropogenic factors and mechanisms of sustainability and changeability of geographical systems.

C. Formation and functioning of geographical systems, detection of critical regions and situations, prediction of their development and the mode of their management.

Oceanic ecosystems.

A. Circulation of oceanic water and natural changeability of the fields of the ocean in a broad spatial-temporal interval.

B. Biota of the ocean, its natural and anthropogenic changeability; the regime of the oceanic euphotic zone and of the biological environment in the rift zones of the oceanic bottom.

C. Energy balance of the hydrosphere's biota, the level of anthropogenic impact and the state of oceanic ecosystems.

External impacts on atmosphere and on ecosystems of land and ocean.

A. Heliocosmic processes, solar-terrestrial interrelations, their evolution and the role in the formation of geospheres and biosphere and the processes taking place in them; the study of a direct impact of these factors on physical, chemical and other processes as well as on biological objects of different level.

B. The influence of solar variations and interplanetary processes on the dynamics and chemistry of the interaction of thermal sphere, mesosphere and stratosphere.

C. The study of the processes of transformation and transfer of energy in the system "Sun-solar wind, geosphere, biosphere".

D. Reflection of the variations of geomagnetic field in the parameters of climate and hydrophysical processes in the World Ocean.

E. The influence of endogenic processes on the irreversible evolutional and periodic changes in the structure, composition and development of the outer spheres of the Earth and of the biosphere.

F. Geological calamities (eruptions of volcanoes, earthquakes, tsunami, etc.); their influence on climate, formation of landscapes and ecosystems of the Earth.

G. The global system of response interactions of the layers of geosphere, its physical fields and biota.

Evolution of processes in the history of the earth.

A. Geochemical evolution of sedimentation cover and geochemical situation on geological boundaries.

B. Models of the geochemical cycle in the history of the Earth.

C. Connection of biosphere evolution with geochemical processes in the history of the Earth.

D. Humidity changes in former epochs.

E. Evolution of geographical systems in the history of the Earth.

Building of a system of models of global changes.

A. Mathematical modelling of global biogeochemical cycles and climate on land, and in the ocean and their changes under the influence of anthropogenic activity.

B. Mathematical modelling of the development of a system of bioms during disturbances caused by climatic, chemical and other nature changes and anthropogenic activity.

C. Building of a global model of the biota of oceanic pelagicus.

D. Simulation of the current changeability of global water cycle with account of geographical distribution.

E. Mathematical modelling of the links "biosphere-climate-geosphere".

F. Simulation of local impacts on the Earth's spheres.

Instrumental, methodological, and information provision; coordination of research and elaboration of recommendations.

A. Creation of a system of the main observed and measured parameters (indices, criteria) for the purpose of IGBP.

B. Elaboration of a strategy for a multi-purpose planning of the space system of remote sounding; determination of the principal groups of tasks.

C. Resolving of methodological problems of an optimal location of overland observation means; development of a system of biosphere-geosphere stations and observatories.

D. Organization of space-borne platforms and systems of space monitoring for the purposes of IGBP.

E. Substantiation of the structure of data banks oriented towards the problems of IGBP, their establishment and replenishment.

F. Coordination of the exchange of observation data and publication of the results of studies under the IGBP programme.

REPORTS BY ICSU BODIES AND OTHER INTERNATIONAL ORGANIZATIONS

CCCO

Introduction

CCCO was created in 1979. Its existence arose out of the recognition that progress in the understanding and prediction of world climate would require oceanographic research and observational systems with a coverage comparable to the global meteorological network.

CCCO's position in the organizational framework is seen in Figure 1 * (note: in the complete report). It can be understood that international marine science involves not only international interaction at scientific level, but also concerted action at government level, for reasons of territorial jurisdiction, the national differences that exist in the organization of marine science and the interests and aspirations of the world's maritime nations.

Thus the first terms of reference of the CCCO are to:

1. Identify ocean-climate research problems requiring increased international attention, stimulate research activities thereon and recommend to IOC and SCOR how these activities should be implemented;

2. Establish requirements for ocean observations that are needed to improve climatic forecasts over seasonal, inter-annual, and decadal time scales and to gain a greater understanding of oceanic aspects of the carbon dioxide problem.

CCCO's function it therefore specifically climatic, and it is charged with responsibility for interaction with the JSC to facilitate the goals of the WCRP. Although its charter does not confine CCCO to WCRP interests this major responsibility has defined the bulk of its activity so far, within the TOGA and WOCE programs. TOGA has done much to test the limits of existing world capability for sustained ocean observation (with some very gratifying results), and further tests will arise with the implementation of WOCE.

Because these experiments have presented new challenges in data acquisition and rapid dissemination, CCCO has therefore maintained as part of its brief a close interest in the technical aspects of ocean observation and modelling through its Ocean Observing System Development Program and through specialist working groups and panels, jointly with the JSC.

The scale of activity is such that the technical business of CCCO is mostly conducted by expert task oriented groups, the busiest ones being the scientific steering groups for TOGA and WOCE, and the three ocean panels which address the activity and organization of research and monitoring within the Atlantic, Pacific and Indian Oceans.

The dominance of TOGA and WOCE has meant that in practice CCCO interests have so far been mainly in the physical sphere. The Committee maintains a Paleontology Panel however, and the importance of global carbon dioxide studies was one of the primary reasons for its creation and a continuing interest. To this end restructuring is taking place to ensure a closer liaison of the CCCO's Carbon Dioxide Panel with the JGOFS Steering Committee.

CCO future programmes and interests

Listed for consideration in CCCO's forward agenda are a number of possible research program topics which may be of interest in this conference. They include:

- Atlantic Ocean long-term variability
- Climatic influences of Sea Ice
- Medium term oceanic variability (already included as a topic for consideration by TOGA)
- Oceanic teleconnections
- Critical variables in Oceanic Monitoring Strategy

All of these are predominantly physical in character.

* Figure 1 will be derived from Figure 2 of the JGOFS paper "Background, Goals, Organization, and Next Steps".

CCO/IGBP interaction

In considering the development of the IGBP, the potential role of CCCO should be taken into account.

CCCO offers:

- Formal oversight and familiarity with the existing international oceanographic research programs.
- The main existing pathway for scientific input to and interaction with the IOC, in relation to activities which might involve intergovernmental action, and an appropriate line of interaction with SCOR and JSC/WCRP where responsibilities overlap.
- Objectives and terms of reference that are directly relevant to IGBP plans in the context of climate research.
- In light of the forgoing, a means of limiting the structural and reporting requirements with sponsoring international agencies.

Within the existing ocean climate research and monitoring activities the IGBP may benefit from assistance and cooperation in,

- Access to data and data products;
- Inclusion of sampling and observation activities within existing programs (eg The WOCE Hydrographic Program, ocean observing networks);
- Technical support (remote sensing archives and processing, dynamical modelling, physical interpretation);
- Collaboration in operational and regional support (opportunities for national participation, ocean panel and working group activity);
- Gaining of intergovernmental recognition and support;
- Optimization of regional representation on working groups, panels and committees;
- Multi-disciplinary integration in new programs (eg Biological flux and surface transport studies).

It would be inappropriate to stipulate at this early stage the form which interaction with CCCO might take, but the IGBP organizers can be assured that our Committee owes its existence to the common objectives of the IGBP and the WCRP, and is committed to serve these objectives the best way possible. At the very least the participation of observers in our respective meetings should be ensured, and means should be found for interaction at secretariat level on a continual basis.

COGENE

For a long time our planet has been 33 to 35 degrees C warmer that it would be without water and carbon dioxide in its atmosphere[1,2]. This "greenhouse effect" is due to absorption and re-radiation back to the ground of part of the infra-red emission from the surface. The process, effected by water vapor and other radiative gases, is intensifying because, excepting water, these gases are being released in ever greater amounts by industrial and domestic sources[3,4].

Each year more and more carbon dioxide, methane, halocarbons and other greenhouse gases enter the air, implying heating of the global beyond its present state[2]. Since the average amount of water in the atmosphere is more stable, the heating increment results mainly from a disequilibrium between CO_2 releases (from burning, decay and respiration) and photosynthesis by plants and algae. The trend is to more CO_2 production and less conversion of it to organic matter because of four worsening processes: greater burning of fossil fuels and biomass; diminishing plant biomass following desertification and forest felling; mounting soil respiration due to cultivation and erosion; and increasing respiration from the growing human and domestic animal populations.

It is commonly thought that human respiration is negligible in the CO_2 cycle, but this is erroneous book-keeping. The yearly accumulation of CO_2 depends of the rate of oxidation of the Earth's organic matter; if this rate exceeds that of photosynthesis, the gas will accumulate. All processes that release CO_2 therefore contribute to the greenhouse effect. Ingested organic matter, like that burned, is mostly converted and released to the atmosphere in a few hours, while that not eaten, rotted or burned can remain sequestered for many years (our grain and butter "mountains" are unintentional examples of possibilities for changing this rate). The average human doing light work exhales about 100 kg C as CO_2 annually; 5 billion (10^9) humans therefore respire 0.5 x 10^{15} gC per year, roughly 10% that of fossil fuel burning[3-5]. Domestic animal respiration is even greater (cattle alone number about 1.4 billion[6], and an average cow breathes out 5-7 times more CO_2 than a man[5]). Smaller populations would mean slower conversion of the carbon to CO_2. Likewise, food waste constitutes probably at least 10^{14} gC a year. With present practices this is nearly all converted to atmospheric CO_2 in short time, but each community could have its "artificial peat pit", where the carbon in such waste would be sequestered for eons. Thus, human and animal food habits and physiology are important considerations in regulating the greenhouse.

Future industrialization and population growth in developing countries can only accelerate the trend. This is a dangerous course and the threat of global climate change must be taken more seriously since room is small for doubting that the CO_2 contents of the ocean and air linked to climatic conditions[7-12]. Corrective action to restore atmospheric equilibrium has, however, hardly been envisaged, nearly all researchers concerning themselves with analysis of measurable phenomena or with attempts to reduce uncertainties in the balance sheet. Great uncertainties do remain[2-4, 8] and they should be reduced, but meanwhile the conception and development of greenhouse controls has become urgent; I here expose 3 approaches for possible exploitation in the near future.

The primitive atmosphere is accepted as having been rich in carbon dioxide and lacking in free oxygen, but after the arrival of photosynthetic organisms O_2 content rose while the CO_2 dropped progressively[1, 13]. This apparently continued until the CO_2 bottomed out during glacial maximums -- for example, around 20 (or 150) thousand years ago it was only 180-200 ppmv[10]. Since the start of the present interglacial 10 thousand years ago, airborne CO_2 has been rather stable at 260-290 ppmv, except in the last 2 centuries, when is has risen to today's value of about 350 ppmv[4, 10, 14,15]. The mean annual increase for 1958-1984 was near 1.2 ppmv, or roughly 10 billion tons of CO_2 (1 ppmv = 7.89 x 10^{15} g CO_2 or 2.15 x 10^{15} gC). The yearly increase correlates nearly perfectly with population growth[16].

Controlling this enormous build-up, confirmed in both hemispheres[14, 15], requires energetic inter- or supra-national action. Expert opinion is that more CO_2 in the air will raise the global mean surface temperature[2,7], with implications for our life style and the stability of the biosphere[8]. The huge mass of carbon already converted to atmospheric CO_2 thus conditions our immediate future and demands that we explore methods for decreasing it. In short, atmospheric equilibrium must be improved, which means recovering at least part of the CO_2 excess. Alternate power sources to fossil fuels need to be put in service. The essential remedy, given the fixed amount of carbon

on Earth, is to change some of that present as CO_2 to another form. The three measures recommended here are all intended as positive controls with that aim, but I do not suggest that negative controls such as stopping forest destruction or restricting releases of CO_2, CH_4 and halocarbons should not be instituted. According to the severity of the anticipated planetary warming, sea level rise, desertification and climate perturbation, one or some combination of these approaches could be employed to curb the greenhouse effect.

Ground cover

The best studies and most appealing approach for the general public is re-greening the desert. Desertification, however, has been combatted since 1977, yet "...more land...and people are affected by desertification today..."[17]. The main reason for this lack of success may be the insufficient reforestation attempted because of underestimating the global aspect of the problem, which resulted in inadequate funding. Thus, it has not been accepted that desertification may be due, at least in part and perhaps mainly, to CO_2 increase in the atmosphere; instead advancing desert is nearly always relegated to local causes[17]. In the spirit of the present paper, reforestation is not merely a remedy for desertification; it is seen as a protection against global climate change, of which desertification is a subsidiary manifestation. The magnitude of re-greening needed to compensate for the CO_2 yearly excess is shown by the following calculation.

The current annual atmospheric excess of CO_2 is 1.5 ppmv, or 3.2 x 10^{15} gC per year[3, 4]. In the context of transforming existing deserts into new woodlands, suppose that on the average over the first 10 years of growth a new tree could store from 1 to 10 kg of carbon a year, depending on local conditions. Taking 6 kg carbon fixed as new plant tissue annually, which in the frequently harsh environment of the desert is not an over-pessimistic expectation, gives roughly 500 billion new trees required to compensate for the present rate of CO_2 increase. Optimum spacing between trees for primary production, forest lifetime and minimization of fire risk must be taken into account. Crowded trees are susceptible to self-thinning, and dead trees result in more fire hazard. Stable, long-life mixed forests, which should be planned, need wider spacings -- varying with soil composition, temperature, humidity, altitude and latitude, etc. A mean spacing of less than about four meters is doubtful for such forests; this implies at most 62,500 trees per km^2. The 500 billion new trees would, then, require the creation of 8 million km^2 of new woodland; this is approximately the size of the Sahara desert.

It must be recognized that at best the above solution indicates solely maintaining the present level of carbon dioxide in the air, which could turn out to be inauspicious because of time lags in the effects of polar ice melting, equilibration with CO_2 in the sea and rising production of CH_4 and other greenhouse gases (ref. 2, 12, 18). As well as limiting these gases, therefore, we may need to reduce the industrial atmospheric excess of about 75 ppmv that has accumulated in the last two centuries[2, 4, 14]. Complete correction of this airborne store would demand 50 times as many trees as would the annual excess, hence does not appear feasible by reforestation. Nonetheless, spread over a century (while maintaining the above annual compensation), removing some of the industrial build-up might be possible by promoting forest undergrowth and soil carbon increases -- which do represent sequestering since at any given time a certain mass of carbon exists in a form other than CO_2.

Tied to the idea of forestation is that of increasing rainfall in arid lands. Schemes for bringing rain to the desert have been evoked for centuries without success. This is an insufficient reason for not persisting, given the current rate of extension of the deserts, the huge amount of irrigation water needed to combat desertification on a large scale, and the salinating effect of repeated irrigation. Some meteorologists feel that greening the desert could worsen the situation because the resulting lower albedo would predict more absorption of solar energy. We cannot accept this conclusion in the context of the Sahara, the world's largest desert, for the reasons given in the following analysis -- which is, however, based on imperfectly understood phenomena, and thus may be controversial.

Everything else fixed, greening the Sahara would mean more heat absorption due to albedo drop, but several factors will, in fact, not remain constant:

- Temperature. Day-time surface temperature will fall due to evaporation of the imported water and shading by the new vegetation, tempered of course by albedo decrease. Night temperatures in most places would drop less than at present because of the increased vegetation and moisture.

- Night irradiation. Because of the much larger plant surface and mass (hence higher heat capacity and lower albedo) following forestation, coupled with the warmer nights, one can expect more irradiation at night of heat stored during the day.

- Convection. This depends on large scale processes; oddly it is suppressed in the hottest part of the Sahara by an anticyclonic "lid". Ordinarily, only about 1/2 the solar energy not directly reflected upon striking the ground is re-radiated as infra-red, the other half goes into convection, which varies with temperature and atmospheric stability. As with irradiation, night convection should increase because of the warmer nocturnal surface, raising the heat to a higher level in the air and facilitating escape to space.

- Evapotranspiration. Humidity above the ground should become greater as afforestation progresses, varying with type, age and extent of the flora, amount of water available and other conditions. Consequently, a more favorable situation for mist and cloud formation can be expected with time (decades). Clouds have two functions here: reflecting sunlight and raining. However, atmospheric water vapor augments infra-red absorption and an exact balance between parameters cannot be predicted reliably. It is sobering to realize that no clouds form above Lake Chad or the interior delta of the Niger River. Nevertheless, added humidity and condensation, favored by the new woodlands, with time could change the lapse rate from dry to nearer wet adiabatic, leading to a cooler day-time surface and warmer air higher up, changing this aridity.

- CCN. Cloud condensation nuclei are often of organic origin, dimethylsulphide production by marine algae being their common starting point. Inland sources of CCN (grass is one possibility) are less well known. At present one sees some clouds over the Sahara but no rain; one reason may be insufficient vegetation for making organic CCN. It is also likely that too much dry dust and high wind inhibit rainfall. Of course, if there is no moisture in the air CCN cannot make rain. Re-evaporation of rain that does fall from middle latitude clouds, not infrequently seen in the Sahara, is another problem. There are indications, though, of the interaction of rain and cloud formation with the surface parameters of temperature, humidity and roughness[19, 20]. Planting mangrove forests on the subtropical coast and in brackish swamps should be tried to help change surface parameters. These threes are high primary producers (we have not, however, found suitable studies of their evapotranspiration).

- Energy transformation. Photosynthesis consumes electromagnetic energy, and heat is absorbed as organic matter is produced. This is a minor factor in the energy budget, but it goes in the right direction and can help lower the surface temperature.

- Parameter equilibration. Interaction of the above items with the overall metabolism of all organisms present (bacteria, protists, fungi, plants and animals), with wind characteristics (air mass temperature, humidity and vertical and horizontal movement) and other environmental phenomena, is to be expected. If organisms proliferate in the soil and humus forms, then surface temperature, humidity and erosion will start to change favorably. Research on these interactions should be implemented to aid in a better understanding and exploiting of the re-greening process.

The above term "trees" should be taken to include tropical and subtropical desert bushes, which are among the best ecosystems for storing organic carbon and nitrogen; their C_4 pathway exhibits high levels of photosynthetic capacity, water-use efficiency and heat tolerance, while showing negligible photorespiration[21-23]. Research will be needed for species selection to establish a suitable mixture of tall trees (C_3) and undergrowth.

It is clear that further study is necessary, but when the above analysis is taken into account it appears most likely that the net effect of greening the Sahara, if done properly, would be a negative contribution to global warming. Thus, even without the benefit of rain, increased cloudiness would reflect more heat to space. In spite of this optimism, however, successful planting of the Sahara cannot be a complete solution to the global greenhouse problem with our present society and population. That fact added to the immense cost of desalting the water

required for such woodlands, at least in the early stages when arid conditions would still prevail, mandates a brief exploration of other means for correcting the CO_2 excess.

Stimulating oceanic photosynthesis

We are too ignorant about the ocean, which is sometimes considered a liquid desert. Several studies have shown, however, that the addition of certain chemicals (nitrate, phosphate and iron) promotes growth of algae and other marine organisms, sometimes strikingly augmenting primary production within a few hours[24-27]. Such phenomena have been known for many years, but have hardly been exploited. Eutrophication, already troublesome in some bays due to domestic and industrial waste, must be monitored in any such undertaking.

Oceanic stimulation has an economic advantage over the other approaches in ease of getting underway, and trials in delimited barren zones could begin as soon as international agreement is obtained. One route would be to bring mineral-rich deep water to the surface by pumping or promoting up welding; the latter might be powered by thermo-electric generation. Alternatively, nutrients could be added to the sea[24-27].

It may also be possible to raise slightly the very low albedo of the ocean by stimulating surface productivity, although no such attempt has been reported. For example, Foraminifera exist in large numbers throughout the sea and they bloom when appropriate food (phytodetritus) becomes available[28, 29]. Selective surface feeding could be tried to raise the population size of reflective strains of these or other organisms.

At the same time, research is needed to elucidate why "...more than 99% of the organic matter in the ocean is dead, dissolved and extremely dilute", and has a mean age of roughly 6,000 years, while only 20-30% of the component molecules have been identified[28, 29*] (* see new in J.R. Toggweiler, Nature 334, 468 (1988)). The CO_2 distribution in the sea likewise remains obscure[18] and should be mapped quantitatively by direct measurement. In addition, there may be a possibility of controlling organic sediment and $CaCO_3$ deposition, which are not well understood[30-33]. These uncertainties contribute to the reason why, although surface water is believed to equilibrate with atmospheric CO_2 in something like one to five years, no estimate of the total oceanic uptake of CO_2 since pre-industrial times has been forthcoming.

Durable polymer production

Perhaps the most intriguing path for sequestering carbon would be manufacture of non-biodegradable polymer. The new product could be used in construction of buildings, bridges and motor ways, any excess over these markets being stored above or below ground. Although deliberate manufacture of non-biodegradable plastics would undoubtedly shock many environmentalists, it could provide an important reservoir for carbon. An added advantage is that part of today's cement making might be replaced by the polymer operation, which would remove a minor contribution to CO_2 build-up[4].

We have imagined a four-stage manufacturing process, designed to avoid fossil fuel usage:

I Photosynthesis fed by atmospheric CO_2 and effected by cyanobactera or other microorganisms to produce sugars, amino acids, etc. (this general type of unit is being exploited for other purposes in several countries)[34].

II Bacterial conversion to chemical stock in the form of polymerizable monomer.

III Fabrication of the non-biodegradable polymer.

IV Storage and exploitation in construction.

The striking efficiency of this approach is evident as follows. Suppose it is decided that the entire industrial-age atmospheric excess of CO_2 must be removed. The 75 ppmv could be compensated by fabricating an equivalent amount (160×10^{15} gC) of polymer. This is only about 200 km^3, or a cube of 5.84 km on a side (the size of one of the biggest iceberg). Thus

storage of the product, even if none went into construction, does not appear to be s serious problem because of the relatively small volume of polymer required. Of course, due to the implied high level of production, even spread over a century, a radical acceleration of the plastics industry would be necessary.

This measure differs from the first two in that it is not geographically circumscribed, the polymer could be made, used and stored anywhere. In fact, a single large country or block of countries could elect to adopt this strategy, for economic or other reasons.

Finally, a short mention of power sources. In principle the nuclear is an energy source that does not generate CO_2, and some people think it is the only possible solution for developing countries. After a long and wide debate, however, accompanied by applications and accidents in several nations, the nuclear has fallen into disfavor and probably will not be able to resume its advance for many years[35]. Nevertheless, a huge amount of energy will be needed in any greenhouse correction project and nuclear as well as solar, wind and hydrogen power should be considered[36, 37].

Conclusion

If the Earth's population were to fall back to a lower level, perhaps a return to a "liberal ecology" would be feasible. In the present situation, however, we must stop deceiving ourselves that "natural causes" will take care of the global environment and that we shouldn't interfere. These natural causes could simply exterminate us because we have already interfered seriously with the atmospheric equilibrium, and any natural process will tend to install a new equilibrium with the new set of parameter values we have created. It would be folly to imagine that such a natural adjustment would be sufficiently gradual to allow us to adjust without pain.

Pursuit of the proposed "Regulate Greenhouse" project would of course necessitate international agreement. The expertise of several existing organizations would have to be called on to ensure adequate surveillance of epidemiological, social and other phenomena. While contemplating an appropriate structure for the project, we should act within and between existing groups to diminish the likelihood of a "natural solution" in coming decades. This implies reinforcing research on all aspects of the greenhouse scenario, including the sources and possible controls on the other radiative gases (especially methane, which is apt to be harder to regulate than the CFCs).

One vicious problem not treated above may be outgassing of the ocean as correction is applied to the atmosphere. Outgassing from the deep ocean will be stimulated as atmospheric CO_2 is diminished, since 50-60 times as much CO_2 is believed to be in the sea as in the air. This "brake" on the establishment of equilibrium cannot be quantitatively estimated from present data. That is, of course, all the more reason for extensive measurement of oceanic carbon dioxide.

In view of the importance of this question, there is too much uncertainty on the parameters essential to a quantitative overview and further research is urgent. Because of these same uncertainties, however, we cannot afford to wait for new data. The risk is too great and by the time the population doubles again (less than 40 years at the present rate), unless global corrective measures are taken severe effects on the biosphere could be seen. Development of a correction must, therefore, be pursued hand in hand with the basic research.

It would be incoherent to try to regulate the atmosphere without constraining what is ultimately de-regulating it: population growth. A viable evolutionary strategy will involve controlling both the environment and species producing its disequilibrium. We cannot anticipate all the difficulties to be encountered in subjecting the greenhouse to scientific regulation. An appreciable period of apprenticeship may await us. We should get started.

The above may appear grandiose; this is because the problem is grandiose. Only a global solution will work, and it must developed in spite of the many uncertainties and difficulties.

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CTS

Introduction

GLOBAL CHANGE provides a potent way in which the scientist and science educators within the ICSU family can collaborate to provide teaching materials for schools and colleges which illustrate the essential role of the scientists in society.

It is of crucial importance that

- we attract more young people into the science professions by showing that science is one of the most worthwhile of human activities and counter the current negative trends in manpower statistics for the 1990s in many developed countries.
- young people understand the role of science within our society and how scientists are able to provide information for the solutions of the natural and man-made problems facing the human race within the political, social, economic and technological constraints imposed on them.

Too often, the immediate issues facing scientists are ignored in the teaching of science in schools and colleges. There are many reasons for this:

- The concepts are too difficult;
- Teachers do not have enough information;
- There is not enough time because of examination constraints;
- and so on. Thus not only do many young people pick up the information from the media which is often handled insensitively and again without the correct infraction, but we fail to inspire our students to choose science for their career.

ICSU can play a very important part in science education. It can bring together the experience and expertise of the world's leading scientists and science educations to collaborate and produce teaching materials. These materials will have authoriative information and demonstrate that science is an international endeavour, that there are no national boundaries. GLOBAL CHANGE provides such an opportunity.

Teaching materials to be produced

Topics from GLOBAL CHANGE will be chosen. Then teaching materials will be designed for use in school and college courses. But first, let us look at four particular points.

A lot of materials are already produced particularly by industrial companies which teachers could use. However, the adaptation to class use is a highly skilled - and difficult - process and the materials that can be directly used. Otherwise we will be wasting our time.

Secondly, we will waste our time unless the work we do is seen to be relevant to the syllabus. Most countries - particularly the developing ones - have very stringent syllabuses to which teachers must work. Again, much of the materials produced for teachers are not used because the teachers cannot relate them to the syllabus.

Thirdly, we must produce materials which involve students - with practical work, discussion, data collection, data interpretation - the sort of things scientists do. It is simply not good enough for us to give information to them. We have to produce it in a form that teachers can use with their students.

Finally, we must produce materials that are very cheap - remembering that we want to influence teachers in developing as well as developed countries.

Thus we must work within the following constraints in producing the teaching materials. They must

(a) be brief and readily assimilated within current syllabuses;
(b) illustrate scientific principles which again are regarded as important in current syllabuses;
(c) be realistic in time. Many teachers are under terrible syllabus constraints;

(d) be easy to use. So much is produced which demands too much of the teacher in terms of preparation time;
(e) be cheap to produce and use.

However, there are two further constraints - and must be met for ultimate success. They must
(f) be interactive. The materials must involve the student. Issues cannot be taught didactically. They must be discussed.
(g) be readily adaptable to meed local conditions.

Thus the teaching materials must be in the form of cheap booklets for teachers with materials for students incorporated which be readily copied (copyright waived). So that a school or college need only buy - or be given - one copy of the booklet.

The booklets should contain
(i) authoritative information about the topic or issue, prepared by CTS but in collaboration with scientists in the GLOBAL CHANGE team, to extend the knowledge of teachers by giving essential information;
(ii) detailed teaching strategies for two distinct cohorts
- junior secondary school
- senior secondary school/college level

These are discussed in detail in Appendix 1.

If it was possible, other teaching aids should be prepared, for example
- computer programs; simulations; games
- slides
- posters
- videos
- locally-produced kits (prototypes)

However, these must be adjuncts to the booklets and main teaching strategies and be dispensable. Otherwise we will never be able to reach schools and colleges in developing countries.

Methods of working

ICSU CTS has set up a small steering committee
Professor D J Waddington, Secretary CTS
Professor Marjorie Gardner, Director of the Lawrence Hall of Science, University of California, Berkeley
Professor Norman Graves, International Geographical Union
Professor Lucienne Gougenheim, International Astronomical Union
Professor Peter Kelly, International Union of Biological Sciences

The project will be carried out initially by two author teams, one headed by Professor Waddington, based at the University of York, UK, the other by Professor Gardner at the Lawrence Hall of Science at the University of California, Berkeley, USA. As will be seen later in the proposal, we will wish to involve other groups after this pilot stage in the project.

There will be a total of six in each team. Already, these teams are taking shape and will include
Professor Henry Heikkenen, Chief Editor of ChemCom (the new ACS project in school Chemistry)
Mrs Christie Borgford, Lawrence Hall of Science
John Holman, Director of SATIS (new UK project in school science)
Andrew Hunt, Director of SATIS 16-19 (a UK project that is beginning to build on the work of SATIS).

Like others to be recruited, they are either schoolteachers or have considerable experience of school teaching.

Timetable of meetings and workshops

1. Two meetings between Professors Waddington and Gardner have already taken place - in London, April 1988 and at Purdue, August 1988, to discuss this proposal.

2. Professor Gardner will be invited to attend the next CTS meeting in April 1989 in Paris. We would also hope to have member(s) of GLOBAL CHANGE there.

3. Invitations to the author teams to participate in the work will be sent in September 1988 so that all opportunities can be used during the next few months to discuss the project with them at little or no expense to the project and to produce initial working papers.

4. A 5-day workshop will be arranged at the Lawrence Hall of Science, Berkeley in early August 1989 at which the final design of the project will be agreed and work begun on 5 units of work - the pilot project. Two authors - one from each group - will be responsible for each unit.

5. During the following 12 months, the two authors will be able to meet to discuss their work and to spend some time in a leading laboratory or institution taking part in the GLOBAL CHANGE programme. Thus the authors will be able to get first-hand knowledge of the background to the work and to involve scientists at this stage in the publication.

6. Following this, there may have to be correspondence between the authors and scientists to check out facts; etc. and gather data and other information which may now be found to be necessary.

7. A 5-day workshop will be arranged at the University of York in early August 1990 to complete the first units of work - the teacher's guides - thus finishing the pilot project. At this workshop, plans for the second phase will be discussed - namely supporting materials for the pilot project work and secondly, the involvement of other groups - worldwide - in the production and dissemination of further materials.

8. The material will be trailed, rewritten and camera-ready copy will be produced during the period August 1990 - August 1991.

9. Publication of the materials will be by ICSU Press and distribution will include the ICASE network.

IAHS

Background

The IGBP is an ICSU effort, the aim of which is to reach understanding of the processes, regulating the total Earth system, and to create tools with which it will be possible to predict future changes in our life support systems.

The involvement of hydrological phenomena in the geosphere-biosphere interactions were analyzed in IAHS's contribution to the UGGI workshop on Global Change, held in Vancouver in August 1987[1]. The conceptual framework on which that document was based understands the water cycle as a continuously working link between the three geospheres: the atmosphere, the lithosphere and the world ocean (the hydrosphere being seen as a confusing concept in its merging of a sphere and a cycle).

The Vancouver document concluded on the role of hydrological research in IGBP with its three main purposes in view:

- understanding key interactions
- predicting possible changes
- detecting signals of change.

Finally the Vancouver document, in view of the fundamental role played by the water cycle in producing and transmitting global change to human society, stressed the fundamental importance of engaging the hydrological community in IGBP issues.

The need to study interactions between the global water cycle and different natural environments have now been raised in a number of documents related to the planning of IGBP:

- Two UGGI proposals to IGBP both from IAMAP/IAHS (LAVIP, Hydrological pathways of global biospheric significance;
- the GEWEX proposal;
- a proposal from IGBP SC/Panel 3 (as of May 1988).

This paper summarizes some comments on these proposals, starting with some general comments on conceptual problems involved in the planning and implementation of IGBP.

General comments on the IGBP programme

Conceptual geophysiological framework

A main challenge for the IGBP in order to master the geophysiology of the Earth, is the great paradigmatic differences between the main scientific groups involved. It is indeed highly desirable to develop, at an early stage, a joint conceptual framework in order to facilitate cross-disciplinary discussions to the maximum possible degree.

There are basically two groups of paradigms involved:

- the ecological ones based on ecosystem theory, with key concepts being energy flows and biogeochemical cycles. Water phenomena tend to be factorized and implicitly treated.
- the geophysical ones, based on physics with key concepts being velocities, pressure gradients, flows, storage, pathways, and hydrothermodynamics.

Seeing the IGBP work as a major geophysiological effort, these fundamental paradigmatic differences tend to create linkage difficulties between individual IGBP-panels, inevitable as long as there is no unified conceptual framework. It is interesting to observe, for instance, that the biosphere-atmosphere interactions are handled by one panel for the marine part, but by three panels for the terrestrial part, one panel concentrating on chemical interactions with the atmosphere, one on the involvement of the water cycle, and one on the effects of climate change on the ecosystems. There is a clear overlap between the two latter panels, although they are operating with different paradigms.

Involvement of the water cycle in the total Earth system

In IAHS's contribution to the earlier mentioned workshop in Vancouver[1], the water cycle is seen as composed of different subsystems or steps:

- An aerial water vapor flow system covering the global and being in continuous water exchange with the underlying ocean and land surfaces
- The wettening of the continents and feeding of the terrestrial ecosystems. This subsystem keeps feeding the soil with moisture, provided in different precipitation modes in different regions, topography exerting a strong influence on its spatial distribution. Through this moisturization, the root zone storage of water is being intermittently recharged, making water, with its load of nutrients necessary for growth, available to the terrestrial ecosystems.
- The recharge of terrestrial water systems, i.e. aquifers and rivers, fed with the remaining water, i e the water not returned to the atmosphere in the plant production process or immediately evaporated from wet surfaces. The water seeping from the downstream end of groundwater aquifers and the overland flow over non-permeable surface combine to form river runoff.

Consequently, one may distinguish between a sequence of water-related functions and changes, involved in the climate change process:

1. Water as a substance in the atmosphere closely involved in shaping the new climate. Water is involved in the radiation balance of the Earth and the feedback phenomena, in the energy redistribution due to water phase transitions, and as a chemical reactant;
2. Changes to be expected in the planetary system of aerial water vapor flow distributing water evaporated from the sea in over the continents;
3. Changes generated by the changes under 2 to be expected in the hydrological phenomena on the continents, involving changes in both amounts, wetting, models of groundwater recharge/discharge, models of runoff formation in the rivers, and in river discharge providing the return flow to the sea;
4. Changes generated by the changes under 3 to be expected in all the water resources systems, projects and schemes, serving the human society and forming the backbone of modern civilizations.

Comments on the panel 3 proposal

General Comments

The draft program of Panel 3, as of May 1988 made available to the IAHS working group, is broad, strong and impressive, starting from the deep involvement of hydrological phenomena right of the heart of the climate change issue. IAHS wishes to underline the Panel's observation that signals of climatic change will probably be seen first in hydrological phenomena and only later in ecological consequences. This is an important statement with evident implications for the monitoring of climate change.

As seen from a hydrological perspective - in view of the fact that the solar-driven plant production is in fact operated by water - climate change will hit terrestrial ecosystems mainly over the changed moisturization of the land surface and the changed water attraction capacity of the atmosphere generated by temperature increase. Secondary effects will be change recharge of terrestrial water systems, producing endless effects both on human water management components and on groundwater-related phenomena, including the characteristics of groundwater-fed wetlands.

Key in the "interactions between atmosphere, vegetation and soil", are water and energy exchange processes. The way IAHS tends to see these processes is that the land surface reacts

in two interacting ways to atmospheric forcing, especially radiation, precipitation and water attraction capacity of the atmosphere:

a) The ecological response of vegetation, sensitive to meso- and microscale hydrological inhomogeneities in the landscape such as the pattern of recharge and discharge areas. On the large scale clear ecohydrological regularities are manifested in the main ecological zones.

b) The hydrological response manifested by the runoff produced, and providing an integrated measure in the mesoscale.

IGBP's interest is primarily directed towards the ecological response, especially changes emerging when the atmospheric forcing changes. These changes are being addressed by Panel 4. The ecological response will vary according to the conditions of water supply in the soil, which differ between different hydrological landscape units. As already indicated, it is however highly probable that the hydrological response addressed by Panel 3, will change first.

IGBP is interested also in the atmospheric response, expected to develop as a feedback when land ecology and hydrology changes through man's activities. That response is an issue raised in the draft program of Panel 3, stressing the need to study the geographical influence function of local surface changes, as well as changes in the water exchange and transfer processes.

IAHS wishes to recall that in modern hydrological theory[2] it has been hypothesized that the vegetation cover in a locality is the result of long term competition between the main plant groups for moisture and energy, as constrained by characteristics of the soil substrate and by nutrient availability, carried to the plants in and only in water solution.

Such theoretical considerations once again illustrate the extremely close link between Panels 3 and 4. One essential conclusion is that it is highly desirable, that ecologists and hydrologists get the opportunity to work close together in IGBP projects in order to be able to close the present gaps between their paradigms and to facilitate the general understanding of the total Earth system.

All the serve time, it is highly important for IAHS to make the hydrological community, which will sooner or later get deeply involved in managing the consequences of global change on hydrological systems and phenomena, interested at an early stage. For that purpose IAHS is deeply interested in supporting IGBP for instance by organizing symposia and workshops around crucial issues.

Hydrology and material fluxes

Overall, IAHS finds very little to disagree with in the Panel 3 program. The program however focuses very much in what has traditionally been called "Quantity" issues in the relationship between hydrology and the biosphere. Attention should also be drawn to problems of erosion and deposition. In particular, there are a number of very valid points raised by Panel 3 in connection with energy and water fluxes which apply with equal force to fluxes of particulate, sediment-associated chemicals and nutrients in ecosystems at global and more local scales:

a) there is a lack of basic measurements of sediment character, as well as sediment (including bedload), particle-associated and chemical transport by rivers in many parts of the globe. The amount of material arriving in the world's oceans in these various phases could be better quantified with further research efforts;

b) there is a need for the application of basic scientific research to further understand the physics of erosion and deposition processes, and the chemical principles which underlie the mobilization of solute species in dissolved and sediment-associated form

c) the uses of satellite imagery in sediment studies has a potential which is far from being realized

d) the interaction of vegetation with flow paths in specific ecosystems not only affects water balances but has very important implications for sediment and solute production

e) the impact of man through activities such as deforestation is felt as much on water quality as on water quantity, and local perturbations in quality can also be transmitted for long distances in a downstream direction.

In addition, there are a number of topics within "quality" research which seem to be very much concerned with the interface between the biosphere and hydrosphere and might be worth highlighting, eg:

1) biological factors and processes have a crucial role to play in determining physical and chemical erosion, and subsequent transformations of liberated materials

- vegetation is a strong determinant of soil erodibility and this influence needs further examination in critical areas such as sub-Saharan Africa

- biological processes help to prepare ground surfaces between hydrological events and make sediment available for removal in storms, and much more work is necessary to quantify these effects

- more focus is required on storage of nutrients in ecosystems which often represent a pool of material much greater that the annual loss in stream flow, and a steady state between vegetational uptake, cycling and release of elements cannot be assumed in drainage basins

- instream chemical transformations of materials during transport caused by biological agencies is an area worthy of further investigation

2) increasingly it is being recognized that erosional systems are complex and involve inputs, transformations, storages and losses, and there is a pressing need to quantify sediment and nutrient budgets for different climatic/vegetational regimes, including those areas of transitional climate and vegetation which are very sensitive to change; such quantification should ideally involve spatial delimitation of areas of erosion and deposition and how these relate to different vegetation at local and regional levels.

3) there is also a need to place erosional systems in a longer-time perspective, not only by encouraging synthesis of existing records but also by developing new techniques, eg studies of radioactive tracers and investigation of lake sediments, and thereby to definitively establish the effects of recent major land-use changes on this aspect of hydrosphere/biosphere interaction.

Problems from the point of view of glaciology

A number of problems regarding the interaction of the cryosphere with climate undoubtedly need attention in IGBP. As separately reported directly from ICSI through Professor Kotlyakov, ICSI suggests the inclusion in IGBP of a number of problems from the point of view of glaciology

1) Biospheric Interaction with Atmospheric Chemistry
   a) Observation and modelling of peak acidity in first snow melt-water;
   b) Catalytic reactions on surfaces of airborne ice crystals (e.g. ozone);
   c) Biogenic ice nuclei for atmospheric ice crystals.

2) Biospheric Aspects of Hydrological Cycle
   a) Interaction and evaporation of snow on vegetation;
   b) Reaction of vegetation to the varying storage and timing of release (snow and glacier melt processes) of melt water;
   c) Acidic shock effects of snow melt water on freshwater ecosystems;
   d) Influence of frozen ground (seasonally and permanently) on soil moisture regime growth conditions for vegetation.

3) Effect of Climate on Ecosystem Changes
   a) Methane release from previously frozen soils;
   b) Changes of Ecosystems by changing the thickness of the "Active Layer" in frozen ground;

c) Geomorphic and ecological consequences of changing snow, glacier and underground ice extents (e.g. debris flows, avalanches, erosional processes);
d) Reaction of ice edge ecosystems to changing sea ice conditions;
e) Effect of changing ice conditions (sea ice and ice shelves) on nutrient, and dissolved gas transport in the ocean through upwelling and downwelling processes;
f) Effect of changing ice conditions on light transmission in the ocean.

4) Understanding the Role of Marine Ecosystem Changes
a) Improved understanding of sea ice as a habitat and its role in marine productivity;
b) Understanding and prediction of glacially-induced sea level change because of its importance to coastal ecosystems.

Relation between IAHS/IAMAP proposals and IGBP

Two of the presented UGGI proposals are closely related to water, both proposed by IAHS and IAMAP jointly.

LAVIP addresses the interaction of human activities on the one hand, and the atmosphere and land surface processes on the other. These interactions are working both ways. On the one hand human activities modify land surface, producing consequences on the total Earth system via changes in water and energy budgets. On the other, climate change will produce consequences on life support systems and land use in different regions. The latter link provides a major argument towards the need to limit the climatic changes, now threatening the life support systems of certain regions.

Man being an essential component of the total Earth system, LAVIP provides an essential and supplementary perspective to the perspectives taken in IGBP. LAVIP would provide in important support to the diagnostic part in the Panel 3 proposal. Panel 3 proposes to assess the impacts on both surface processes and the atmosphere from man-induced changes of the atmosphere and the land surface respectively. LAVIP includes a way of observing land surface changes. There is therefore a close linkage between LAVIP and the Panel 3 programme.

The second IUGG contribution of relevance, the Hydrological pathway proposal stresses the need to study streamflow generation, flow paths of water in the ecosystem, solute concentration along various flow paths in the ground etc. What is proposed is micro- and mesoscale studies of the interaction of water supply pathways and solute concentration with vegetation. These phenomena are indeed basic in the interactions between soil, vegetation and the water cycle.

The hydrological pathway proposal, evidently concerns essential biospheric aspects on the hydrological cycle. It remains in an earlier stage of preparation than LAVIP. It mainly expands on the rationale for stronger focus on the role of hydrological pathways in supplying vegetation with water and nutrients, a perspective more or less absent in the Panel 3 program. It also indicates some activities needed in order to bring into a more explicit focus these pathways in the root zone. It is therefore evident that also this proposal is closely related and supplementary to the Panel 3 proposal.

In conclusion, both proposals add crucial components to the overall problem of understanding the processes regulating the total Earth system and developing capability of predicting future, mainly man-induced changes. IAHS and IAMAP should therefore be encouraged to develop the ideas of their contributions further. Possible IAHS contribution would be interdisciplinary workshops and symposia on issues of ecohydrological relevance. One theme of immediate interest might be the interaction between ecohydrology and landscape ecology.

Other UGGI programmes

UGGI is involved also in the planning of the ambitious and very timely global scale project GEWEX. GEWEX is a project of fundamental interest to the hydrological community because it addresses the core of hydrological phenomena involved in the crucial interactions between atmosphere, land surface and oceans focused also in the IGBP. The land surface components in the fully coupled comprehensive global circulation models discussed in that proposal are mainly

the same as those focused by IGBP Panel 3. The linkage is therefore very close between both programs. Consequently, GEWEX should be made maximum use of in the IGBP program, especially in view of considerable overlapping with the Panel 3 program. The GEWEX program brings out also land surface scale problems and the research problems of parameterization. It also stresses the need for meaningful experiments on both catchment scale and GCM scale.

Some further comments

Water consumption in biomass production

In early IGBP efforts, evapotranspiration was discussed as linked primarily to vegetation and stomata resistance. When reducing the scale of approach down from grid scale to catchment scale also water evaporation from moist surface has to be taken into account.

It is worth-while at this stage to bring attention to an effort (3) to relate the biomass production in various ecohydrological zones to the corresponding evapotranspiration. Combining zonal data, one comes out with the conclusion that there is a tremendous difference in total water consumption for biomass production in different main ecosystems. Part of that difference may perhaps be due to soil evaporation between the plants. Thus, in wet climates, the water consumption tends to be of the order of 200 m^3/ton biomass, whereas in dry climate it may be 1000 m^3/ton.

It may be quite interesting to see this difference from the aspect of increased agricultural development in semi-arid countries. The emerging question is to what degree such a non-productive evaporation loss might be made more productive through soil management efforts with the aim to increase infiltration. This would be an issue of major importance for the question of sustainable development of the dry tropics. If the water could be made more productive, in terms of biomass production, increased plant production would be possible to reach without tapping water, directly of indirectly, from the terrestrial water systems. It is easy to imagine the relevance of this issue in view of the widespread famine in already water stressed, semi-arid countries.

River runoff as ground truth

The IGBP envisages the coupling of river runoff to be used as ground truth for validation of GCM:s. It also envisages simplified water balance models. In the further development of these ideas, it is necessary to recognize the differences in runoff generation process between different hydroclimatic zones and the difference in information content of river runoff in arid and humid climate respectively.In the former case, the value is reduced by the high evaporative losses over seepage areas and water surfaces, but also by the fact that there may exist a deep groundwater flow, not drained by the rivers.

For this reason, hydrological research has to pay increased attention to differences between climatic zones. Hydrological differences are related not only to hydroclimatical differences but also to morphological regions, especially the differences in response to precipitation between flatlands as opposed to slopelands.

References

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(2) Eagleson, P.E. & Segarra, R.I. (1985): Water-Limited Equilibrium of Savanna Vegetation Systems, (Water Resources Research No 10, 1985, p 1483-1493).

(3) L'vovich, M.I. (1979): World Water Resources and their Future, (Translation by the American Geophysical Union) LithoCrafters, Inc, Chelsea, Michigan, p 250 ff.

ICL

Introduction

The Inter-Union Commission on the Lithosphere was established in September 1980 by the International Council of Scientific Unions at the request of the International Union of Geological Science and the International Union of Geodesy and Geophysics. It seeks to provide an improved understanding of the development of the Earth, especially those aspects on which human society for its well-being.

By its terms of reference as expressed in the subtitle of the International Lithosphere Program:

The Framework for Earth Resources and the Reduction of Hazards

ICL has the mandate to cooperate closely with the two international programs, International Geosphere-Biosphere Programme (IGBP) and the UN-Program of the International Decade of Natural Disaster Reduction (IDNDR).

There is growing awareness that the lithosphere is an integrated part of the earth as a system. The lithosphere is embedded in spheres surrounding it from below (asthenosphere, tectonosphere) and above (hydrosphere, atmosphere, biosphere), reacting and interacting with it.

ICL is presently preparing its science plan for the 1990s, redefining its program and reshaping its structure. Two of its proposed subcommissions will be directly related to the IGBP: "Paleoenvironmental Problems" and "Contemporary Dynamics and Deep Processes". They will cover those fields in which present day processes like volcanism dramatically effect the hydrosphere and atmosphere on a short time scale; the rich and comprehensive library of global changes is opened in the paleoenvironmental studies.

ICL will also establish a new Coordinating Committee "Geoscience Observatories" which should be closely linked to the Geosphere-Biosphere Observatories of the IGBP. The Federation of Global Digital Seismic Networks, affiliated to ICL, could with its observatories, its communication lines and its well established international links form the necessary infrastructure on which a net of Geosphere-Biosphere-Observatories can be built.

Existing (GPS) and developing (GLRS) satellite methods for positioning and remote sensing of events on the Earth's surface in real time are an essential observation platform for IGBP.

The ocean floor, also in the vicinity of mid-oceanic ridges, is entirely without permanent observatories. The availability of ocean bottom boreholes and transoceanic telephone cables is a unique opportunity to establish a network of permanent observatories at the ocean bottom with physical and chemical probes. At selected locations observatories should also be established in the shallows.

ICL-Coordinating Committee 'Data Centers and Data Exchange' can also offer its experience, as well as ICL-Coordinating Committees 'National Representatives' and 'Developing Countries' with its international communication links.

Under the present ICL-structure its Working Group 5 'Paleoenvironmental Evolution of the Oceans and the Atmosphere' has the closest and direct links to the IGBP.

The definition of the involvement of the solid earth sciences in the IGBP needs improvement. ICL is conducting an international conference "Geosphere Fluctuations: Short Term Instabilities in the Earth System" at Hamburg on 13-15 December 1988. In particular it will address the problem fluctuations in the mass energy fluxes.

The scientific rationale for this conference has been defined as follows:

"Geosphere Fluctuations: Short Term Instabilities in the Earth System"

Biosphere and geosphere are subject to changes because of natural and artificial processes and at variable time scales. While short and long term global changes of the biota have been

investigated for many years, short term variations of the geosphere of the system Earth have not been studied or understood, in particular not in a global perspective and in their impact on the future of mankind.

We live on a planet bathed in the solar radiation field and slowly cooling by conduction and convection. While some features of the system can be treated by steady state models, there are fluctuations in the mass energy fluxes. An obvious and dramatic type of fluctuations is revealed by the great ice ages. But as in all convecting systems, there is noise, which leads to phenomena like the little ice ages, the 100 year flood, desertification, Sahels, El Ninos, catastrophic ice motions ... To discern noise from short term systematic changes of the environment within the sciences of the solid earth represents a major and challenging problem.

As the human population moves towards 10 billion next century, and as the reserves of the human life support system are strained, the influence of even minor fluctuations of the earth system may reach catastrophic proportions.

This workshop will be devoted to an analysis of the sun-earth phenomena which influence the biomass and man, with particular attention to our knowledge of fluctuations on the scale of seconds to 1000s of years where geologic history tells us that the sun-earth phenomena have significant magnitude to be of great importance.

From the workshop discussions we expect important new insight into potential contributions of the solid earth sciences to IGBP.

IFIAS-ISSU-UNU

At the International Symposium on Human Response to Global Change held in Tokyo, Japan, September 19-20, 1988, the following objectives were adopted for the forthcoming "Human Dimensions of Global Change Programme":

"Dramatic, potentially threatening, and possibly irreversible change in the global environment results from past and present human activities. Such change leads to serious impacts on human conditions, with the risk of compromising prospects for life in the future. This body has therefore resolved to initiate an international research programme to investigate both the human causes and consequences of global environmental change. The objectives of the research programme are:

- To improve scientific understanding and increase awareness of the complex dynamics governing human interaction with the total Earth system;
- To strengthen efforts to study, explore, and anticipate social change affecting the global environment;
- To identify broad social strategies to prevent or mitigate undesirable impact of global change, or to adapt to changes that are already unavoidable;
- To analyses policy options for dealing with global environmental change and promoting the goal of sustainable development;

In pursuit of these objectives, the research programme will undertake several activities, including initiatives

- To undertake selected core research projects central to the purposes of the programme;
- To develop appropriate information systems and methodologies that will enable the execution of a research programme of this scope;
- To explore the ethical, cultural, and legal traditions and frameworks which underlie and shape the human aspects of global change;
- To propose procedures and techniques for assisting in the translation of research findings into policy-relevant terms.
- To promote educational efforts devoted to human activities having significant effects on the global environment."

Introduction

The Human Dimensions of Global Change Programme is being established as an international initiative to bring social scientists, natural scientists, and those involved in the management of human activities together in a set of research activities focussed on key areas of human interaction with the earth. The Programme has been under consideration from early 1987, and has now progressed to the point where initial activities can be outlined.

In this brief Report, the historical development of the Programme, its current status, and an outline of its proposed future development are presented. Particular reference is made to the deliberations of the recent Tokyo International Symposium on Human Response to Global Change (September 19-20, 1988). The Symposium was a culminating point of the process of preparatory discussions and meetings.

A series of advisory meetings has been held to help formulate the dimensions and possible content of a international programme in the human sciences. The first in this series of meetings was held in Toronto, Canada, in June 1987. This Toronto meeting was an "ad hoc" meeting, involving a number of international agencies and concerned individuals and organizations, called

to explore the possibility of providing a complementary programme in the human sciences akin to that being planned for the International Geosphere-Biosphere Programme (IGBP) by the International Council of Scientific Unions (ICSU).

The Toronto meeting determined that such a need existed, and an Interim Steering Committee, composed of the International Federation of Institutes for Advanced Studies (IFIAS), the International Social Science Council (ISSC), and the United Nations University (UNU), was constituted to continue the process. In the course of the next twelve months, a Secretariat was established, and workshops and consultative meetings were held as follows:

- "Managing Global Change" Workshop, sponsored by the Royal Society of Canada, held at: Hamilton, Ontario, Canada, June 1987.
- Workshop on an International Social Science Research Program on Global Change, sponsored by the U.S.National Science Foundation and Institute for Social Research, University of Michigan, held at: Ann Arbor, Michigan, September 1987.
- Interim Steering Committee Meetings, held at: Paris, France, and Milan, Italy, November, January, March 1987.
- Human Response to Global Change Programme Meeting, sponsored by Swedish Council for Planning and Co-ordination of Research, held at: Stockholm, Sweden, February, 1988.
- International Political Science Association Meeting, held at: Moscow, U.S.S.R., March 1988.
- Human Response to Global Change Meeting, sponsored by IFIAS, Center for Advanced Studies, Bariloche, CEUR, and IDRC, held at: Buenos Aires, Argentina, April 1988.
- Man-Society-Global Change" Meeting, sponsored by Polish Academy of Sciences, IFIAS, and IIASA, held at: Mragowa, Poland, May 1988.
- "Human Dimensions of Global Change: A Chinese-U.S. Workshop, sponsored by Chinese State Education Commission and U.S. National Science Foundation, held at: Beijing, China, May 1988.
- Resources for the Future Meeting on Controlling and Adapting to Greenhouse Warming, sponsored by RFF, IFIAS, and others, held at: Washington, D.C., June 1988.

These meetings, and other efforts, have contributed to the shaping of the Programme, and the submission of topics form interim review at the Tokyo Symposium -- all ultimately advisory to the work of the Interim Steering Committee.

In addition to these meetings, the Steering Committee, assisted by an Interim Secretariat (housed at IFIAS/Toronto), has begun to create an interim programme structure, and to assist in the development of the programme initiatives.

Programme development

The primary impetus for this new Programme is the recognition that environmental changes have now reached a new level of global complexity; and that there is a need to cope at a more comprehensive level with the human interactions that are helping to shape those changes. One response is this effort to mobilize elements of the international human sciences community -- and other concerned parties -- to undertake jointly the analysis, understanding, and evaluation of human dimension of global change. This, in turn, derives from the strong belief that the human sciences are now prepared to undertake the kind of international research programme that has characterised the physical sciences (e.g. the International Biological Programme, 1960-70).

Major programme themes

The Research Programme itself is conceived of as being of two kinds, core research and affiliated research. Core research will be funded, at least in part, by the programme itself, while affiliated research will be comprised of selected projects contemplated or already in operation at various national, international, or institutional levels. It is assumed that Working Groups to elucidate aspects of the programme will be established, and that they will determine research based on certain criteria, including interdisciplinarity, long-term perspectives, linked to global change processes, complementary with IGBP projects where appropriate, and also policy-relevant where appropriate. Efforts will also be made to direct the research to the general public and policy community, as well as to the scientific and research communities.

Major themes of the proposed programme are, in part, reflected by the Working Groups that were constituted for the Tokyo Symposium, since they derived in turn from the directives and suggestions of the planning process up to Tokyo. To state these in general form, it is clear that to begin with, an appropriate conceptual orientation and appropriate framework for the fundamental interactions between humanity and the environment is required, together with a compatible structure for considerations of global modelling and the integration of data needs and methodologies. Particularly important in understanding the relationship of these general themes with more specific aspects of global change is an examination of economy-environment interactions, especially with regards to human industry in all its forms, or industrial metabolism. All these interactions are shaped in part by implicit ethical and cultural norms and values, as well as by explicit legal norms and institutions, science and technology policy, and general social descisionmaking processes that can be studied by policy analysis.

Of special concern at the present time are issues of industrial restricting, equitable development, and concern for the present and future needs of the most vulnerable among the world's peoples. These issues, combined with others, require the application of new methods of risk assessment to determine those areas that are the zones most sensitive or vulnerable to hazards. At both the global and the local level, one of the most pressing potential risks is the prospect of climate change, which will likely express itself in its earliest and most explicit form as gradual sealevel rise. Here, as elsewhere, a major focus of concern is in the alteration and degradation of those areas that are common to all humankind, including the globe itself, which ought perhaps to be regarded as the ultimate global commons.

Within this broadly thematic view of the problems and issues at stake, the Working Groups at the Tokyo Symposium proceeded to identify areas of special research priority that ought to be undertaken in some form by the new Programme. These will be presented in fuller form in the Report of that meeting, currently in preparation.

Current and future activities

At its first meeting subsequent to the Tokyo Symposium, the HDGP Steering Committee agreed upon the following:

- The interim Secretariat will prepare a budget for 1988-9 and 1989-90, assuming at least $300,000.00 available annually;
- The interim Secretariat will prepare a Funding Proposal for consideration by the Steering Committee and a subsequent Donors Meeting;
- Steps would be taken to arrange an informal Donors Meeting at the earliest opportunity;
- A Scientific Advisory Committee, composed of distinguished scientists appointed in their own right, would be established;
- The results of the Tokyo Symposium would be made available in the following formats: (i) Status Report; (ii) Symposium Report; (iii) Selected papers would appear in a forthcoming issue of the International Social Science Journal; (iv) A special issue of the UNU Newsletter; (v) IFIAS News; (vi) book format, published by UNU, in association with IFIAS and ISSC.

- Preparations for future consultative meetings would be undertaken.

Proposed meetings now include:

(1) Hungary - April 19-20, 1989 (Energy)

(2) Netherlands - May 1989 (HDGP in Western Europe)

(3) Moscow - Spring 1989 (Modelling and Data)

(4) Oslo - May 1990 (International Symposium).

IGU

Introduction

The IGU contributions are coordinated by the IGU/IGBP committee (chair: H.TH. Verstappen, the Netherlands) mentioned in report 4, Appendix 6, p.185. The present activities concern: Global data base planning, monitoring/forecasting environmental degradation, natural Hazard surveys, coastal/sea level rise studies, resource system and environmental management, human response to Global Change and recent climatic change. They are related to various aspects of the IGBP and are implemented by the following groups:

IGU activities related to the methodologies of igbp working groups 1-4.

Modelling - WG 1

Commission on mathematical models (chair: M. Fischer, Austria) re: IGBP-WG.1. Task: International Exchange of emerging concepts, models, theories and quantitative techniques in analytical geography. Joint research programmes emphasizing common theoretical and methodological themes such as dynamic self-organizing systems and discrete choice processes.

GIS - WG 2

Commission on geographical information systems (chair: M.D. Lyew, Costa Rica) re: IGBP-WG.2. Task: to promote inter-disciplinary activities of spatial data handling through meetings, publications and training programmes and to promote the critical elements of the scientific infrastructure required for applying GIS technology. A high-level meeting was organized in part with ICSU funding in May 1988 in Newcastle-Upon-Tyne (U.K.) by R. Tomlinson, Canada, on the topic of Global database planning.

Data of past - WG 3

Study group on historical geography of Global Change (chair: to be decided) re: IGBP-WG.3. Task: research on anthropogenic factors in the evolution of the geobiosphere and the creation of historical geographical databanks on the evolution of man-affected natural geosystems with the aim of forecasting landscape changes for the purpose of planning and management.

Monitoring - WG 4

Commission of geographical monitoring and forecasting (chair: S.A. Eevteev, USSR) re: IGBP-WG.4. Task: Advancement of monitoring and forecasting. Selection of optimal sequence of observations of multipurpose geographical analysis and prediction of the state of the environment, interpretation of the trends in the development of regional situation and of their place among ecological problems of global significance.

IGU activities related to environment and geo-biosphere interactions.

Geomorphology

Commission of measurement, theory and application in geomorphology comtac (chair: A. Schick, Israel). Task: Comparative research aimed at integrating empirical an theoretical approaches in geomorphology.

Commission on frost action environment (chair: J.P. Lautridou, France) Task: study of frost action processes and the resulting landforms and sediments. Palaeogeographic reconstruction of the cold environments of the quaternary.

Commission on coastal environment (chair: R. Paskoff, France) Task: the study of long-term and short-term coastal change and the physical and human components of this environmental system.

Geoecology

Commission mountain geoecology and resource management (chair: J. Ives, Canada)
Task: Study of land and resource conflicts in various mountainous regions of the world.

Study group on rapid natural hazards (chair: C. Embleton, U.K.) Task: To undertake a series of case studies of particular hazards in diversified environments: including an assessment of their relative magnitude and frequency and the production of hazard maps on an internationally agreed basis.

Hydrology

Commission on water resources and management (chair: A. Hermann, FRG)
Task: To be reformulated.

Climatology

Commission on climatology (chair: M. Yoshino, Japan).
Task: A. Tropical climates, including atmosphere-ocean-land surface interactions: topical and extra-tropical climatesystems and feed-back system with evolution of the physical environment.
B. Recent climatic changes, including modelling, circulation systems, analysis of satellite data, impact of man-induced processes.
C. Topoclimatological research and mapping, including study of local climates, energy and moisture exchange on earth-atmosphere interface, etc.

Oceanography

Commission on marine geography (chair: A. Vallega, Italy) Task includes:
The development of marine zones of coastal states and the specific problems of semi-enclosed seas.

Both the methodology contributions and the environmental contributions are considered important. The most interesting geographical work can be expected from those groups having a broad inter disciplinary scope and emphasizing the man-environment interactions.

The draft IGBP programme

Comments to IGBP report 2, 3 and 4.

The objectives of the IGBP are to describe and understand the interactive physical, chemical and biological processes that regulate the earth system ... and the manner in which they are influenced by human action (report 2, p.2). The reports and coordinating panels reveal that strong emphasis is on physics and (bio)chemistry which is probably inspired by spectacular issues such as the ozone hole and the green house effect (CP 1+2). This, however, somewhat resembles a doctor trying to cure the symptoms rather that exploring the causes of the disease, which in this case is the stressed geobiosphere ecosystem, particularly the terrestrial past of it. This is insufficiently represented in CP 3 (biospheric aspects of the hydrological cycle) which should be broadened to cover: geobiospheric aspects of terrestrial ecosystems and concentrate on landscape ecological equilibria. CP 4 deals with the effects of changes in terrestrial ecosystems but then should not be restricted to climatic change but also include human perturbation. This would concord with the underlying themes B-III and D-I (pp.3-4, report 2). Generally the abiotic aspects of global have been underrated compared to biotic aspects although the balance is probably better than it first appeared (see E.G. report 3, p.5 ISRIC Workshop). The anthropogenic aspects are, however, very weak indeed. One may argue with justification that inclusion (on the CP level) of the study of the complex antroposphere-geobiosphere interrelations would intolerably complicate the programme and are beyond the scope of ICSU. However, it is essential that on the operational (W.G.) level the effects of these interactions in terms of landscape and land use changes should be properly incorporated in the programme. This concerns the WG's 3 and 4 but, in view of the special methodologies involved and as to establish an efficient link with the HDGC programme, it seems preferable to establish a separate WG-5 for this purpose.

It is remarkable that the anthropogenic influences included in figure 3.1, p. 14, report 4 have already been left out on the figure of p. 19 of that same report.

Additional suggestions

It follows from the comments to reports 2, 3 and 4 (heading B) that the IGU considers the element of human perturbation of the geobiosphere insufficiently stressed in the programme and it thus proposes to establish a working group for this particular aspects in concordance with the underlying themes of IGBP B-III and D-I and the objectives of IGBP specified on p.2 of report 2. And in order to link with human dimensions of Global Change programme, another suggestion is to add the UN decade on natural hazard reduction to the listing of appendix 2, p.136, report 4.

Priorities

Leaving apart the views expressed on the general concept and philosophy of the IGBP the IGU considers the (II) efficient structuring of the programme through modelling and data and information system and (II) the selection of the proper data input, as the two major priority areas. The IGU commissions and study groups mentioned in the introduction can contribute to the programme in the following manner:

- Modelling, through its commissions on mathematical models and climatology;
- Data and geo information systems, through its commission on GIS (already implemented);
- Environmental data extraction of the past, through its commissions on: historical geography of Global Change and on geomorphology (Comtag, frost action, coastal environment).
- Geo-biosphere observatories, through its commission on geographical monitoring and forecasting, geomorphology (comtag, frost action, coastal environment), hydrology, geoecology (mountain geoecology, rapid natural hazards), hydrology and oceanography. The programmes of these groups for the period 1984-1988 have been specified and some activities scheduled for 1989 have been submitted to ICSU for support.

The IGU holds the view that activities of broad multidisciplinary scope in the area of natural environment and particularly the man-environment interactions should be the focus of its attention and it will concentrate its own input in IGBP in this area. This concords with p. 14, report 4 where the IGBP recognized the: 'needs to consider the full range of anthropogenic activities that have contributed and are contributing to Global Change. Land use for example ... can be assessed through studies on current conditions and historical and proxy records'. These views are also translated in the Plan for Action (pp. 39). Several other sections of the plan for action (report 4) also open vistas for IGU cooperation such as 4.2.2 (p. 23/23) where mention is made of 'the effect of rare climatic events' which may be an opening for hazard surveys such as desertification, flooding, mountain hazards, etc. Also 5.4 (p. 57/67) where the 'effects of climatic change on landscape and soil' are mentioned further entrees for physical geographers exist.

IIASA

Introduction

IIASA, the International Institute for Applied Systems Analysis, is a nongovernmental, interdisciplinary research organization founded in 1972. Among its most relevant objectives are the initiation and support of individual and collaborative research on problems associated with environmental change, and thereby to assist scientific communities throughout the world in tackling such problems. The Institute's sixteen national member organizations, located in eastern and western Europe, Asia, and North America, are scientific and professional bodies, rather that political ones. The Institute is particularly suitable for bringing together the appropriate personnel to solve scientific research problems involving east and west.

The present IGBP activities at IIASA are centered on the Environment Program, led during the previous three years by R.E. Munn, presently being succeeded (1 November 1988) by Dr. Bo Döös. The program includes a group of 25 research scholars working on three designated projects plus ad hoc activity groups. The projects concentrate on management of large international rivers (International Water Resources Project), modeling of European Acid Rain distribution (Traceboundary Air Pollution Project), and ecologically sustainable development of the biosphere (Biosphere Project). The ad hoc activities include studies of environmental monitoring strategies, and of European future development.

The Biosphere Project devotes a significant portion of its effort to IGBP-related research activities. IGBP-related activities at IIASA are of two kinds; coordinating and assisting in the activities initiated by other IGBP groups (limited thus far to hosting or cosponsoring meetings), and developing research products within IIASA which are aimed at furthering IGBP goals. Among the activities for 1988-89 are the following:

A. Hosting or Cosponsoring Meetings with IGBP

1. Proposed meeting of the IGBP Working Group on Geosphere-Biosphere Observatories. Along with the Polish Academy of Sciences, IIASA has offered to cosponsor and to host this meeting, which is to examine the relationships of Global Biosphere Observatories to existing national, regional and global monitoring systems.

2. Proposed meeting of the IGBP Coordinating Panel on Effects of Climate Change on Terrestrial Ecosystems. IIASA's Biosphere Project is interested in hosting this meeting during the second half of 1989. The meeting would be designed to define the integrated hierarchical modeling structure which will best achieve the IGBP objectives for predicting structural and functional characteristics of global vegetation change.

B. Developing Research Products within IIASA

The Biosphere Project initiated a study of global vegetation change in 1987. Funded in part by the Alfred P. Sloan Foundation and the U.S. National Science Foundation, the study is aimed at generating a mathematical model of global vegetation, including agriculture, as defined by the forces which control and change vegetation. The model is being designed to illustrate the geographical consequences of changing climate and land use, based on plant responses to environmental variables. A primary objective of the study is to provide for IGBP a pilot project based on available data and modeling approaches. This exercise would help define the full scale research program on global vegetation change for inclusion in the Global Change Program, at the end of its current three-year planning phase.

A group of advisors (not necessarily the committee of the whole) meet as needed to examine the assumption, review the progress, and advise on the problems of the vegetation change studies. The Global Vegetation Change Advisory Committee at IIASA presently includes the following individuals:

Dr. William R. Emanuel, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN, USA

Prof. C.S. Holling, Department of Zoology, University of British Columbia, Vancouver, BC, Canada

Academician V.M. Kotlyakov, Director, Institute of Geography, USSR Academy of Science, Moscow, USSR

Dr. I. Colin Prentice, Institute of Ecological Botany, University of Uppsala, Sweden

Prof. Thomas Rosswall, Swedish Royal Academy of Sciences, Stockholm, Sweden

Prof. H.H. Shugart, Jr., Environmental Sciences Department, University of Virginia, Charlottesville, VA, USA

Dr. Brian H. Walker, CSIRO, Division of Wildlife and Ecology, Canberra Australia

The research as presently construed, consists of five distinct activities, two of which have been completed at this writing.

1. Initial Meeting

The project began with a meeting of 65 invited participants at IIASA in April 1988. The meeting objective was to examine the requisite processes, data sets, and approaches to modeling global vegetation change from available information. The meeting brought together the principle and potential contributors to the project: model users including IGBP leaders who will observe, advise on, and assimilate from, the entire project as it unfolds, and the scientists who either delineated ecologic-biospheric relationships relevant to model characteristics, or contributed to model construction. The meeting included several individuals representing each of the following areas of concern: model applications in analyzing environmental and policy issues; climatic, soils, and tropospheric compositional determinants of crop and ecosystem geography; physiological constraints on vegetation response to environmental change; vegetation and land use classification systems applicable to modeling; remote sensing and mathematical modeling approaches to understanding vegetation change.

The meeting results are being summarized, and will be detailed in a monograph outlining the function of the global vegetation modeling system and therefore, how it will be used, and by whom; the salient vegetation responses to climate and soils which must be incorporated; the land use and soils effects and responses to be included; the geographic climate data sets and classifications available; the modeling approaches which are most appropriate for the task; and the nature of the model interfaces with its prospective users. The document will provide specific recommendations on the data collections and process understanding which is required to build valid global vegetation models. More locally, the ideas in the document have defined the approach to eventual attainment of the modeling objective at IIASA and will define the working groups needed to tackle the individual sub-tasks.

2. Summer 1989 Workshop for Model Development

The results of the April meeting at IIASA will not be available in final form until at least January 1989, but the ideas expressed there provided the basis for developing an initial global vegetation model. Eight ecologists and modelers and six graduate students spent much of the three summer months of 1988 at IIASA, developing a global vegetation model. The senior scientists included:

Dr. Gordon Bonan, NASA, Greenbelt, MD, USA
Dr. William R. Emanuel, Oak Ridge National Laboratory, Oak Ridge, TN, USA
Dr. Sandra Harrison, University of Uppsala, Sweden
Mr. Janos Hrabovszky, Vienna, Austria
Dr. Michael Korzhukin, GOSKOMGIDROMET, Moscow, USSR
Prof. I. Colin Prentice, University of Uppsala, Sweden
Dr. Thomas Smith, Australian National University, Canberra, Australia
Mr. Michael Ter-Mikaelian, GOSKOMGIDROMET, Moscow, USSR

In addition to the established scientists, three Biosphere staff members (Allen Solomon, modeling coordinator; Victor Targulian, global soils transformations; Ferenc Toth, GIS techniques) and six graduate students in the IIASA Young Scientist's Summer Program (YSSP) worked within the group. The six students, who possess strong biological and modeling backgrounds, were drawn from different countries (Bulgaria, Finland, France, Sweden, USA, USSR), providing a wide range of experiences and approaches to problem-solving.

The result of the interactions among these 17 workers, plus interactions involving frequent, shorter-term visitors to the project, is the initial development of a state-of-the-science climate and soils-dictated, geographically-explicit global vegetation model (Universal Vegetation Model, or UVM). The model is being constructed hierarchically, with an overall comprehensive global framework of environmental "cells", within which more precise and explicit models will generate monthly and annual dynamics at a landscape scale; these models in turn, are to be based upon spatially explicit, stand-level models of behavior of plant functional types. The critical and non-trivial aspect of the work will be realistic treatment of transient vegetation responses to non-linear changes in environmental (i.e., climate, land use) forcing. The output of the summer's efforts includes a description of model approach and the activities involved in its preparation (for Spring 1989). The modeling group will meet in November 1988 to evaluate 1988 efforts and to plan future work.

3. Summer Workshop for Continued Model Development

The model approach developed in summer of 1988 is to be fabricated into a functional model and subsequently formatted to produce output in a Geographic Information System (GIS). The current timetable would complete this task by the end of summer 1989. The participants of the summer 1988 workshop are working through the fall 1988 and spring 1989 on the project to complete the prototype model, primarily at their home institutions. Another summer-long workshop in 1989, including both ecological modelers and selected graduate students, will be aimed at completing and testing the prototype model. The current plan is to invite to IIASA, individual scientists who specialize in the regional vegetation of specific regions of the world. They will each be involved in one of a series of verification exercises in which we model modern vegetation in their region of specialty. Their verbal and written description of the model shortcomings revealed by the exercises will be the basis for consequent modifications of the model. This iterative process during the summer will be followed by synthesis activity in fall 1989.

4. Policy Exercises

The application of the model prototype will include a series of three workshops designed to bring together IGBP leaders, policy analysts, decision-makers, and scientists. The workshops will be highly structured, based on our continuing development of the "policy exercise". These workshops are based on free-form and operational gaming techniques, and are designed to induce interactions between academics and policy makers, or indeed, between other groups which share the same problems but not the same concept of the problem nature and solution.

We expect to run three separate meetings of 3-4 days each, during September, October and November 1989. Each workshop will include about 10 participants, none of whom will attend more than one exercise. The format for each workshops will be the same, with environmental change scenarios constraining multiple runs of the global vegetation model, and with participants working through the conflicts in resource distribution and utilization represented by the model output. The results of the workshops should differ depending upon the group dynamics, and should provide a rich assemblage of comparable and contrasting responses to the problems presented. The results of the workshops will be analyzed by study leaders during fall of 1989. The results of the work will be synthesized in the form of a book describing the consistency of policy exercises, and their implications, i.e., policy implications of the workshops in the context of the vegetation change project.

5. New Directions in Global Vegetation Change Studies

The work on global vegetation change is leading us to consider development of a related study on global soils change. Specifically, our concern with multi-decadal and centennial lags in vegetation response to climate change brings us to concern with the consequent transient

responses by soils to vegetation change. Until now, many of us viewed the critical control on vegetation densities and dynamics exerted by soils as essentially constant. Some investigators, after careful consideration, still holds the view of relative constancy in soil feature, for example, as expressed on page 58 of IGBP Report No. 4. However, it seems increasingly clear to us that certain critical "rapid" soil responses (change in soil fertility, change in soil acidity and salinity, change in humus, structure and texture of surface horizons, and so on) will parallel or lag the vegetation and climate change, with approximately the same time constants as the vegetation transient responses. These vegetation-soils-vegetation and climate-soils-vegetation-climate feedbacks must be recognized and at least coarsely defined for effective modeling of global vegetation change. By cooperating closely with the International Soil Reference and Information Center (ISRIC), we hope to develop a plan for meeting the IIASA needs in global soils change study, and to examine this plan at a workshop on linked changes in global vegetation and soils which we tentatively expect to hold during mid-year 1989.

II The draft IGBP Programme (IGBP Report numbers 2, 3, 4)

We have no substantive comments on the IGBP planning documents (IGBP Report Nos. 2-4). The documents provide a carefully assembled and clearly state set of ideas and ideals, all of which are laudable, particularly as a beginning for the planning process. We expect that production of a plan for conduct of specific research projects during the 1990s will correct even the minor deficiencies. Among these, IGBP planners may wish to examine the comprehensiveness of the action plans advocated by coordinating panels. For example, Terrestrial Biosphere-Atmospheric Chemistry Interactions is very meticulously and logically planned. However, it currently is being planned essentially to examine the effects of the biosphere on the atmosphere. We noted, however, that the remainder of the "interaction" is of equal or greater significance to the Geosphere-Biosphere system, and to the future of human life on the planet. For example, the uncertainties in the nature of effects by atmospheric chemistry on the biosphere are so great that it is presently impossible to quantify the global carbon cycle (effects on plants of CO_2 "fertilization") let alone in the future. It is also impossible to determine the future presence or absence of forests in developed countries (atmospheric pollutant effects on plants). These are neither scientifically trivial nor functionally unimportant to the biosphere.

As another example of the need for a more comprehensive treatment, we suggest that the detailed concepts behind the plans presented on Effects of Climate Change on Terrestrial Ecosystems are expressed so succinctly that they comprise more of a final, rather that an initial, working proposal. Yet, effects of climate change are only one of several kinds of extrinsic pressures which will be operating to transform global terrestrial ecosystems. Land use changes and related soil and hydrological changes certainly could be more important than climate change in the low-latitude rain forests, and perhaps, more important that climate change elsewhere as well (e.g., Clark et al. 1986, in OIES-2, UCAR, Box 3000, Boulder, CO). Changing atmospheric chemistry (see above) could quickly surpass climate change in importance as a determinant of vegetation in many places.

Similar considerations could be applied to the other plans for working groups and coordinating panels, provided in IGBP Publication No. 4. We believe that despite its overall strength, the IGBP program could profit from a review of the plans, even if such a review only identifies already-functional or proposed programs which will fill in the few remaining gaps.

III Additional suggestions

The planning has been quite extensive and well-conceived, up to this time. In broad outline, as well as in detail, the IGBP research approach and expected implementation appears to be very sound. There seems to be surprisingly few earth processes in the "Earth Systems Science", a phrase applied to the Global Change Programme in the U.S. Also, we find little reference to understanding the critical role of microbes and insects in biospheric functioning at all levels. However, we recommend additional consideration in only one area of earth science, that of global soils which form the terrestrial Geosphere-Biosphere interface. The report by the Coordinating Panel on Effects of Climate Change on Terrestrial Ecosystems suggests variables which could be measured for IGBP activities in effects of climate change in forcing soils

changes, but the objectives appear to apply only insofar as soils constrain the construction of predictive vegetation models. The Coordinating Panel on Biosphere Interactions with the Hydrological Cycle advocates research on vegetation-soils interactions, but without specific proposals. Similarly, the Working Group on Techniques for Extracting Environmental Data of the Past discusses specific, focussed problems (permafrost soils changes, soil erosion), but proposes not research on the topic. The issue of soils change, including the main functions, interactions, linkages and feedbacks associated with the world soil cover (the pedosphere) are significant phenomena to be considered in attempts to attain all major objectives of the IGBP. We believe the issue requires more holistic and comprehensive treatment than that which it is presently accorded.

The pedosphere contains the most intensive and heterogeneous interactions between biotic and non-biotic elements. Indeed, global physical, chemical and biological processes are linked at many time and space scales, and through fluxes of many kinds of matter and energy in the pedosphere. In short, the pedosphere regulates most important atmospheric, hydrospheric, biotic, and anthropogenic processes on the land surface. To carry out the basic IGBP aim of describing, understanding, and forecasting the interactive earth system processes, particularly the processes in terrestrial systems, it is essential that we study global soil change.

The issue is to define and quantify the role of the pedosphere within the geosphere-biosphere system. The high functional, structural, spatial and temporal complexity of the pedosphere has been recognized by soil scientists for several decades. It is now clear that soils are organized and structured natural entities in their own right. The following polyfunctional nature of soils requires their consideration by IGBP:

1. Soils ar the main source and sink of moisture and nutrients for autotrophic plants and thus, the medium for all life. They define human activity in agriculture, forestry, construction and habitation. Without knowledge of the natural and human induced changes in properties of global soils, the IGBP objective of understanding the role of human activity in changing the earth system will be stymied;

2. Soils form the terrestrial carbon sources and sinks of most significance to, and of greatest uncertainty in, the global carbon cycle. Without the understanding required to predict future behavior of this central biogeochemical cycle, even the most fundamental IGBP goals will not be realized;

3. Soils are the planetary feature which redistributes (transforms) atmospheric precipitation into different terrestrial water fluxes (infiltration, surface and underground horizontal flows). Soils are the main sources of soluble mineral and organic components and suspended particles in terrestrial and aquatic water fluxes. Without knowing the changing stratification of chemical composition and water permeability of soils, we cannot understand the global changes in biotic and non-biotic geochemistry of the water fluxes.

4. Soils are an organized, horizontally and vertically layered, structure of the land lithosphere. Without an understanding of the differing sources, magnitudes, kinds and rates of change within the vertical structures or from place to place geographically, models which purpose to link geosphere, biosphere and atmosphere, or to link biosphere and atmosphere in a valid way, cannot be successful;

   a. Soils result from a subaerial in-situ process of solid land substrata transformations by atmospheric, hydrologic, biotic and anthropogenic influences over time, requiring comprehensive rather than piecemeal approaches to understanding soils transformations;

   b. Soils result from many interactions of biotic and non-biotic (physical and chemical) processes, the study of which is of greatest priority to the IGBP.

The soils are at once, the most inert component of the terrestrial ecological systems, and the most dynamic component of terrestrial geological systems. They form the reactive surface where all other processes and forces, including human activities, interact, forming new and unique features on all time and space scales. The reactive pedospheric system is a self-organizing natural superstructure of increasing complexity over time. Transformations of the pedosphere, both functional (regimes of warmth, moisture, nutrients and gas exchange) and structural

(changing profile characteristics of profile texture, humus content, structure, mineralogy, and so on), strongly influence the current and future functioning of the terrestrial biosphere-geosphere system. The soil system regulates and redistributes almost all fluxes of matter and energy through the biogeochemical cycles of the earth.

Soil profiles and soil cover are also the vertical and spatial blocks of memory of past atmospheric, hydrological, biotic and lithospheric interactions. These profiles record the complex combination of the stable properties of pre-Pleistocene and Pleistocene litho- and pedogenesis, the evolving properties of Holocene pedogenesis and the more recent human induced soil transformations. Pedologists are rapidly learning to unravel the information recorded in soils, in part with new and evolving methods (radiocarbon dating, lichenometry, amino acid racemization, and so on), and they will make considerably more progress during the expected lifetime of the IGBP. The delineation of such soil-memory information is of great importance because defining past, present and future global soils change requires the distinction among

1. Properties acquired from former stages of natural soil evolution which are completely nonrenewable when they are destroyed;

2. Properties of the latest stage of natural soil evolution in situ (mainly in the Holocene); and

3. Properties induced by different stages and types of human use of the soils.

The need is to understand the main factors, processes and results of the spatially and temporally distributed pedosphere transformations in:

1. The natural environment during the Pleistocene and Holocene time of soil formation and evolution;

2. The anthropogenic effects on soils which exist now and have envolved since human exploitation of nature and soils began;

3. The future changes in the soil cover of the earth, due to changing climate, vegetation and human use of the pedosphere.

Without knowledge of the main spatial and temporal transformations induced in soils by natural processes and human activities, we can never accurately predict the interactions and changes in components in the geoshere-biosphere system, or of the interactions and changes in components in the geosphere-biosphere system, or of the whole system. For this reason, we recommend that the Special Committee of the IGBP consider adding the above-enunciated soils considerations to appropriate coordinating panels, or that the Special Committee consider forming a separate coordinating panel on global soils transformations.

IV. Priorities for an IGBP

IIASA has no preferences for priorities other than those which follow logically from the IGBP research activities which are finally approved.

In the context of the Global Change research programme, the world's soil mantle may be seen to constitute a special facet or subsystem: the pedosphere.

Soils are rooting media and sources of bio-production and therefore key components of life support systems. They are also sinks and sources of biogeochemical elements and membranes or filters for pollutants. Soils however are also organized and structured natural entities in their own right, constituting a mosaic of small reactors where other spheres interrelate and form something new and unique. The end-products are relatively stable, and form blocks-of-memory of past atmospheric-hydrologic-lithospheric-biologic interactions. At the same time these archives are liable to change, gradually or abruptly and partly irreversibly, under human influence of varying type and intensity.

The world's soils therefore deserve adequate attention, notwithstanding the fact that they are difficult to describe and to classify from a purely scientific point of view (forming a continuum in space and time, and being neither dead matter nor fully living bodies with self-reproducing capacity).

It is recommended to study, through actual measurements and modelling:

a) The long-term dynamics (natural and man-induced) of the major pathways of soil development.

b) The shorter-term dynamics of the end-products of soil formation, i.e. the major soil types of the world.

For the former, the creation of biosphere observatories (GBO's) and of megatransects, in combination with Man & Biosphere reserves, would constitute a convenient framework. It is hoped that reference soil sites can be identified at these GBO/transects that are representative of the major soils of the world. Guidance for the identification of major soils will be the 1:5 million FAO/Unesco soil map, any updated version of this map, the 1:1 million digital soil and terrain database now in preparation through the ISSS-SOTER programme, and any recent national soil maps.

The shorter-term dynamics can be studied partly in the framework of UNEP/FAO/Unesco programmes for the assessment and monitoring of status and risk of the various forms of human-induced soil degradation (erosion, aridification, salinization, acidification, compactation, nutrient depletion) or transformation (organic matter enrichment, intensive fertilizing, empoldering, paddy field construction etc.) A first global assessment, at an average scale of 1:10 million, of the status of human-induced soil degradation will be available early 1990 from UNEP, through an ISSS-ISRIC project presently in execution.

There are however a number of specific IGBP-related soil studies that should contribute to the development of interactive models of soils-vegetation-atmosphere system. Some of these studies are:

1. The study of soil-related environmental data of the past (using thin layer diagrams with radioactive tracer elements) to reveal the mode of formation of soils and soil crusts (pedolites), and to verify assumed mechanisms of soil forming processes and factorial influences. Such studies would support the preparation of paleopedomaps as proposed by INQUA.

2. The effect of future climatic change on trends in soil development through long term monitoring at soil reference sites, and the recording of the instantaneous effect of single events (for which the frequency may or may not change with over-all climate change).

3. The contribution of the different soils of the world, their vegetative cover and their animal life, to the production of greenhouse gases (CO_2, CH_4, NO_x), including a study of the microbiological processes involved.

4. The influence of physical properties of bare topsoils on albedo and evaporation; and the calibration of soil surface features in general with remotely sensed observations.

5. The effects of intermediate term anthropo-technogenic influences on major soils - through the commencement or continuation of long-term soil fertilizing and tillage trials, or through the tracing and quantification of past human-occupational influences on soils; the classification and geographic delineation of the various anthropo-technogenic influences is a prerequisite.

6. The changes taking place in soil organic matter in major soils (content, vertical distribution, composition, colloidal activity) under the influence of human activity - with special reference to the low-activity clay soils of the tropics (cf. IUBS-TSBF programme) and the chernozemic steppe soils.

7. The influence of the various forms of atmospheric dust on the properties of soils of relevant areas.

8. The influence of acidifying (bio-) industrial components in precipitation on the properties and processes of soils of affected areas.

9. The pathways of organic, metallic and radio nuclide pollutants in major soils, as well as the role of natural geochemical elements (geo-pedomedical reference studies)

10. The sensitivity (or "tolerance") of the different soils of the world to any climatic change as regards their main soil formative process: identification of "ecotonal" soil mantle situations (fragile lands).

11. The effect of increasing sealevels on low-lying coastal soils - including their production of greenhouse gases.

12. The effect of climatic change on soil moisture and soil temperature patterns, and hence on spatial patterns of agriculture (rainfed and irrigated), forestry and fisheries; the changes in the total world production potential of food, fiber, fuel and timber.

13. The spatial extrapolation of the results of the various SCOPE-initiated studies on biogeochemical element cycles (N, S, P, C) in relation to the world's differences in soil mantle composition.

14. The long-range effect of net nutrient-pool transfer from the atmosphere (N, S) and from the lithosphere (P, K) into the pedosphere because of increased agricultural production - as well as the countereffect of nutrient loss through local loss of organic matter (tropical deforestation, peatland cultivation etc).

It should be obvious that many of the above studies should combine terrain observations with modelling, as well as subsequent testing/verification of such models. Further and more specific suggestions for soil-related IGBP studies will emanate form two forthcoming meetings cosponsored by the ISSS Committee on International Programmes:

a) "Soils and the Greenhouse Effect" (ISRIC, Wageningen-Holland, August '89)

b) "Global Soil Dynamics in a Changing Environment" (probably at UNEP, Nairobi, Kenya, February 1990)

The 14th General Congress of ISSS in Kyoto-Japan, August 1990, will moreover try to orient the activities of its existing scientific (Sub)commissions and Working Groups towards IGBP goals. This may for instance involve a systematic analysis of the spatial macro and micro variability of the world's soil - contrasting the effects of "accidental" biological influences (from man, plant and animal) against the systematic geologic - geomorphologic - climatologic and especially hydrologic influences, present and past, on soil formation. An ISSS handbook on soil spatial variability, and how to deal with it, may be the result.

ISSS Committee on International Programmes (Global Change Committee)

Dr. I.P. Abrol, India
Dr. R. Arnold, USA
Dr. J. Greenland, England
Prof. Dr. Victor A. Kovda, USSR
Dr. P.A. Sanchez, USA
Prof. Dr. H. Scharpenseel, BRD
Dr. W.G. Sombroek, The Netherlands
Prof. Dr. Y. Takai, Japan
Dr. P.B. Tinker, England
Dr. G. Vachaud, France
Dr. G. Varallyay, Hongarie
Prof. Dr. D.H. Yaalon, Israel

IUBS

IUBS support of the IGBP

The international Union of Biological Sciences has been an enthusiastic supporter of a global research program since the initial presentation of the IGBP concept at Ottawa. Official support of the IGBP was expressed by the IUBS General Assembly at its meeting in Budapest, Hungary, in 1985, and since then by the actions of the Executive Committee. In addition, IUBS, in cooperation with SCOPE and UNESCO sponsored a conference at IUBS Headquarters on January 8-10, 1987, on "Geosphere-Biosphere Observatories: Their Definition and Design for studying Global Change." The Proceedings were published in Special Issue 16 of our journal BIOLOGY INTERNATIONAL. BIOLOGY INTERNATIONAL also served as the medium to publish a report "A New Look at Ecotones, " the results of several workshops organized by SCOPE, IIASA and MAB. Copies of these publications are appended to this report.

The Scientific Program of IUBS includes several initiatives of interest to IGBP, as described in IGBP report No.4, especially the four programs grouped under the "Decade of the Tropics" label (Tropical Soil Biology and Fertility, TSBF; Responses of Tropical Svanannas to Stress and Disturbance, RSSD; Human Biology and Comparative Studies on Tropical Mountain Ecosystems) and the Bio-Indicators Program. In the appendix to this report we include copies of Special Issues of BIOLOGY INTERNATIONAL describing these programmes.

The sections, and committees of IUBS, in particular the International Association for Ecology (INTERCOL), which is the section on ecology of IUBS, have also supported efforts to define the objectives and opportunities for IGBP. INTERCOL'S workshops on soil ecology, which are appended, are especially relevant to these goals. Also INTERCOL, with SCOPE, sponsored an international workshop on the problems of scaling across space. Further, ecologists have informally discussed the problems of measuring variation across landscapes and the technical problems of establishing ground truth of remote sensing observations. Landscape ecology is especially relevant to the concerns of the IGBP.

Thus, the biological community, organized through IUBS, is enthusiastic about the opportunities in this global effort.

Opportunities for direct participation

IUBS assumes that individual biologists and national and scientific members will play a variety of roles in the IGBP. However, IUBS itself proposes to organize studies on the role of diversity of life forms, communities, landscape elements and species, on ecosystem processes to contribute directly to the goals and objectives of IGBP. A proposal for this program, to culminate with an International Congress on Diversity in 1991, will be presented in Stockholm, and a draft of the report has been published in issue No.17 of BIOLOGY INTERNATIONAL. This proposal has been examined and endorsed by the Executive Committee and will be further discussed at the IUBS General Assembly in Canberra, Australia, in October 1988. It represents the opinions and ideas of numerous biologists world-wide. The project would concentrate on the role of diversity in biological controls to exchange of energy and materials across marine and terrestrial interfaces.

Need for greater biological expertise in the IGBP

Examination of the published reports the IGBP (IGBP Report No.1 to 4) leads us to conclude that there has been an inadequate consideration of the role of the biota in the regulation and influence on global processes. The programme appears to stress the physical and atmospheric aspects of Global Change. We feel that this research program must directly examine biological processes and determine more carefully how significant the biota is in processes regulation. A prior assumption of significance or lack of significance is not adequate. We realize that inclusion of biological processes within IGBP makes the program more complicated and difficult. However, IUBS is ready to help formulate research to determine the role of the biota

in mediating and controlling global processes. Critical comments in IGBP reports No.1 to 4 may be helpful in this context.

The report from the February, 1988 Cambridge meeting of the Special Committee does not adhere in our opinion to the objectives of IGBP as enunciated in report No.1, pp. 3 as

"To describe and understand the interactive physical, chemical, and biological processes (underline ours), 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 Coordinating Panel on Terrestrial Biosphere-Atmospheric Chemistry Interactions appears to us to stress the atmospheric chemistry interactions and to treat the Biosphere as a source or sink of various gases. We feel that without a better understanding of the biological processes involved no global knowledge of the problem can be acquired.

The coordinating panel on Biospheric Aspects of the Hydrological Cycle in their report laid appropriate stress on the importance of the role of vegetation in the hydrological cycle, but such concerns are not translated into a research programme. The programmes offered in our opinion stress physical processes, and hydrology, and do not consider seriously the vegetation.

The coordinating panel on the effects of climate change on terrestrial ecosystems is the most biological oriented, and it addresses important issues. Nevertheless it stresses using "simple" mechanistic models and we fear that simple means unrealistic biological models, which do not take into account the real dynamics of biological systems.

In brief, we urge that greater efforts be made to include realistic and valid biological process studies in the IGBP. IUBS is ready and willing to assist in the endeavor. In the opinion of IUBS it is essential that environmental scientists of all types design the most complete and useful IGBP study that is feasible given the resources and tools available to the world scientific community.

The middle atmosphere responses to changes (M.A.R.C.)

IUGG's Associations (IAMAP; IAGA; IAVCEI; IAPSO) ask that a programme, M.A.R.C., (The Middle Atmosphere Response to Changes in natural and anthropogenic forcing) be implemented in the IGBP, to address the following questions:

1) What is the role of the Middle Atmosphere in processing source gases of tropospheric/biospheric origin and in what ways do natural effects, such as solar variability, volcanism, and other natural climate variability mask changes of anthropogenic origin?

2. How are processes occurring in the Middle Atmosphere acting to change climate and in what ways do changes in the Middle Atmosphere cause changes in the lower atmosphere/biosphere?

3. To what extent can the answers to the above questions increase our ability to predict changes in the global environment?

The middle atmosphere, as discussed here, is the region above the tropopause up to approximately 80-100 km. Its present state results from both external forcing (radiative, chemical, dynamic, and, in its upper part, corpuscular) and complex internal interactions between dynamics, chemistry, and radiation. External forcing comes from both above and below and can be a result of both natural and anthropogenic effects. For example, the formation of ozone in the upper stratosphere depends on the intensity of the ultraviolet radiation that dissociates molecular oxygen; this solar ultraviolet radiation is known to vary with solar activity, thus giving rise to ozone changes. It is imperative to identify which aspects of ozone change are due to anthropogenic effects and which are due to solar variability. Although satellite observations have indicated short-term global ozone changes that are associated with the 27-day solar rotation period, long-term global ozone changes associated with, e.g. the 11 year solar cycle remain to be unambiguously identified.

Another example of this type involves middle atmospheric processes which affects the radiative balance of the troposphere/surface system. Gaseous sulphur emissions from violent volcanic eruptions are transported into the stratosphere; here chemical changes transform sulphur in its gaseous form to a sulphate aerosol. Very large volcanic eruptions, such as El Chichon, result in sufficient stratospheric aerosol concentrations to alter the balance between solar radiation and infrared radiation in the troposphere which can temporarily obscure other climatic effects such as greenhouse warming.

Transport-chemistry processes in the stratosphere differ from those in the troposphere in some important ways. Since no rain and snow precipitation takes place in the middle atmosphere, no rain-out occurs there. Also, middle atmosphere dynamical processes take place on a larger horizontal scale than they do in the troposphere. These features, together with the absence of localized chemical sources and sinks in the middle atmosphere, lead to a greater tendency for global effects to occur in the middle atmosphere compared to more localized effects in the troposphere. Because of the greater amount of convection in the lower atmosphere, vertical exchange occurs on a shorter time scale in the troposphere than in the middle atmosphere. Thus, middle atmosphere effects tend to occur on relatively long time scales.

Changes in the middle atmosphere processes can also affect the troposphere in important ways. For instance, ozone changes in the middle atmosphere can affect the amount of solar ultraviolet radiation incident on the upper troposphere. This can produce more ozone there by the so-called self-healing effect. Ozone in the upper troposphere is quite an effective greenhouse gas, especially in the tropics. Also, tropospheric ozone irradiated by UV-B is a major source of O('D) which initiates many chemical reactions in the troposphere. Thus, changes in tropospheric ozone may occur by either changed stratosphere-troposphere exchange processes or by changed solar ultraviolet fluxes reaching the troposphere. These changed tropospheric ultraviolet fluxes can be produced by changes in the overlying ozone column which is itself caused by both natural and anthropogenic effects.

Certainly, the phenomenon of the Antarctic ozone hole represents one of the greatest changes in the geosphere-biosphere system that has been observed during the past decade. This phenomenon which subsequently was shown to be a consequence of anthropogenic chlorine emissions was totally unpredicted by stratospheric models. In a relatively short period of time, large observational programs have indicated its cause to be due to a complex interplay: of middle atmosphere dynamics, leading to extremely cold lower stratosphere temperatures in the Antarctic; cloud microphysics, leading to polar stratospheric clouds; and heterogeneous chemistry, leading to transformations of relatively inactive species to reactive radicals which very effectively catalyze ozone destruction. The challenge of seeing to what extent similar processes may be taking place in the Arctic lies before us. In any case, the Antarctic ozone hole stands as a striking example of how complex middle atmosphere processes can produce dramatic responses to anthropogenic influences, far removed from the principal anthropogenic sources of chlorine. Also, the influence of the Antarctic and maybe Arctic ozone hole on the global ozone distribution needs to be better understood.

Another recent line of research involves the striking role of the Quasi-Biennial Oscillation (QBO) in modulating stratospheric, mesospheric, and tropospheric climate. The manner in which this takes place is not understood.

It should be stressed that these associations were first discovered in stratospheric data analyses. It is of great significance that the QBO, which has been thought of as a tropical stratospheric phenomenon, can modulate tropospheric climate to such a large extent. From the above examples it is clear that investigations of the Geosphere/biosphere-system must include study of the Middle Atmosphere!

The MARC program will be based on an integrated approach consisting of four major components:

Diagnostics: Assessment of already existing data to understand processes and to characterize changes which have already taken place in the middle atmosphere.

Process-oriented Measurement Programs: Measurements need to be made to test chemical, dynamical, and radiative theories of processes that occur in the middle atmosphere. The Antarctic Aircraft Ozone Experiment was a very necessary and successful example of such a program.

Long-term Monitoring: Systematic, continuous, carefully calibrated measurements of a variety of variables are needed to obtain a comprehensive understanding of the long-term behavior of the system under consideration. They will rely on both space-based observations and dedicated global ground-based networks.

Modelling: In order to understand the processes indicated above, it is necessary to continue the development of multi-dimensional interactive circulation models which take into account the processes controlling the exchange of various chemical species from the surface and the radiative, dynamical, and chemical feedbacks which take place in the coupled troposphere-stratosphere-mesosphere systems. In parallel to the above, which requires next-generation computers, smaller models will continuously be needed to address specific problems and to test various hypotheses.

IUGG is willing to work in collaboration with the Panels of IGBP to begin immediate planning of Workshops, Symposia, and Campaigns to implement these diagnostics, measurements, long-term monitoring, and modelling efforts.

Furthermore, IUGG is willing to help in planning Middle Atmosphere participation in the development of IGBP's data and information systems.

Relationship between M.A.R.C in IGBP and other programmes

Clearly, there is much activity in national agency programs to study the middle atmosphere, especially regarding ozone. There are also important ongoing international negotiations involving the use of the chlorofluorocarbons that lead to ozone destructions. One of the roles of M.A.R.C.

will be to develop the scientific knowledge of the middle atmosphere which will be needed in the future by IGBP.

There is also S.T.E.P., SCOSTEP's Solar-Terrestrial Energy Program, which has a working group on the subject "Middle Atmosphere Response to Forcing from Above and Below". This group's activities will involve a more comprehensive study of the middle atmosphere than does MARC which focusses on biospheric effects. Other parts of STEP involve the study of those processes that lead to forcing of the middle atmosphere. In this sense, STEP includes a more comprehensive study of the middle atmosphere and its forcing than does MARC. STEP, although quite separate from IGBP, is important since it may produce research results that will later prove to be very useful for IGBP.

IUGS

(I) Relevance of the geological record to ICSU's IGBP programme

The objective of the International Geosphere and Biosphere Programme of the International Council of Scientific Unions is to describe and understand the interactive physical, chemical, and biological processes that regulate the total earth system. This is also the objective of earth scientists, especially those who are oriented to understand processes, recent or ancient. We recognize that the priority in the IGBP will fall on those areas that deal with key interactions and significant change on time scales of decades to centuries. It has been said that earth scientists are dealing with ancient old rocks, and that they have little to contribute to studies of short-term global changes. The purpose of this communication is to present arguments demonstrating that the billion-year old geological record is very relevant to the IGBP's effort.

The interactive physical, chemical and biological processes on Earth can be described as fluxes of matter and energy across the atmosphere, hydrosphere, lithosphere, and biosphere. The processes which could produce significant changes in short time are those of abnormal rates in earth history, also known as catastrophic events. The magnitude of those events are inversely proportional to their frequency. Natural catastrophes, such as earthquakes, storms, volcanic eruptions or explosions, have been referred to geologic hazards. From the magnitude/frequency inverse law, one does not expect greater natural catastrophes during the next centuries that what have been recorded in history; there seems to be little reason for alarm. However, the anthropogenic disturbance of the fluxes of energy and material has been of such magnitudes, that catastrophes which normally occur only once in a million or a billion years could be happening in not too distant future.

Catastrophic global changes could be induced by sudden fluxes caused by anthropogenic activities. The ICSU's program on Nuclear Winter was designed to study a sudden flux of energy into terrestrial system. Were there occurrences of comparable flux in the earth history? Yes, we could go back to the history of last 10^8 years, at the end of the Mesozoic Era, to find such a case history of interactive physical, chemical, and biological processes which produced significant changes in 10^1 to 10^2 years. The terminal Cretaceous event was probably an impact event, and the scenario of subsequent environmental devastations could be referred to as the Impact Winter.

The ICSU's project on Nuclear Winter was inspired by the investigations of the Impact Winter by earth scientists. Programs of modelling atmospheric (ozone depletion), climatic (darkness and freeze), and geochemical changes (NO_x and acid rain) in the wake of a nuclear war have been modified from those of the Impact Winter. It would be foolhardily to verify the Nuclear Winter studies, but the predictions of the Impact Winter have been tested by geological investigations of sediments which were deposited after the Impact Winter. Investigations of the K/T boundary event indicated that environmental catastrophes of darkness and freeze led to mass mortality, that ocean pollution suppressed fertility of organisms and thus causing drastic reduction of biomass, and that ozone depletion resulted in biocidal damages and genetic mutations, which were an apparent cause of accelerated extinctions and specifications.

The Nuclear Winter scenario could be irrelevant if the mankind is wise enough to avoid such a catastrophe. Yet secular and gradual fluxes in a few centuries may have accumulative effects not unlike what might be produced in a few hours by a holocaust. Interactions of biosphere and geosphere in earth history, as indicated by the lesson learned from the billion-year geological record, often involve feedback mechanisms. The additive effects could be nonlinear. Often, after the cumulative result reaches a threshold value, there would be the straw that breaks the camel's back. One example is the concern if the current warming trend will have nonlinear effects on delegation of Antarctica. Earth scientists have predicted that the Ross Sea shelf ice could be detached, if the present rate of CO_2 input to the atmosphere continues for a century. The consequence would be a sudden rise of sealevel a few meters above the present, causing the drowning of numerous coastal cities. Studies of the climatic history during the last 100,000 years ago may tell us if such an event has actually happened.

Some consequences of the interaction of physical, chemical and biological processes are irreversible, as in the cause of species extinction. The current extinction rate, caused by human

perturbation, is compared to that of the "Great Dying" at the end of the Mesozoic. By the time the consequences, such as the reduction of genetic diversity caused by the destruction of tropical forests, are visible, it is already too late because irrevocable damages have been done. A lesson can be learned, however, from the earth history.

(II) Comments on IGBP planning

A task group on Past Global Changes was called into existence by the IUGS Executive Committee. The first meeting of the group was held at Samedan, Switzerland, in April, 1988. The meeting was attended by

K. J. Hsü, chairman, representing IUGS Commission on Marine Geology
R. A. Price, representing IUGS Scientific Advisory Board, and the International Commission on Lithosphere
N. W. Rutter, representing the International Union for Quaternary Research
A. Strasser, representing R. N. Ginsburg and IUGS Commission on Global Sedimentary Geology
P. Teleki, representing IUGS Advisory Board on Remote Sensing
I. Thornton, representing International Association of Geochemistry and Cosmochemistry
F. Zwahlen, Hydrogeologist, representing Swiss National Committee on IGBP

The group studies the documents prepared by ICSU's Special Committee on IGBP after their July, 1987 and February, 1988 meetings as well as a discussion paper prepared by Price on IUGS and the IGBP on Global Changes, dated January, 1988.

The group supports the goals and objectives as outlined by ICSU's Special Committee. They would like to add, however, that it is not only necessary to obtain information "on the cyclicity of key elements among the terrestrial ecosystems, the oceans and the atmosphere", but also on that of the lithosphere. Furthermore, not only the climate-induced feedbacks affecting cycles, but also other environmentally induced should be taken into consideration. In other words, the group share the opinion contained in the Price Report that the IGBP's Global Change Study should not only emphasize climatic changes, but also other global changes in geosphere and biosphere, such as pollution, desertification, soil erosion, destruction of tropical forests, etc.

In reviewing the existing structure of the IGBP Panels and Working Groups as outlined by the July, 1987 report, we welcome the initiatives of the Special Committee. We suggest, however, that the term of reference of several groups be modified to take into consideration global changes other than climatic. We suggest that the goals of the Working Group on Techniques for Extracting Environmental Data of the Past should be enlarged to address not only problems of techniques, but also records of past global changes. We also expect that the Working Group on Geo-Biosphere Observatories may take into consideration the work by observatories of soil-earth geophyscists.

We recognize that Special Committee members have been appointed to ICSU's panels and working groups. We would like to inquire if additional members from the community of earth scientists might be appointed, and if ICSU would consider nominations by IUGS.

(III) IUGS activities related to IGBP

Discussions with ICSU's staff and with members of the Special Committee on IGBP have conveyed to us the impression that the major thrust of the ICSU's program is aimed to initiate and to coordinate multi-million dollar, international, and inter-disciplinary research projects. The efforts of the IUGS are, on the other hand aimed to define the present state of knowledge, and to suggest areas of future research. We have envisioned, therefore, that the IUGS activities related to IGBP would be similar in nature and in scope as its past Geodynamics Project and Lithosphere Program.

IUGS's Task Group on Past Global Changes has identified four major themes as top priorities in the IUGS's program on IGBP. They are:

1) Past global changes (esp. the last 10^5 years) in the marine record.
2) Past global changes (esp. the last 10^5 years) in the terrestrial record.
3) Anthropogenically inducted global changes.
4) Interaction of organisms and paleoenvironments and the possible consequences of anthropogenically reduced genetic diversity.

The investigations of the record of past global changes will provide a baseline against which to compare and evaluate the nature and significance of present and future changes in the global ecosystems, and also a framework within which to elucidate the important processes in the coupled geosphere-biosphere system. The evaluation of this record, in our opinion, is a necessary prerequisite for the success of the IGBP. It is also a major contribution the international geoscience community can and should make to the ICSU's program.

The IUGS's task group is, therefore, scheduling a workshop on Past Global Changes, which will meet in April, 1989, at Interlacken Switzerland. Four working groups, with the names of the leaders of WG in parenthesis, have been constituted:

WG 1 Record of Oceans and Atmosphere (Shackleton, Ginsburg)
WG 2 Record on Land (Rutter)
WG 3 Anthropogenic Changes (Thornton, Price)
WG 4 Reduction of Genetic Diversity (McLaren, Hsü)

We recognize that much of the environmental data from the past have been stored in ocean sediments and in terrestrial sedimentary rocks. One purpose of the Interlacken workshop is, therefore, to evaluate the desirability of setting up an Inter-union Commission on Past Global Changes, in cooperation with other ICSU bodies such as INQUA, IUGG, SCOR, etc. It is foreseen that the emphasis of the IUGS program is less to extract new data, but more to document the existing environmental data, and to extract the significance of such data to IGBP's stated objectives of predicting changes on time scales of decades to centuries.

IUPAB

Introduction

The field of biophysics has for several decades been involved in radiation biology, and IUPAB has maintained a Special Commission in this area. In 1987, IUPAB made a firm resolution to shift the area of involvement of this Special Commission toward the broader field of environmental biosphysics, renamed it the Special Commission on Environmental and Radiation Biophysics, and appointed Professor Dusan Vucelic as its head, with a mandate to expand the activities of the Special Commission. This Special Commission will plan and implement the contributions of IUPAB to the IGBP.

The draft IGBP programme

While I personally support in general terms the IGBP planning as described in Reports 2-4, IUPAB and its Special Commission on Environmental and Radiation Biophysics have not had an opportunity to study these plans in detail and have no comments to make in this, its initial report to the IGBP.

Additional suggestions

The Special Commission on Environmental and Radiation Biophysics of IUPAB is especially interested in environmental factors that results in local subsets of the world population being subjected to severe and debilitating diseases and physical abnormalities that have as their known or probably basis interference with normal biophysical functions in the human body or in food organisms. This could result from environmental factors, such as heavy metals, being present in local areas in excessive or in deficient amounts, or from the presence of toxins, viruses, or genetic factors in a localized geographic area or population. The understanding of biophysical phenomena and the use of biophysical techniques could be critical both in the identification of the specific environmental factor involved and in the planning and execution of corrective measures leading to the alleviation of human suffering. As an example, in particular geographic regions of the Balkans, most of the inhabitants of particular villages and groups of nearby villages suffer from a particular form of lethal nephritis, such that an estimated 30.000 people are afflicted with the disease and 2,500 to 4,000 people die from its effects annually. The specific geographic localization of the disease strongly suggests an environmental or genetic basis for its causality. Much knowledge of normal kidney function has come from biophysical studies, and it seems reasonable to expect that similar studies will be needed to elucidate the etiology and progression of this disease.

Thus, IUPAB suggests that the plans for the IGBP include provision for a Working Group on the environmental basis for human disease and suffering and its alleviation.

Priorities

IUPAB has no specific priorities for the IGBP, feeling that all of its programs are important and worthwhile. However, the possibilities for involvement of IUPAB to the IGBP are greatest in the biological and biophysical areas, and programs that have the potential to reduce human suffering, especially in less developed areas of the globe, are worthy of the highest priority.

IUPsyS

The I.U.Psy.S., valuing highly the importance and potential impact of IGBP, took up activities relating to this ICSU Project as early as 1987. An I.U.Psy.S. Task Force for IGBP was set up which conducted a review of behavioral science research of direct relevance to man-environment interaction processes as they become critical in the study of global change. On this basis I.U.Psy.S. support of, and participation in, IGBP activities was proposed for the following topics and fields of expertise:

(1) Evaluation/assessment of (natural and man-made) environments (e.g., scenic evaluation, landscape assessment); environmental awareness.

(2) Psychological evaluation of (natural and technological) hazards and risks; study of intra- and interindividual covariants of risk perception.

(3) Behavioral indicators of environmental quality, esp. of environmental toxicants (through objective tests and neurobehavioral assays).

(4) Study of human behavior as effecting variables central for human eco-systems, research on environment-related attitudes and values.

(5) Macro-system effects (weather, climate variations etc.) on experience and behavior.

(6) New methods of in-field study of behavior suitable (and necessary for) the study of on-the-site behavior-environment interactions.

I.U.Psy.S. is ready to cooperate with IGBP-activities of ICSU in these areas.

Executive summary

The Antarctic, including the continent and Southern Ocean with the sub-Antarctic islands is a critical area in the studies of the International Geosphere Biosphere Programme. Major interactions between the atmosphere, ice, ocean and biota affect the entire global system through feedbacks, bio-geochemical cycles, deep ocean circulation, and changes in ice mass balances. The effects of global climate change in Antarctica can be larger and more pronounced than at mid-latitudes, and therefore better seen and monitored. Antarctica is also a rich repository of paleo-environmental information in its ice sheet and ocean and lake sediments.

Four major, interconnected, interdisciplinary research thrusts define and encompass the research priorities of an Antarctic component of the IGBP:

- Detection of global change in Antarctica;
- Study of critical processes linking Antarctica to the global system;
- Extraction of paleoenvironmental information;
- Assessment of ecological effects.

Under each of these four major headings, several research tasks are identified.

Causes of global change include changes in atmospheric composition, primarily the greenhouse gases and stratospheric ozone (which is already decreasing strongly in Antarctica). The most effective indicators of climatic change which can be readily monitored in Antarctica include sea ice extent and thickness, changes in ice sheet mass and velocity, sea level, temperatures, radiation fluxes, and flora and fauna on the continent, the surrounding seas and on sub-Antarctic islands.

Processes linking Antarctica to the global system include the functioning of the high latitude regions as heat sinks that help to drive the global circulation. The sea ice feed-back processes amplify the climate signal at high latitudes. Physical-chemical and biological ocean processes effect bottom water formation, the CO_2 sources and sinks, and the global thermohaline ocean circulation. Mass balance changes of the antarctic ice sheets effect global sea level, and the possibility of the disintegration of the West Antarctic ice sheet needs to be investigated. Study of these processes must include attempts to interactively model them in coupled numerical models.

To understand future changes, Antarctica can provide highly relevant paleoenvironmental data from ice cores, sediment cores from the ocean and lakes, and from other sources; the striking results obtained from the Vostok deep ice core illustrate this. Collection and comparison of such data sets with other global paleoenvironmental data remains a high-priority research objective.

Finally, assessment of ecological effects includes the modeling of predicted environmental changes of biological significance and their adequate monitoring. Changes in sea ice extent will affect the overall primary production, carbon fixation, and hence the global CO_2 budget. Ozone depletion results in increased ultra-violet radiation which may affect the Antarctic organisms. Numerous feedback processes link the biological and physical components of the entire system; for example, through the CO_2 budget of organisms. Moderate warming in Antarctica can result in higher plant production and relatively rapid colonization of newly de-glaciated areas.

The task ahead for the remaining two years of the IGBP planning phase is to further develop a research strategy for the IGBP in Antarctica. Some of the research priorities outlined above are part of existing or planned programmes and these will be taken into account in planning efforts. Tasks that must be included in an Antarctic component of the IGBP include:

- Provide the Antarctic input to the ongoing and developing international programmes studying global change, including: World Climate Research Programme (WCRP), World Ocean Circulation Experiment (WOCE), Solar Terrestrial Energy Programme (STEP) and Joint Global Ocean Flux Study (JGOFS);

- Monitor the rate and extent of change in the Antarctic sea ice, temperatures, gas exchange, biota, and communities;
- Establish a system to measure changes in Antarctic snow accumulation and ice flow which will affect sea level;
- Further clarify the past global environmental changes using deep ice cores and sediment records;
- Study the processes changing Antarctic stratospheric ozone and the consequential changes in ultraviolet radiation and its impact on the biosphere.

Introduction

A growing awareness that the activities of man are beginning to change many aspects of the environment in which we all live has led to a realization that we must equip ourselves to detect these changes, to understand them, and to predict their future trends. This realization is the unifying theme of the International Geosphere Biosphere Program (IGBP) of the International Council of Scientific Unions (ICSU), which has grown out of many simultaneous national and international proposals for coordinated, interdisciplinary research to investigate and understand the intricate and possibly delicate linkage of processes that control the conditions for life on our planet. Phenomena and processes in the antarctic region that have an important role in global change include the following:

- The Antarctic regions has a high negative radiation budget and so acts as one of the Earth's "refrigerators". Any changes in the budget will have global consequences on atmospheric and oceanic circulation.
- Antarctica provides unique conditions for investigating the impact of man-made pollutants on atmospheric ozone.
- Conditions beneath the ice shelves and girdle of sea ice promote the formation of bottom water that drain northward to cool the global change.
- A detailed record of past global climate and atmospheric chemistry extending over hundreds of millennia is preserved within the antarctic ice sheet, and in the sediments of the ocean and land.
- Because climate change is predicted to be largest at high latitudes, detection of such change above the background of high natural variability should be sought in the polar regions.
- The Antarctic ice sheet contains enough water to raise sea level some 60 meters. Any greenhouse climate warming which makes even a small change to this volume of ice can have a significant impact on sea level.
- Polar seas play an important role in the exchange of CO_2 between ocean and atmosphere. These processes are controlled by the sea ice cover and biological processes.
- Plant communities existing under polar conditions are sensitive to minor changes in temperature, and are therefore good indicators of climate change.

Some other problems are not presently encompassed in existing international research programmes. There is no established strategy either for early detection of climate change in Antarctica, or understanding and prediction of the probable effect of climate warming on atmospheric and oceanic circulation, ice-sheet volume, and sea level. Sea ice and oceanographic studies around Antarctica are mainly in an exploratory phase.

This report recommends a considered set of high priority elements for an Antarctic component of the International Geospheric Biosphere Program that builds on existing efforts, and fills important gaps. Emphasis is on important process and interactions that link the basic elements of the Antarctic system: atmosphere, land, oceans, ice and biota.

We identify four interdisciplinary research themes within which priorities are established:

(i) Detection of changes of global importance best observed in Antarctica, which are fundamental to establishing current trends of change and provide a foundation for understanding the underlying processes.

(ii) Study of processes linking the Antarctic sea ice cap, and biological systems, to the global ocean and atmosphere, which quantify Antarctica's relevance to global change and human activity.

(iii) Use of paleoenvironmental information from Antarctic sources,which provide a context for interpreting current changes on the 10 to 100 year time scale of principal concern to IGBP.

(iv) Study of ecology in the changing Antarctic environment, which assesses the impacts of climate on antarctic biota, and their possible feedback effects on climate.

Detection of changes of global importance best observed in Antarctica

It is important to detect changes in the earth system that are occurring now. The antarctic environment offers a number of unique opportunities for doing this because of favorable observing conditions, remoteness from anthropogenic emissions to atmosphere and ocean, and potential amplification of climate change at high latitude.

Atmospheric Composition

The Antarctic Ozone Hole - Large decreases in ozone amounts observed over Antarctica in the southern spring during the past decade have attracted worldwide attention. The link between halocarbons and ozone amounts, through complex photochemistry in the polar night and with the return of the sun, is now well established. Changes in ozone and trace gases may have major impacts on climate and ultraviolet radiation received at the surface, with corresponding detrimental effects on surface marine and land organisms. To study these effects, the tropospheric and stratospheric chemistries of the polar regions, including chemical interactions with ice clouds and other aerosols, must be addressed as well as studies of the physical processes that are active in this domain. Research on the temporal and spatial distributions of the chemical species that participate in ozone production and destructive reactions should also be undertaken.

Atmospheric Carbon Dioxide - The study of the temporal variability of carbon dioxide is an important factor in the earth's infrared radiation balance and man's alteration of climate. There is a need for long time-series and atmospheric background observations for the southern hemisphere, and for establishing the paleo-atmospheric record of carbon dioxide as recorded in antarctic ice cores. The role of the Southern Ocean as a sink for this important atmospheric trace constituent should also be investigated.

Other Important Trace Gases - Tropospheric concentrations of methane, a number of anthropogenic fluorocarbons, nitrous oxide, and perhaps carbon monoxide are increasing, presumably in response to man's activities. Many of these gases also pay a key role in the chemistries of other short-lived trace species such as ozone. Antarctic represents an important region for the study of southern hemisphere trends of these gases, and is a unique region for the study of their past variations in ice cores. Water vapor also plays a key role in the atmosphere's infrared radiation balance, and its key dynamics relative to sea-ice distributions and climate represent another important area of study.

Indicators of Climate Change

Because climate change probably will be amplified at high latitudes, detection of such changes should be sought in polar regions. On sub-Antarctic islands south of 50°S, a data-sparse region of the globe, terrestrial and marine ecosystems and small glaciers are particularly sensitive to climate change. Also, the rate of colonization of newly ice-free areas and changes in the composition and productivity of biota are indicators of the effects of climate change. Antarctic parameters likely to be sensitive indicators include sea-ice extent and thickness, ecosystems and glaciers on sub-Antarctic islands surface, tropospheric, and stratospheric temperatures, the radiation fluxes at the top of the atmosphere, and the area of ice-sheet affected by summer melting. Detection of a systematic trend in any of these parameters will require a long-term, internally consistent monitoring programme in order to separate meaningful decadal trends from the large interannual variability that exists in the Antarctic. Most of the necessary data can be acquired by sensors aboard satellites, but a considerable effort is required to convert these data into estimates of the relevant geophysical or biological parameters.

The following should be monitored:

- Sea ice extent and thickness, primarily from satellites.
- Continent-wide, surface, tropospheric, and stratospheric temperatures, the first with satellite infrared sensors, the latter with radiosondes and rockets.
- Upward terrestrial and reflected solar radiation at the top of the atmosphere, from satellites.
- Changes in distribution of surface melting using passive microwave data from satellites.
- The position of fronts and the grounding lines of the large ice shelves and of glaciers in the maritime Antarctic and on sub-Antarctic islands.
- The changes in the flora, fauna, and microbiota of selected terrestrial and marine sites in the Antarctic and sub-Antarctic.

Antarctic Ice and Sea Level

Approximately 75% of the world's fresh water is contained within the Antarctic ice sheet, representing some 60 meters of equivalent world ocean sea-level rise. Any substantial changes in ice sheet mass will directly affect global sea level with worldwide consequences. The West Antarctic Ice Sheet, the disappearance of which could lead to a 6m sea-level rise, is of special interest because it is grounded largely below sea level. Similar marine ice sheets that existed during past northern hemisphere glaciations appear to have disintegrated rapidly with major changes in the order of the 100 year time scale of interest for the IGBP.

It is still unknown whether the Antarctic ice sheet is currently growing or shrinking, although investigations on the West Antarctic ice sheet may provide new insight. To determine and model the present course of this contribution to sea level change, it is necessary to carry out the following investigations:

- Detect changes in surface elevation over the complete ice sheet using satellite-borne altimeters;
- Detect changes in ice sheet extent and surface characteristics, primarily by high resolution satellite imagery;
- Detect changes in the velocity fields of the ice sheet surface be means of satellite remote sensing.

Processes linking the Antarctic ice and biological systems to the global ocean and atmosphere

The circulation patterns of the global atmosphere are influenced by Arctic and Antarctic boundary conditions through pole-to-equator temperature differences. A large part of the intermediate and deep water masses of the global ocean outcrop at the sea surface or beneath the sea ice surrounding the Antarctic continent. This tree-dimensional oceanic structure is due in large part to processes of freezing and melting beneath sea ice and ice shelves that alter the density field and promote vertical exchange. As a result, the Antarctic perimeter is one of the principal zones of oceanic ventilation and geochemical exchanges between the surface

environment and the deep ocean. Freezing and melting processes and associated ocean circulation also effect the mass balance of the sea and shelf ice. The sea ice, through its effects on heat and moisture exchange, affects both the atmosphere and ocean and, along with clouds, is a highly variable element affecting the earth's albedo and heat energy balance, and climate. Melting or freezing beneath the ice shelves may, through coupling of the ice shelves and ice streams, affect the balance of the vast mass of inland ice.

This illustrates just some of the complex linkages that exist within the Antarctic domain, and their role in global scale processes. Below we isolate several crucial aspects of understanding this interactive system.

Radiation Budget

On the Antarctic continent neither the areal extent nor the albedo of snow vary significantly. In contrast, the extent of sea ice covering the ocean surface, and hence the albedo of these regions varies greatly seasonally and internationally. The Southern Ocean is also a cloudy region.

The relative importance of Antarctic clouds and sea ice on hemispheric albedo is complicated by limited knowledge of how sea ice and cloud distribution are related. Such a relationship is potentially important in view of the effect of sea on moisture transfer between ocean and atmosphere. Clouds also affect the outgoing long-wave radiation at the top of the atmosphere. Over the Antarctic ice sheet, clouds may increase the long-wave loss because of strong temperature inversions. The fact that the surface can be colder than most of the troposphere also means that radioactively active trace gases may have different radiative budget effect in Antarctica than elsewhere.

For high-latitude cloud cover, including stratospheric clouds, there is a need to develop suitable algorithms for mapping cloud fraction and cloud thickness from remote sensing data. The current algorithms fail in polar regions due to the complexity of snow-cloud discrimination and the vertical temperature structure. Solutions to this problem will need to integrate multiple sensor information from radiometric scanners and sounders.

Global Thermohaline Ocean Circulation

The abyssal waters of the world ocean contain 50 times the mass of CO_2 present in the atmosphere, and must play a major role in determining its atmospheric concentration. Deep ocean ventilation occurs through relatively small windows near the continental slopes off Antarctica. Processes of bottom water formation acting there are key elements in understanding the carbon cycle of the present and future. Hydrographic data on temperature, salinity, oxygen, and C-14 have been used to estimate bottom water production rates and residence times that apply under present climate conditions, but potential changes in these parameters are virtually unknown. In order to investigate the potential response of the climate system to increased greenhouse gases, we must understand the mechanisms by which bottom waters form.

During the winter, rapid sea ice formation occurs near the coast, especially in polynyas of various size that are maintained along ice shelves by offshore catabatic winds. Brine excluded from the sea ice initiates haline convection, thereby increasing the density of the shelf waters. Circulation of the modified water beneath the ice shelves results in further cooling. On exiting the cavity beneath the ice shelf and undergoing further mixing with upwelling deep water, the water attains a density sufficient to sink at many locations along the continental slope. It is therefore plausible that significant changes in the sea ice and ice shelves of Antarctica, perhaps related to an increase in atmospheric CO_2 or to a sea level rise, could induce changes in the mechanisms, locations, and rates of bottom water production.

The state of the abyssal waters feeds back to affect the melting of ice. Upwelling of deep water into the antarctic gyres is closely related to the large vertical heat flux that limits the thickness of sea ice there. The thickness of the ice shelves is influenced by the heat flux from waters circulating under the ice shelf.

The following investigations are crucial:

* Investigate water modification in relation to freezing and melting of sea ice.
* Determine oceanic thermochemical fluxes in relation to the evolving dimensions and mass balances of ice shelves.

Biogeochemical Cycles

The Southern Ocean only covers 10 percent of the world ocean, but plays a major role in global carbon flux. It probably has a significant influence on the interannual variation of the world ocean's capacity to take up atmospheric CO_2.

As the sea ice forms in winter salt is rejected which causes deep convection and mixing of surface water into the deeper layers of the ocean. The surface waters after the summer season of open walter are rich in dissolved gases such as carbon dioxide and oxygen. These gases are therefore mixed into the deep waters around the Antarctic following the freezing. The dissolved gases play an important role in interactions with the marine ecosystem, and replenishing of the gases to the oceans in the polar regions is a critical feature for replenishing the gases and nutrients in the world's ocean.

Much of the world's deep water is formed in the sea ice zone of the Southern Ocean. High wind stress, local microbial productivity and sea ice cover will all vary to produce a range of potential incorporation in surface waters. The flux of biogenic and clastic materials in the Antarctic is linked to the formation, sinking and northward movement of cold water as well as the transport pattern and re-suspension and erosion by bottom currents. All this will be affected by changes in sea ice cover due to climatic warming and changes in the flux are well documented in the upper layers of ocean sediments. The very rich bottom fauna of the Antarctic shelf regions indicates the strong biogenic flux of mainly silicious pelagic organisms from the euphotic zone to the seabed. The Joint Global Ocean Flux Study (JGOFS) should address the biogeochemical fluxes in the Southern Ocean. Those studies should be considered as integrated and essential parts of IGBP in the Antarctic. They involve inter alia long term and short term observations by sediment traps and current meters.

Sea Level

If, as is predicted, there is a major climate warming over the next century, the boundary conditions acting on the Antarctic ice sheet will change. Possible effects include: increase snow accumulation associated with atmosphere and less sea ice; increase surface melting in summer associated with higher air temperatures; increased melting of ice shelves from below associated with the penetration of warmer ocean water and/or changed patterns of ocean circulation. These interactions between the ice sheet and the bounding ocean and atmosphere must be quantified by empirical studies and theoretical models of the physical processes involved.

The most important potential short-term consequence of these changes in boundary conditions is an increased discharge from ice-streams flowing into ice shelves weakened by thinning and the calving of icebergs. The ice streams may also be susceptible to rapid change due to internal instability, independent of climate. Fast flowing ice streams are responsible for most of the ice drainage from Antarctica, and changes in their rate of flow hold the potential for large, rapid changes in the mass of the ice sheet, and therefore in sea level.

In order to understand and predict the potential changes, it is necessary to carry out the following research:

- Seek relationships through empirical studies and physical models which give precipitation and accumulation on the ice sheet in relation to atmospheric temperature and sea ice extent;

- Investigate factors affecting ice-shelf stability including pinning mechanisms in areas of grounded ice and especially basal melting and relate ocean characteristics seaward of and beneath the ice shelves;

- Map the Antarctic ice streams and investigate the physics of fast glacier flow with emphasis on processes at glacier beds that allow rapid large changes in flow velocity.

Climate Modelling

Attempts have been made to model global climate using sophisticated atmospheric Global Climate Models (GCMs) coupled to ocean and ice models, but the simulations have been deficient in reproducing the present distribution and seasonal changes of sea temperatures and sea ice around Antarctica. Yet such models also predict that the largest changes in surface temperatures due to a doubling of CO_2 content, or other perturbations in climate forcing, would occur in and around Antarctica. It is vital for these models to improve their present day simulations if they are to be credible in predicting future conditions.

Greater understanding of the physical processes and feedbacks involving clouds, the seasonal sea ice cover, the ocean-atmosphere heat exchange, deep water formation and circulation in the Southern Ocean is essential to the modelling endeavour. Ice cover modifies not only the surface albedo and oceanic salt distribution, but also the fluxes of energy, moisture and water (gases, aerosols, and nutrients) between atmosphere and ocean, as well. These changes in turn affect cloud cover, precipitation, evaporation and biogeochemical cycling.

A major need in climate modelling and prediction is to parameterize the mechanisms by which the deep ocean is coupled to surface conditions in the Antarctic. Most importantly these involve the circulation under the ice shelves and consequent phase changes and buoyancy fluxes; and convection fluxes over the continental shelves and deep basin controlled by the freezing or melting of sea ice.

As coupled climate modelling develops, a separate need arises to model successfully the meridional fluxes within the ocean which ultimately tie Antarctic ocean processes and conditions to the rest of the world oceans.

Program elements that need to be addressed include:

- Modelling the presence of a high ice cap at high latitudes, especially if the model has limited spatial resolution, as has been common for long integrations.

- Sea ice processes, both thermodynamics and dynamic, the formation of leads and growth and decay of sea ice as it subjected to strong winds, and the interaction between the ice shelf and the ocean.

- Changes in cloud cover, including amount, height and type.

- Changes in precipitation and the possibility for increased snow accumulation over the polar cap as the climate warms.

- Changes in the radiation balance, arising through changes in water vapor, ozone, cloudiness and albedo. In turn, this becomes linked to the overall heat balance.

Antarctic sources of paleoenvironmental information

The variability of climate on the 10-100 year time scale, the main focus of IGBP, is part of a much longer time scale of variations in environmental conditions. The variations seen on the short time scale cannot easily be separated into those due solely to "noise" or short term fluctuations and those that represent real trends. Paleoclimate data can provide a detailed record of climate-related parameters that will place modern observations of change in the context of Tertiary and Quaternary glacial interglacial cycles and the post-Wisconsin variability which has included periods both colder and warmer that a present conditions.

The historical context of current climate variability is essential information for understanding the significance of trends that are becoming evident today. Ice cores and the geological records can provide that context in terms of the limits of variability, the rates of change, and sets of parameters that lead up to abrupt climate change. Studies of these events through the Antarctic records are central to IGBP aims and are interdisciplinary and multidisciplinary in scope.

Ice Cores

Annual resolution of environmental parameters over several hundred to several thousand years can be obtained in areas of high snow accumulation in Antarctica. Records covering several hundred thousand years may be obtained with century time resolution from the Antarctic interior. Paleoenvironmental indicators preserved in the ice include: oxygen and hydrogen isotope rations (proxy records of temperature), CO_2, CH_4 and other radioactively active atmospheric trace gases, atmospheric and volcanic dust (turbidity), cosmic dust, cosmogenic isotopes, anion and cation species, acidity, air content and isotopic composition, crystal size and orientation, and temperature. Together these provide a detailed record of the global climate and air composition, and of the ice sheet elevation at the time and in the area where the ice accumulated as snow. Simultaneous studies of the changes in other paleoenvironmental records, such as sediments and glacial morphology, are needed to reveal cause and effect relationships for changes in global climate and ice sheet thickness.

Terrestrial and Marine Sediments

Permafrost cores in ice free areas of Antarctica, (e.g., the Dry Valleys of Southern Victoria Land) contain a record of past environments in the compostion of their sediment and in the stable isotope composition and salinity of their water. Lake bottom sediment and moss-bank cores are likely to yield important information even on short periods (+/- 100 years) and furnish information on Antarctic pollution history. A Holocene glacial history record constructed from studying elevated marine sediments, delta deposits and moraines may also present background information vital for the interpretation of recent and future climatic changes and effects.

Tertiary and Quaternary marine sedimentary basins are widely distributed within and peripheral to the Antarctic craton. These sedimentary successions provide important information on: global-interglacial climatic cycles; former extent of glacial and marine ice; biotic and sedimentary reactions to climatic cycle history, including widespread marine transgression and regression, sea level fluctuations, terrestrial and marine ecosystem development and extinction, physical destruction of the geological record by glacial advances; atmospheric CO_2 and correlation of paleoenvironment events and histories across the many regions of the Antarctic continent. Furthermore, marine water temperature and organic productivity values, trends and events may be derived from stable isotope analysis of fossil biota. Paleontological, sedimentary and geochemical studies of Antarctic Cenozoic material provide, then, a crucial link in the deciphering of relationships between polar marine and terrestrial ice volume and global sea level fluctuations, global climate, paleooceanography, paleobiogeography and organic evolution.

For Antarctic paleoenvironmental data to be effectively directed towards achievement of IGBP objectives the following must be accomplished.

- A geographically and temporally complete Antarctic terrestrial and marine sedimentary and biotic record must be recovered. This will require the use of technically advanced remote sampling devices, operating beneath thick ice sheets, ice shelves, glaciers and deep continental shelf waters.

- Terrestrial and marine paleoenvironmental histories in the southern high latitudes will be more accurately resolved if ice sheet and sediment cores are independently dated, stratigraphies correlated, and geochemically and biotically derived paleoenvironmental data compared.

Glacial Morphology

Areas of Antarctica not covered by ice or sediment show traces of past ice cover such as erratic moraines and glacial erosional features. These data complement the information derived from ice and sediment cores for the reconstruction of Antarctica's ice cover and past ice dynamics.

Ecology in the changing Antarctic environment

The predicted global change scenarios such as climate warming, ozone depletion, and increased human pressure on resources will affect the living components of polar ecosystems. In turn we can expect that large physical and chemical systems such as the ocean and the atmosphere will be affected via feedback mechanisms by the changes in biological systems. The processes involved in such feedback mechanisms require further study before any meaningful predictions can be made about changes in the environment on an Antarctic and global scale. All these changes will be more readily detectable at high polar latitudes than at lower latitudes because of the likelihood of greater relative physical and chemical change in polar regions, and the sensitivity of polar organisms. The magnitude of the responses of the biota and of feedbacks will be different in the Antarctic than in the Arctic. This represents the rationale for monitoring organismic response to change in both polar regions.

In the Antarctic, only 2% of the continent is colonizable by terrestrial organisms. Also, the Antarctic is isolated from other continents and is surrounded by ice and open ocean. In the Arctic, the land systems are extensive and connected to large temperate land masses, they support a great diversity of life, and surround a largely frozen ocean. The Antarctic terrestrial and marine biota is also a much older and a more highly specialized biota than that of the Arctic.

We may expect that terrestrial organism of the Arctic will be in less jeopardy that those of the Antarctic since they will have more opportunities for a real relocation and adjustment. In contrast, a moderate warming of the polar regions will result in a higher plant production and in a relatively rapid recolonization of newly de-glaciated areas. From this major terrestrial feedbacks to the climate can ba expected, particularly in the Arctic where the ice-free areas are much larger than in the Antarctic. We also expect that Antarctic marine organisms, which are more specialized and which have narrower ecological tolerances that Arctic marine organisms, will show greater responses such as redistribution than their Arctic counterparts. The Antarctic marine system will have several orders of magnitude greater feedback effects than Antarctic terrestrial systems, and the magnitude and fluctuations of this feedback must be understood and monitored. The ecological importance of the pack ice zone to the overall primary production and carbon fixation and hence to the global CO_2 budget is still unknown.

Modelling of Predicted Environmental Changes of Biological Significance

Because of the complexity and wide natural variability of biological systems, and because of the limited logistic, fiscal and personnel resources, it is critical to identity those parts of Antarctic ecosystems which are known or predicted to be sensitive to the likely environmental change and which are amenable to study, measurement and monitoring.

Close collaboration with physical and chemical scientists with ocean, atmosphere and ice systems should identify, via modelling, the predicted environmental changes of biological significance (for example, the magnitude and direction of sea ice and sea-level changes).

Ecosystems Monitoring

Emphasis in monitoring change should be on organisms or processes that are directly linked or very proximal to environmental changes. For example, it may be better to work on phytoplankton at the base of the marine food web than on the top marine predators, which can be affected by a greater complexity of direct and indirect controls. However, top predators will integrate changes over many seasons, thus may contribute to documenting long-term trends. In particular, historical and current cohort strength fluctuations demonstrated in several species of Antarctic seals may be related to fluctuations in environmental parameters such as pack-ice extent, krill abundance, and El Nino-Southern Oscillation events. The demonstrated major decline in Indian Ocean sector elephant seal populations may be associated with long-term environmental changes. Wherever possible, measurements should be of phenomena that are capable of recording responses to environmental change. For example, organisms such as corals and molluscs may show annual increments, and demographic analyses of populations may show past effects.

The Antarctic and sub-Antarctic terrestrial systems including the freshwater lakes are very sensitive to changes in solar radiation and temperature. Presently rapid de-glaciation takes place in many areas and even short warm summer periods have a large effect on plant and animal life in those habitats. For some biota long-time series of environmental and biological data are available as a base for further monitoring and for the detection of climatic impacts. In order to understand the underlying processes, SCAR's programme BIOTAS will focus on comparative studies on colonization of selected terrestrial habitats. The BIOTAS planning group has emphasized the need to work closely with IGBP in the marine field, close collaboration with scientists of the CCAMLR ecosystem monitoring programme should be part of any Antarctic IGBP initiative.

Effects of Ocean Changes on Dimethyl Sulphoxide Emitting Phytoplankton

A novel suggestion for possible biological research appropriate for a Antarctic IGBP includes the effects of ocean changes on dimethyl sulphoxide emitting phytoplankton. Abundant unicellular algae in the Southern Ocean are emitters of dimethyl sulphoxide which in the atmosphere may change cloudiness patterns and may offset greenhouse effects. Here satellite monitoring for specific pigments may be appropriate, in association with suitable field and laboratory ground truth studies.

Effect of Ozone Depletion on Antarctic Organisms

Another interesting topic is the effect of ozone depletion on Antarctic organisms. Recent reports on the "ozone hole" over Antarctica have renewed concern about the consequences of increased levels of Ultra-Violet radiation (UV-B in particular) reaching the earth's biosphere. One area of concern involves the phytoplankton, which constitutes the base of the food web in the aquatic ecosystems. Studies have shown that increased levels of UV exposure results in reduced primary production and in altering community structure. By weakening the base of the food web and altering trophodynamic relationships., UV-induced changes could have far-reaching effects on the entire Southern Ocean ecosystem.

The effect of UV-B on the genetic constitution (DNA) of aquatic and terrestrial Antarctic organisms should also be studied.

Relationship to other planned and ongoing programmes

Within the international scientific community there are a number of ongoing or planned programmes which include the study of Antarctic interactions within the global system and which contribute to the aims of the IGBP. The proposed SCAR contribution to IGBP is designed to complement these through the study of specific Antarctic interactions not covered by other programmes.

The World Climate Research Programme (WCRP) encompasses the study of the global climate system, including oceans and ice, in order to determine to what extent climate can be predicted at the scales from months to decades. Global scale remote sensing of the earth's surface and cloud cover are carried out by the International Satellite Cloud Climatology (ISCCP) and International Satellite Land Surface Climatology (ISLSCP) projects and include the Antarctic regions. A World Ocean Circulation Experiment (WOCE) is a main component of WCRP, particularly addressing the longer time scales. One project within WOCE is the study of the Southern Ocean, and specifically the Antarctic Circumpolar Current and its interactions with the global ocean. Proposed WOCE observations will include the global fields of the physical and chemical properties of the ocean, the sea surface topography and motion, and surface ocean fluxes of heat, moisture and momentum. Time varying fluxes of carbon and associated biogenic elements in the global ocean are to be evaluated by the Joint Global Ocean Flux Study (JGOFS).

Atmospheric trace gases and aerosols and the processes by which they affect climate are the subject of the proposed International Global Atmospheric Chemistry Program (IGACP) which includes regional projects in the Antarctic. The marine ecosystem in the Antarctic in monitored under the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR).

Changes in the sun's energy output (both as electromagnetic radiation and charged particles) occur at a variety of time scales. The interactions of the solar wind with the earth's magnetosphere and atmosphere are most easily observed in the Antarctic. Solar-terrestrial interactions are undoubtedly an important factor in global change and their study is the theme of ICSU's Solar-Terrestrial Energy Programme (STEP) to be carried out in the 1990s by both ground and satellite-based observations. STEP and IGBP are complementary to each other, and the Antarctic plays a vital part in each.

Close liaison and co-operation between a SCAR contribution to the IGBP and the above and other international programmes is essential for a successful study of global change.

Next step

IGBP planning is proceeding through international and national committees. The polar regions are crucial in the context of IGBP-global change, and warrant special attention.

Steps necessary for developing and implementing the scientific goals of IGBP in Antarctica will be initiated by SCAR. They include:

- Develop a focused SCAR action plan for an Antarctic component of the IGBP;
- Outline a strategy for a cobernet programme for collecting "early-warming" data on global change, including the selection of suitable parameters such as sea-ice and temperature and sites for geobiosphere observatories;
- Examine the adequacy of present and planned surface and satellite observational systems for the Antarctic, and recommend optimal strategies for their use in an Antarctic component of the IGBP;
- Outline a strategy to archive, catalogue and distribute Antarctic data relevant to IGBP;
- Examine the adequacy of existing coupled numerical models of use in the Antarctic, and improve these models where needed;
- Examine ongoing and planned programmes in the Antarctic and their potential role as Antarctic components in the IGBP.

SCOPE

SCOPE: A programme for analysis of critical environmental problems of global significance

Through its Scientific Committee on Problems of the Environment (SCOPE), the International Council of Scientific Unions undertakes to foster and organize collaboration among scientists from more than 35 countries, representing a wide range of disciplines, in the preparation and dissemination of careful analyses of environmental problems of global significance. The mandate of SCOPE is to environmental changes and the effects of these changes on human-beings; to assess and evaluate the methodologies for measuring environmental parameters; to issue recommendation for current and future research and to stimulate new approaches; to establish itself as a source of informed advice for the benefit of research centers, organizations and agencies with respect to environmental problems.

Each effort involves the enlistment of experts from all relevant disciplines, critical examination and synthesis of available evidence, and publication, after careful review, of the principal findings, with respect both to established knowledge and to controversial questions, together with recommendations for future research and sound environmental management practices.

Relations between SCOPE and IGBP

Two main characteristics of SCOPE's method of operation can be stated as follows:

- The problems selected are multi-disciplinary, have major significance on the world environmental scene and do not duplicate other collaborative efforts;
- SCOPE does not engage directly in research at bench or field level.

SCOPE sees therefore a very clear complementarily between its and IGBP's efforts in that SCOPE may assist IGBP a) in pointing out what research is needed and b) at a later stage, in looking further at the results in the context of the then available knowledge.

The General Assembly of SCOPE, at its VIIth meeting in Budapest, reviewed with IGBP officers present at the meeting the status of relations already existing between IGBP and SCOPE and the ways to develop further collaboration between these two bodies. In particular the Assembly:

- noted with appreciation the development of the International Geosphere-Biosphere Programme (IGBP);
- stressed the complementarity between SCOPE and IGBP, whereby IGBP establishes or coordinates global research and measurement programmes, whereas SCOPE identifies and reviews international environmental problems and research needs;
- noted with satisfaction close collaboration between SCOPE and IGBP;
- recommended that the SCOPE Executive Committee take appropriate and continue its efforts to identify and review key issues of global environmental concern."

It should be noted that SCOPE participated actively in the preparatory phase of the Global Change programme by organizing, together with its U.S. Committee and with Intecol, a preliminary international workshop in St Petersburg, Florida (November 1985) on spatial and temporal variability of biospheric and gespheric processes, the results of which have just been published as SCOPE 35, "Scales and Global Change", by T. Rosswall, R.G. Woodmansee and P.G. Risser. We can also cite the two expert meetings organized jointly by MAB and SCOPE in January 1987 to a) review the concept of geosphere-biosphere observatories and give recommendations on their design and definition in the context of global change studies and b) develop a working definition of ecotones, or landscape boundaries, and identify testable research questions. Results of these consultations have been published as special issues 16 and 17 respectively of "Biology International", the IUBS science magazine.

Meanwhile, part of SCOPE's projects have in return received impulses from the emerging Global Change programme discussions and can be seen as regular SCOPE projects with special relevance to Global Change. Such projects are labelled as Global Change related projects. Some follow the standard format of major SCOPE studies, with a series of workshops and topical working groups over a 3-4 year period, culminating in a synthesis report. This will be the case of the current projects on organic matter budgets, on ecotones in a changing environment and on trace gas exchange. Other efforts, like our previous contributions to the planning of IGBP, will focus more narrowly on critical methodological issues and involve a less ambitious workplan and duration. Such studies address, for example, experiments at the ecosystem level, the use of small catchment zones for integrated ecological studies, and the needs for long-term ecological research programmes and sites.

Organic matter budgets - the effects of climate change on production and decomposition in coniferous forests and grasslands

The predicted rapid changes of global climate will certainly effect the fundamental ecological processes of the planet. However, predicting the response of ecosystems to these climate changes is complicated by interactions among the effects of concurrent changes in temperature, water availability and atmospheric carbon dioxide concentration on a number of key ecosystem processes such as primary production and decomposition of organic matter.

To improve our understanding of ecosystem response to climate change, closer collaboration among plant physiologists, microbiologists, ecologists, soil scientists, atmospheric scientist and mathematical modelers is required. Whole-plant response to simultaneous changes in atmospheric carbon dioxide content, temperature regime and water availability has to be investigated. The direct and indirect effects of these environmental changes on soil processes must also be documented. Finally, ecosystem models need to be developed that link the plant and soil responses to climate change. These diagnostic and predictive models should be designed to work at multiple spatial and temporal scales for extrapolation and analysis of various climate-change scenarios.

In response to this need SCOPE initiated, in the second half of 1987, a study on the effects of climate change on production and decomposition in coniferous forests and grasslands. The objectives of this project, as stated at the preliminary meetings of the scientific committee responsible for the conduct of the project, are to:

1. Critically assess our understanding of the effects of climate change on production and decomposition processes in coniferous forests and grasslands, both temperate and tropical.

2. Review extant forest and grassland ecosystem models and evaluate their usefulness for studies of the effects of climate change on production and decomposition processes.

3. Develop a foundation for the design of diagnostic and predictive models to describe the effects of climate change on production and decomposition processes in coniferous forests and temperate and tropical grasslands.

The workplan of this project includes the organization of three international workshops (35-45 participants) in 1989-90, four or five working groups (4-5 participants), each focussing on a specific model, and the publication in 1991 of the corresponding reports.

The first workshop, to be held in Woods Hole, USA, in April 1989, will a) review existing knowledge on the rates of production and decomposition and on factors controlling these rates in coniferous forests and grasslands, b) review existing whole system models that include climatic parameters and provide production and decomposition estimates on outputs and c) develop guidelines for further data collection and analysis and model development. The second workshop will aim to discuss and select forest and grassland models, climate scenarios and test regions in forests and grasslands to conduct modelling exercises. The third, or synthesis workshop, will draw conclusions from the entire study and develop foundations for the design of diagnostic and predictive models, as well as plans for future research on ecosystem response to global change.

It is anticipated that the IGBP Coordinating Panel on Effects of Climate Change on Terrestrial Ecosystem will participated in the activities of this project and, in particular, in the three main workshops. The conclusions of the Organic Matter Budgets project will contribute to the definition of a scientific basis, on which an IGBP research programme on the effects of climate change on forest and grassland systems can be formulated.

Ecotones in a changing environment

The science of ecology is undergoing a transition with increasing consideration of heterogeneity in ecological systems. Natural and human disturbances cause most ecological systems to be patchy at several spatial and temporal scales. Most studies thus far have considered each landscape element or "patch" as a homogeneous unit and examined how patch size, shape, contagion, etc., influence several response variables including genetic variation, population dynamics, species diversity, energy flow, and nutrient cycling. The transition zones between patches may also be important in mediating the structure and functioning of ecological systems. Ecotones may influence landscape characteristics by exerting control over the flow of materials, information, and energy between patches. Ecotones may also serve as patches themselves, and provide primary habitats or refuge for species. To address these various issues, in 1987 SCOPE decided to launch a project that focusses on ecological flows and biodiversity associated with ecotones in hopes of advancing ecological theory and improving land management.

Studies on the relationships between landscape structure, ecological flows, and biodiversity are especially important now because human activities are becoming increasingly prevalent in most landscapes. These activities are often of a kind and scale that is without natural counterpart and often result in novel patterns at the local, regional, and global levels. Research on ecotones needs directly consider the linkages between differing organizational levels.

The SCOPE study is designed as an expansive investigation of biotic diversity and ecological flows associated with ecotones. These are examined within the context of four general questions:

1. How do ecological system boundaries influence biotic diversity and the flows of energy, information and materials?

2. How will biodiversity and ecological flows associated with ecotones respond to environmental changes, especially in a global climate, sea level, land use, and atmospheric trace gases?

3. To what extent will human alteration of ecotones influence global response variables?

4. How should ecotones be managed within a changing environment?

Activities of this project will be centered around three international workshops. The first workshop, entitled Biodiversity, Ecological Flows and Ecotones, will examine the patterns of biodiversity and ecological flows associated with patch boundaries, the mechanisms underlying these patters, and their consequences for system functioning. It will be basic in approach and focus primarily on landscapes subject to natural agents of change.

The second workshop will focus on the influences of human-induced environmental change on biodiversity and flows at ecotones, especially changes in global climate, sea level, land use, and atmospheric trace gases. One of the goals is to assess which species and which ecological systems are most susceptible to such changes and the factors that underlie this sensitivity. This knowledge is necessary for management. It may also be necessary in the context of the IGBP which is examining human-induced changes in the biosphere.

The third workshop will consider how ecotones should be managed within the context of a changing environment and to what extent susceptible species or ecotonal systems can be stabilized, preserved, or restored to maintain or create optimal landscape characteristics.

It is anticipated that this project also will contribute to the work of the Coordinating Panel on Climate Change Effects on Terrestrial Ecosystems and to the planning of an integrated long-tem research programme in this field.

Trace gas exchange

Despite the importance of atmosphere-biosphere exchange for the composition of the atmosphere, and consequently also for global climate, the processes which control the flux rates and the magnitudes of the fluxes from many ecosystems remain poorly known. This is due to the complexity of the biological and physico-chemical systems involved, as well as to the difficulty of actually measuring exchange fluxes in the field. To improve our understanding of atmosphere/biosphere interactions, a close collaboration between chemists, biologists, and atmospheric scientists is required. Analytical methods to determine the relevant gas fluxes at the concentrations and against the background levels found in the natural atmosphere need to be developed and verified; ecosystems need to be characterized in relation to their potential for gas exchange with the atmosphere; physiological controls and biochemical processes involved in gas production and uptake have to be investigated; and the micrometerological theory and field methods required to measure the exchange fluxes have to be developed. Finally, diagnostic and predictive models need to be developed at multiple spatial and temporal scales for extrapolation and analysis of scenarios of environmental change.

The multidisciplinary collaboration required to fulfill these tasks has begun to develop in the last few years, especially between atmospheric chemists and micrometeorologists. There still remains, however, a need for more intensive interaction between disciplines, including ecology, microbiology and plant physiology. This appears particularly urgent at this time, in view of the development of the IGBP.

In response to this need, in 1987 SCOPE initiated a project on Trace Gas Exchange between Terrestrial Ecosystems and the Atmosphere with the aim to foster interaction between the different scientific disciplines relevant to the study of biosphere/atmosphere exchange and also between the members of the international scientific community involved in the planning and execution of future research projects in this field.

The scientific advisory committee appointed for the conduct of this project defined the following objectives:

1. Critically assess our understanding of the controls and interactions in the plant-microorganism-soil-water system which regulate trace gas exchange with the atmosphere. Emphasis is initially to be placed on the exchange of methane and the oxides of nitrogen, but the scope of the group's activities may eventually be broadened to include other gases of importance for atmospheric chemistry and climate.

2. 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 assess measurements at larger spatial scales such as aircraft-based techniques and approaches using remote sensing.

3. 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. Such models form a critical link between the scale (in time and space) at which measurements are conducted and the scales which are of interest for a scientific understanding of the exchange of gases between the biosphere and the atmosphere. These range from the microscopic scale, at which microbiological production and consumption of gases take place, to the regional and global scales relevant for atmospheric chemistry and climate.

The first main international workshop of this project will be organized in February 1989 as a Dahlem conference in Berlin. The goal of this workshop is to develop an understanding of the chemical, biological and meteorological processes involved in the exchange of trace gases between the biosphere and the atmosphere, and to investigate the role of this exchange in regulating the atmospheric chemistry and world climate. The workshop is intended to provide a state-of-the-art review of this scientific problem, and to initiate and advance interactions between the disciplines and nations involved. This workshop will focus on the biological controls of methane and nitrogen oxide emissions from terrestrial systems.

A second international working meeting (Stockholm, 1990) will add three important topics. Firstly, the role of oceans in trace gas exchange will be considered; secondly, other key trace gas species (S compounds, ammonia, hydrocarbon) will be included and thirdly, attention will be paid to global modelling aspects and especially to the scaling issues induced by the extrapolation from local data and measurements. This Stockholm conference will be a coordinated effort of the SCOPE project on Trace Gas Exchange and the IGBP Panel on Terrestrial Biosphere-Atmospheric Chemistry Interactions. It is expected that the results of this conference will contribute to the development of an IGBP research programme on trace gas fluxes.

Methodology studies

Biogeochemistry of Small Catchments

Small catchments with surface areas ranging between 1 to 10 sq.km. have usually been studied in undisturbed landscapes but data also exist for agricultural and even urban catchments. Such units are large enough to mirror complex interplay among different environmental parameters, yet sufficiently small to be manageable by a team of researchers from the fields of biology, geology, chemistry and the atmospheric sciences. Principal objectives of work on small catchments is the gathering of biochemical data which permit the quantification of the flux of elements, minerals, organic matter, gases and water entering or leaving the system. Equally important is the understanding of interactive processes that operate within a catchment. In the final analysis units of material fluxes will be subjected to modelling to bring to light the overall environmental operation principles of small catchments. At present, data is being collected from about 100 small catchments, mostly situated in the sub-arctic and temperate zones on North and Central Europe and North America.

Thus a substantial body of information already exists in different parts of the world. The main objective of the SCOPE project is to synthesize this existing knowledge to further develop the emerging multidisciplinary "small catchment approach". The results of individual catchments are local and strictly speaking unique, but at the same time comparable on the global scale thanks to common approach and methodology. So they may contribute to the better understanding of the geosphere-biosphere functioning.

One international workshop on the biogeochemistry of small catchments will be organized in Czechoslovakia in 1990. It is anticipated that the results of this workshop will encourage the creation of a world-wide network of small catchments yielding scientifically reliable information on both short-term and long-term environmental changes, large or subtle, man-made or natural, as well as providing guidelines for environmental monitoring programmes.

Ecosystem Experiments

The need to conduct ecosystem-level experiments in order to develop an understanding of the potential consequences of global change on whole system function is readily apparent. We already have some experience in conducting these experiments and an ample demonstration of their utility. However, there are many types of experiments that have not been attempted but from which vital information could be derived.

In response to this need, in 1987 SCOPE established a committee to develop a plan for reviewing our collective experience in the performance of ecosystem experiments and to assess the kinds of experiments needed to understand the consequences of global change. An international workshop, held in June 1988, undertook to review current knowledge in the area, taking into account natural experiments (Mt St Helen, El Nino episodes, major fires, past climate changes), large-scale human-induced changes (desertification, deforestation, acidification, water diversion, etc.) and controlled ecosystem studies. The second task of the workshop was to develop general guidelines for future experiments, addressing in particular the following areas:

i) What are the most critical needs in the understanding of ecosystem functioning that can, or only, best addressed by experimentation?

ii) What design protocols need to be considered in order to unambiguously interpret the results of whole-system manipulations (replications, duration, interactions, etc)?

iii) In view of the high cost and long-term nature of ecosystem manipulations, what mechanisms can be utilized to ensure the involvement of a wide group of scientists, both nationally and internationally?

Long-Term Ecological Research

SCOPE, the U.S. Committee for SCOPE and the MAB National Committee in FRG organized jointly in September 1988 a workshop to address the issue of long-term ecological questions and appropriate research facilities in an international context. The objectives of the workshop were:

i) To provide a forum for describing and analyzing selected existing long-term ecological research sites and networks from various countries;

ii) To further define the rationale for long-term ecological research and identify important existing and emerging scientific questions which could most appropriately be addressed at these sites;

iii) As possible, to formulate a plan for international communication and coordination among long-term ecological sites.

Discussions during the workshop considered a number of vexing questions, such as the proper balance between studying specific phenomena and collecting data on comparative core topics, the need for both longitudinal (temporal) and spatial data, the relationship between research programmes on these specifically dedicated sites and other related sites, the ways in which site-specific research augments or detracts from other research programmes, the appropriate amount of centralization of data storage and manipulation, and the costs of establishing and maintaining site-specific long-term ecological research programmes.

SCOR/IOC

Introduction

The Committee on Climatic Changes and the Ocean (CCCO) was established by SCOR in 1979 and is cosponsored by the Intergovernmental Oceanographic Commission of UNESCO. CCCO was charged with the development of the oceanographic activities required for the success of the World Climate Research Programme. The CCCO's functions are to identify ocean-climate research problems requiring increased international attention, stimulate research activities thereon and recommend to SCOR and IOC how these activities should be implemented. The CCCO being the main international scientific body dealing with the oceans and climate change, therefore cooperates with the WMO/ICSU Joint Scientific Committee in planning the World Climate Research Programme.

The core programme of CCCO has three major components:

- TOGA - A Study of the Interannual Variability of the Tropical Oceans and Global Atmosphere
- WOCE - The World Circulation Experiment
- OOSDP - Ocean Observing System Development Programme

CCCO, whose Secretary and supporting staff operate within the framework of the IOC Secretariat at Unesco Headquarters in Paris, oversees TOGA and WOCE as part of its overall responsibility to stimulate international ocean/climate research. The intergovernmental aspects of these programmes are co-ordinated by the IOC through its Technical Committee on Ocean Processes and Climate and by the joint WMO/IOC Intergovernmental TOGA Board.

Other programme elements include data management activities, modelling efforts, palaeoclimatological studies, development of a research programme which will investigate problems in the field of coupled ocean-atmosphere boundary layers, and an oceanic carbon dioxide research and monitoring programme. This last effort will be carried out in close collaboration with JGOFS.

The Ninth Session of CCCO was held in Paris in May 1988. The Committee reviewed the progress being made on the two main oceanographic components of the World Climate Research Programme.

The first of these, the Tropical Ocean Global Atmosphere (TOGA) experiment, which commenced in 1985, involves a decade of intensified observations with rapid distribution of data as a direct input to the modelling of the coupled tropical ocean-atmosphere system. TOGA is specifically intended to test the predictability of interannual climate variation and the influence of the tropical oceans on the global atmosphere as evidenced by such events as "El Nino".

The second, the World Ocean Circulation Experiment (WOCE), with an intensive 5-year observational programme, including shipborne, satellite and drifter measurements, commencing in 1990/1991, will provide a data set for the testing of models for the prediction of climatic change. WOCE will provide the data necessary to model the full-depth circulation of the global oceans as a component in the evolution of long-term changes in global climate. WOCE will establish a physical oceanographic basis of foundation for other global-scale climate- related projects now in the planning stage, including the Global Energy and Water Exchanging Experiment (GEWEX) and the Joint Global Ocean Flux Study (JGOFS). It will also provide an input to other major co-operative ventures such as the International Geosphere-Biosphere Programme (IGBP).

Among the elements considered crucial to the future success of the WCRP by the Committee are the development and reliability of various support systems, the evolution of necessary technologies, and increased international co-operation on the part of the developing and developed countries. At its most recent meeting, for example, CCCO heard presentations on the progress of satellite programmes, new developments in numerical modelling techniques, and the

results of experiments which increase the understanding of momentum transfer at the air/sea interface at high wind speeds.

TOGA is breaking ground in international collaboration, while WOCE will present new challenges for intergovernmental bodies, such as IOC, as the appropriate mechanisms for fostering those aspects of ocean research and related services requiring intergovernmental co-ordination.

Tropical ocean and global atmosphere

Now in its fourth year, TOGA has achieved a greatly expanded and intensified network of subsurface temperature observations in the tropical Pacific using expendable bathythermographs deployed from merchant vessels, an enlarged tide-gauge network development of data distribution under various intergovernmental frameworks, and the establishment of special TOGA ocean data analysis centers in France and the USA. Recent developments will result in an improvement in data coverage of the Indian and Atlantic Oceans, which so far has been inadequate. A number of major experimental studies of upper ocean processes have been undertaken, although access to some critically important oceanic regions remains a concern.

Progress also is being made in the development and comparison of models incorporating ocean data. For the first time, there is "real time" reporting of the climate system as it evolves through the Climate Diagnostics Bulletin, published by the Climate Analysis Center (CAC) of the USA's National Oceanic and Atmospheric Administration.

The Seventh Session of the TOGA Scientific Steering Group (SSG) was held in Cairns, Australia, 11-15 July, 1988. Progress continues to be made in developing the observation systems in all three tropical oceans. The SSG took an important philosophical step that took notice of the fact that TOGA has been largely Pacific Ocean and El Nino/Southern Oscillation oriented. It decided to propose an enlarged charter for the JSC/CCCO TOGA Numerical Experimentation Group (NEG) which would also encompass atmospheric variability on all TOGA time scales, including the 30-60 day oscillations. It was anticipated that this would aid in leading the focus of TOGA away from this limiting orientation. Another important step, often previously deferred, was taken with the decision to establish a study group that would plan for an eventual reanalysis of the entire ten-year TOGA data set, including all delayed data, using the most advanced models and algorithms. There is accumulating evidence that many initial analyses were flawed in ways that are now, or will eventually be, correctable.

The SSG's great interest in a preliminary proposal to vastly increase the number of ATLAS-type moored buoys by as many as 60 in the Pacific Ocean reflects the realization that improved in situ observations of the wind field and thermal substructure are required to quantify the net heat fluxes necessary to improve the performance of coupled models. In addition, it was agreed that effort should be devoted to improving analyses of the low-level atmosphere if atmospheric models are going to produce better surface salinity field (and later, with the new expendable instruments, the subsurface structure) for deriving dynamic heights and for model calculations of heat fluxes. The SSG also endorsed an ambitious proposal by U.S scientists, with possible support of Australian, Japanese, Chinese and French scientists, to carry out a Coupled Ocean Atmosphere Response Experiment (COARE) during 1991-1992. Its goal is to better understand the physical processes which maintain the mean and transient states of the warm pool regions of the western Pacific.

Operational near-real-time ocean modelling is now underway by French oceanographers for the Atlantic Ocean. Model runs assimilating FOCAL/SWQUAL data have compared well with USSR SECTIONS data. Beginning in 1989, it is planned, as part of TOGA, to run the model regularly to provide a "real-time" monthly description of oceanic conditions as is currently done in the Pacific. Recent statistical studies fail to substantiate claims of correlations between the position of the Atlantic Inter-Tropical Convergence Zone (ITCZ) and Sahelian rainfall. Further work needs to be done to establish unambiguously the relationship of Sea Surface Temperatures to tropical droughts.

Impressive progress can be reported in the Indian Ocean with the near completion of the TOGA tide gauge network by Professor Wyrtki; the development of new expendable bathythermograph

(XBT)lines by Mauritius and Pakistan, USSR oceanographic studies of air-sea interaction; and the contributions of Australian and French regional studies. Regional throughflow studies, however, were curtailed due the failure of a request of access to strait waters by a research vessel. The first attempts at numerical modelling in the Indian Ocean were initiated by Florida State University and the Oxford University Group. The results again emphasize that poor resolution of the heat fluxes is a major problem.

World ocean circulation experiment

Gearing up for the implementation of the World Ocean Circulation Experiment is currently presenting the greatest challenge to CCCO. WOCE will combine microwave data from new extensive array of deep oceanographic hydrographic sections across all major ocean basins, direct current measurements and studies of water formation and mixing and the exchanges between basins.

WOCE will be the first attempt ever to survey the ocean circulation globally, even for a brief period. The aim is to collect a data base that will support the development of the global eddy-resolving ocean circulation models which should be feasible with increased computer power by the end of the century. WOCE is expected to carry oceanography into a new era of global analysis and modelling, similar to the advance in meteorology as a results of the global weather experiment in the 1970s.

The development of satellite observing techniques, in particular microwave altimetry and scatterometry, has made possible systematic global mapping of sea-surface height and windstress as well as the provision of information on the surface fluxes of heat and water. Satellites especially designed for this purpose will be available during the period of the Experiment. The programme of in-situ measurements planned for WOCE is designed to ensure that the most detailed description possible of the ocean's circulation is obtained using other measurement techniques concurrently with the satellite observations. These measurements are to be utilized in the three Core Projects and will require a massive deployment of the available oceanographic vessels and instruments, as well as the investment of substantial additional resources. It will also be necessary to upgrade existing procedures for processing data exchange, and archiving, and to establish special data analysis centers to create data bases in the form required for diagnostic and prognostic modelling.

Activities in support of the planning phase of WOCE have been carried out thus far mostly by the WOCE Scientific Steering Group and its expert working groups and committees, as well as within national programmes. Wider international interest is expected to develop at the International WOCE Scientific Conference, to be held at Unesco Headquarters in Paris.

The Conference will be held at Unesco Headquarters, Paris, from 28 November to 2 December 1988. It is being hosted by IOC and sponsored jointly by IOC, WMO, ICSU and SCOR. It will explain the objectives and plans of WOCE, review national plans and hopefully stimulate wide international interest in the Experiment, which is considered by its planners to be a vital rung in the ladder leading to global climate prediction.

The Implementation Plan for the World Ocean Circulation Experiment (WOCE) is being finalized in preparation for its presentation and review at the International WOCE Scientific Conference. The Plan will be published in two volumes. The first will give an overview of WOCE, its organization, and specific requirements for resources needed for its implementation. The second will give the detailed scientific framework for WOCE, including the three "Core Projects" which form the heart of the Experiment. The Implementation Plan is being designed to provide individual scientists, institutions and nations with the basis on which to assess the opportunities for them to participate in WOCE and to develop their own research plans.

As facilitating forerunners to the Conference, regional WOCE workshops were held in Qingdao, China (6-8 April 1988) and in Buenos Aires, Argentina (18-22 July 1988) to assist developing countries in the regions to organize themselves for making a coordinated contribution to WOCE. The success of these workshops has stimulated planning for others; the next one will likely be in Singapore in early 1989.

WOCE-TOGA issues

Certain aspects of climate variability are not covered by either WOCE or TOGA, particularly climate variability on time scales up to a decade. WOCE is global but does not take into account variability, being mainly a "snapshot" description of ocean circulation. On the other hand, TOGA is focused on the tropical ocean upper layer and its coupling to the atmosphere. The CCCO Tropical Atlantic Panel recognized that additional efforts were needed to address this gap. Accordingly, the Panel is evolving plans for an experiment covering the whole Atlantic, that would complement existing WOCE and TOGA plans, and map the evolution of the ocean circulation at basin scale. Such an experiment would allow testing of hypotheses based on meridional heat transport that address unexplained long-term large horizontal-scale SST anomalies that appear in the historical data.

Ocean carbon dioxide programme

It was agreed at CCCO-9 that the draft CO_2 proposed programme had already become outdated and that a revised version should be produced before distribution as a working document. It was further recognized that the terms of reference of the CO_2 Panel should be revised in light of the developing interrelationships with JGOFS. The principal change incorporates a statement to "work co-operatively with JGOFS to ensure adequate measurement of satellite ocean color, in-situ biological measurements, dissolved organic carbon and related carbon system measurements, and sediment flux". Membership changes were also planned.

Air-sea fluxes

Following a meeting in New Orleans, 4-9 January 1988, the JSC/CCCO working group on Air Sea Fluxes developed a Global Data Assimilation Programme for Air Sea Fluxes. It consists of two phases. The preparatory phase (1988-1990) will be devoted to a series of studies on methods for assimilating data, particularly new forms of satellite data; the dependence of satellite sensor algorithms on the assimilation scheme; and the interdependence of wind and wave data on both the algorithms and the assimilation scheme. The second phase, the fully operational phase (1991 onwards), will produce 6-hourly flux fields at about 10 X 10 resolution, consistent with the then operational global forecast models. The assimilation scheme should encompass all relevant microwave data including both wind and wave information. This phase will be preceded by a test phase which would coincide with the calibration and validation phase of ERS-I.

The Committee noted that the working group was fulfilling its charge but expressed concern that certain questions were being left unaddressed. Japanese scientists, for example, have recently shown that the wave-stress relationship employed by the careful filed experiments. The working group will consider this and other field work that may have bearing on its work.

Ocean observing system development programme (OOSDP)

The OOSDP Group met in New Orleans, 9 January 1988. The Voluntary Observing Ship pilot study, the initiation of which was stimulated by the Group, has developed a plan to establish a subset of at least 50 of the voluntary Observing Ships (VOS) operating in the North Atlantic which have a good record of reporting. Recruitment of these ships is currently underway to include them in the VOS Special Observation Programme - North improvement in data accuracy which would be achieved from the VOS fleet of the World Weather Watch. CCCO endorsed this effort and also endorsed the maintenance of a climate satellite data base which the Group began as a pilot effort. Some means needs to be found to maintain and distribute it regularly.

Paleoclimatology

The CCCO Paleoclimatology Panel reported on several findings which may well be to IGBP in the context of records of past global change:

(i) The Vostok record of atmospheric CO_2 indicates high CO_2 (280 ppm) during interglacial times and low CO_2 (200 ppm) during glacial maxima.

(ii) A reconstruction of the global deep water circulation was deduced from the distribution of ^{13}C in the shells of benthic foraminifera. Deep water formation occurred in the North Atlantic but not in the Norwegian Sea which remained ice-covered year round. Intermediate water was formed in the North Atlantic from the Mediterranean outflow and from sinking waters south of the polar front. A deep front in the Indian Ocean separated well oxygenated intermediate waters from cold, poorly oxygenated deep water.

(iii) Accelerator mass spectrometry offers a new way to obtain a ^{14}C age from the climatic record of deep sea sediments. Comparison of ^{14}C ages of benthic and planktonic foraminifera in Pacific cores indicates the ventilation rate of the ocean changed from about 2000 years during glacial times to about 1500 years during the last 10.000 years. A North Atlantic core indicates deglacial warming (10° off Portugal) occurred in less than four centuries about 12.000 years ago. Evidence of such an abrupt climate change is also being found in Pacific cores.

(iv) A time-dependent, two dimensional model of the climatic system with an interactive ocean, atmosphere, cryosphere, and continent was run with forcing by insolation varying according to the Milankovitch model. The continental ice volume simulated was in agreement with the geological and isotopic record.

Programme support

CCCO has now been in existence for nine years, It has traditionally been supported by its two sponsoring organizations, IOC and SCOR, from their regular budgets. SCOR has been grateful for continuing grants from ICSU which provide a large part of SCOR's annual financial allocation to CCCO. Similarly, IOC receives some Trust Fund contributions from certain Member States which are designated for use by CCCO. A large grant from several US agencies to SCOR provides the salary of the CCCO Secretary and certain operational expenses. Several countries have seconded staff to the programme; the CCCO Secretariat is supported by the U.S.A. (2) and France (1): the International WOCE Planning Office by Canada (1), U.K. (1) and FRG (1). These types of support are vital to a large and complex programme such as that being developed and implemented by CCCO.

SCOR/JGOFS

Introduction

At the recent General Meeting of SCOR in Acapulco, the retiring President, Professor G. Siedler, identified the JGOFS initiative as a highlight of his term in office. He noted that the formal decision to launch the Joint Global Ocean Flux Study under the auspices of a new SCOR scientific planning committee had been taken by the Executive Committee at its meeting in October 1987. He expected that JGOFS will eventually constitute an important oceanic component of IGBP and close contacts have already been established between the two programmes. This relationship was the subject of discussions between the SCOR officers and Professor J. McCarthy in Acapulco.

The first steps in planning for JGOFS were taken in early 1987 when SCOR, at the request of several national and international bodies interested in flux studies, convened an International Scientific Planning and Coordination Meeting at ICSU headquarters in February. It brought together scientists from a number of countries who are active in studies of major biogeochemical studies in order to discuss current and planned national and international research programmes in this field. The meeting was asked to consider whether it would be appropriate to establish and develop an international coordinated programme of ocean flux studies which would provide a framework for cooperation between existing national programmes in the field of flux studies and with related international experiments such as the World Ocean Circulation Experiment (WOCE), the International Global Atmospheric Chemistry Programme of ICSU.

That meeting heard presentations about a number of existing programmes of ocean flux studies (USA, FRG, UK, France, Japan) and about relevant activities in other countries such as Canada, China and The Netherlands. It became clear that while these national programmes have different specific emphases (the European studies focus more strongly on coastal zones, for example), there are many common goals and elements to be found among them. The unanimous decision was taken that there should be an internationally coordinated Joint Global Ocean Flux Study whose goal was stated as follows:

> To 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, the sea floor and continental boundaries.

One rationale for JGOFS was that plans for studies of oceanic biogeochemical cycles already existed in a number of countries and it was agreed that major benefits could be gained by combining these in a coordinated international effort. A central focus on the carbon cycle is expected to help elucidate the questions surrounding the fate of anthropogenic CO_2. About half of it is know to be taken up by the oceans, but the processes by which this occurs and the capacity of the ocean to absorb increasing levels of CO_2 are largely unknown. Thus, JGOFS is extremely relevant to the WCRP and IGBP.

A long-term goal for JGOFS has been defined: to establish strategies for observing on long time scales, changes in ocean biogeochemical cycles in relation to climate change.

The possible basic elements of a JGOFS programme were discussed under the categories of global studies, process studies, coastal ocean studies and modelling activities. It was agreed that a global oceanic CO_2 project which had been considered in the context of WOCE, should be planned and carried out instead by JGOFS in close association with WOCE. A statement was issued and sent to various satellite agencies stressing the importance of satellite ocean color measurements for JGOFS.

In considering how JGOFS could best be planned and organized, it was agreed to propose that a Scientific Planning Committee be established under the auspices of SCOR. The meeting suggested that SCOR consider the following terms of reference for this committee:

- To identify the fundamental scientific issues and detailed goals and objectives for an international Joint Global Ocean Flux Study;
- To develop a scientific plan and to establish requirements for carrying it out;
- To recommend the necessary actions to be taken to implement the plan and coordinate and manage the resulting activities;
- To collaborate, as appropriate, with other related programmes and planning activities;
- To report regularly to SCOR and related bodies on the state of planning and accomplishments of JGOFS.

The participants in the February 1987 planning meeting also wished to take advantage of the enthusiasm and momentum generated by their discussions. It was recognized that the North Atlantic is the best studied of the ocean basins and that this ocean is a priori the best possible place to develop process studies and document the variability of the carbon system. It was also recognized that several countries were already planning programmes in this basin. It was, therefore, decided to convene a workshop in order to consider the feasibility of coordinating these programmes in a scientifically beneficial manner. The offer of France to host this workshop at the Ecole Polytechnique in Paris was accepted and it took place in September 1987 under the Chairmanship of Dr. M. Whitfield (UK).

The specific topics to be addressed by the North Atlantic Planning Workshop included:

- Detailed information on national ship tracks, mooring plans and scientific programmes;
- Advantages and disadvantages of combined national efforts;
- Satellite data variability and interpretation;
- Modelling, theory and data management;
- Upper ocean programmes (water column studies);
- Benthic flux studies.

It was expected that this workshop would provide an international perspective for the scheduling of individual national programmes of ocean flux studies in the North Atlantic and for an assessment of the proposed scientific objectives and geographical coverage of these programmes. Taking into account the goals for JGOFS as stated at the first international planning meeting, the workshop was also expected to see to what extent it will be feasible and beneficial to coordinate national efforts in an international study of ocean fluxes in the North Atlantic Ocean.

The main results of the North Atlantic Planning Workshop was the recommendation that a JGOFS Pilot Study take place in 1989. This effort will be a process-oriented study, focusing on the spring bloom and associated phenomena, progressing from south to north. The major international effort would be concentrated on a series of stations and moorings along the 20 W line in the northeast Atlantic basin. The meeting broke into a series of working groups on process Studies and Integrative Topics which addressed questions arising from the various national presentations such as the needs for process studies, the advantages of time series and transect studies, the benefits of international coordination for JGOFS studies in the North Atlantic, and so on. These groups formulated recommendations on upper ocean studies, particle flux studies, benthic flux studies, boundary exchanges, issues of modelling, sampling strategy and data management for JGOFS, remote sensing and basin-scale studies. The meeting ended with a serious consideration of the urgency and complexity of some of the planning issues which needed to be addressed in order for a JGOFS Pilot Study to be underway in early 1989. It was recognized that they presented a challenge which could only be met by a coordinated international effort.

Since these two preliminary planning meetings SCOR has moved to approve the recommendation that there should be a Joint Global Ocean Flux Study conducted under its aegis and has established an international planning Committee for JGOFS with the following membership:

B. Zeitzschel, FRG, Chairman
P. Brewer, USA, Vice-chairman
H. de Baar, The Netherlands
O. Brown, USA
S. Calvert, Canada
K. Denman, Canada
J.C. Duplessy, France
H. Elderfield, UK
R. Eppley, USA
M. Fasham, UK
D. Hu, China
I. Koike, Japan
K. Kremling, FRG
J.F. Minster, France
T. Platt, Canada
S. Tambiev,USSR

The Committee also has a number of corresponding Members, among them Professors J. McCarthy and T. Nemoto of the SC-IGGB. For the time being, all staff support for the JGOFS programme is being provided by the SCOR Executive Secretary although an effort to establish a JGOFS Secretariat is underway.

JGOFS activities to date

The first meeting of the JGOFS Committee took place in Miami in January. The meeting concentrated on two major items: the development of a Science Plan for JGOFS and the establishment of planning and management strategies for the Pilot Study.

The Science Plan, to be produced during 1988, will provide the scientific background and rationale for JGOFS, will identify and elaborate upon its detailed scientific objectives, discuss the technical problems to be solved in order to meet these objectives, and introduce preliminary proposals for strategies to meet them.

The Committee approved the recommendation of the North Atlantic Planning Workshop that there should be a coordinated programme on the 20° W transect (see above). The JGOFS North Atlantic Pilot Study, which will begin in early 1989, is being coordinated by a group of national chief scientists from the participating countries (Canada, FRG, The Netherlands, UK and USA).

At its first meeting the Committee established two working groups on topics which it considered needed to be addressed on an urgent basis; Data Management and Modelling. The Data Management group will give first priority to issues which can be resolved before the Pilot Study while the Modelling group will begin by reviewing existing models to determine which biogeochemical and physical parameters and fluxes appear to be most critical in controlling the global distribution of CO_2, nutrients and other biogeochemical tracers. This is expected to yield results which will influence the design of sampling strategies for JGOFS.

The JGOFS Committee has agreed that it should not be preoccupied with the Pilot Study at this early stage and should focus on the development of the Science Plan. There are, however, some existing plans for flux studies in the Pacific Ocean which may well benefit from coordination. Accordingly, an ad-hoc Pacific planning group has been working in correspondence towards a JGOFS Pacific Planning Workshop which is expected to take place in late 1989 after the Science Plan is published.

The Second Session of the JGOFS Committee took place recently in The Hague (Sept. 13 - 15). The meeting was hosted by The Netherlands Marine Research Foundation as were subsequent meetings of the JGOFS North Atlantic Pilot Study Cruise Coordinating Committee and the newly-established CCCO/JGOFS CO_2 Panel.

The main result of the JGOFS Committee meeting itself was that substantial progress was made towards the development of the JGOFS Science Plan. It began with a review of recent developments in national plans for oceanic flux studies and of information on activities in countries not yet formally involved in JGOFS. These discussions revealed an encouraging proliferation of plans for programs in several regions of the world's ocean, reaching well into the early 1990's.

The status of planning for the North Atlantic Pilot Study was reviewed briefly by the JGOFS Committee - a subsidiary committee chaired by Dr. T. Platt (Canada), which also met in The Hague, has the lead responsibility for the development of the Pilot Study. The plans for this process study of the 1989 phytoplankton bloom along the 20 degree West meridian involve six countries and are now in a very advanced stage.

While the Pilot Study plans are progressing under the leadership of this Cruise Coordinating Committee, the JGOFS Committee itself turned its attention to the important issues of longer-term plans for the overall program. Preliminary plans already exist in a number of countries for regional and process studies in the Pacific and Antarctic Oceans. However, the Committee renewed its commitment to produce a "Science Plan" before it proceeds any further with the development of an internationally coordinated JGOFS field program beyond the North Atlantic Pilot Study. Such a document is intended to enunciate the overall goals and objectives of JGOFS, to provide the acientific rationale for various components of the programme approval and to describe the basic strategies (global survey, regional and basin-scale studies, modelling and process studies) to be used in addressing the scientific problems.

Other issues discussed by the JGOFS Committee included remote sensing and future color scanners (what is the level of precision required for these instruments?), cooperation with WOCE, particularly with regard to global in situ measurement programs for CO_2 and pigments, and the links between JGOFS and other international global scientific programs such as the International Geosphere-Biosphere Program ("Global Change") and the International Global Atmospheric Chemistry Program.

The new CCCO/JGOFS CO_2 Panel will take the lead in planning a global survey of oceanic carbon properties in conjunction with the WOCE program. At its first meeting, the status of national plans were discussed, as were technical issues of measurements of the carbon system, chemical models, links to atmospheric measurement programs and modelling activities, data management, and so on.

The JGOFS science plan

Although JGOFS has been in existence for a very short time, the Committee has agreed, as noted above, to give a very high priority to the development of a basic scientific document before proceeding to make detailed plans for the international programme (other than for the North Atlantic Pilot Study). Such a document would elaborate upon the scientific rationale and plan Chairman drew a parallel with WOCE for which a "Scientific Plan for the WOCE" was published by WMO in 1986. This publication has become a basic working document for the WOCE community and is about to be complemented by a "WOCE Implementation Plan". For JGOFS (unlike WOCE), however, many of the fundamental equations and parameters are not known, or are poorly understood at best. For this reason, it was suggested that a JGOFS Science Plan would need to include more objective analysis of the basic scientific information than does the WOCE plan. A JGOFS Science Plan must also demonstrate that it is feasible to develop a truly global plan for flux studies which is not simply a compilation of existing national plans. Issues of technology need to be solution of old problems. Finally, it has been agreed that the JGOFS Science Plan should be regarded as an evolving document which can be revised periodically. In other words, the existence of a formal document ought not to limit the development of new scientific ideas for JGOFS.

In the discussion at the two sessions of JGOFS, many ideas have been exchanged as to the content and format of the proposed JGOFS Science Plan. Some suggestions as to its format were seen to have the disadvantage of pre-imposing an experimental plan upon the scientific problems which require discussion. It was agreed that these problems need to be presented in detail before a strategy for their solution is developed in the Science Plan. There was a consensus that issues of modelling and the needs of JGOFS for developments in this field must be addressed in the plan. Another important feature of the plan is that it must emphasize the global nature of JGOFS.

The committee has reviewed the original statement of the goal of JGOFS as formulated by the first international planning meeting. In its view, this goal needs to be restated in a much more specific and detailed manner. As an example, the central question for JGOFS relates to the fate of about half of the 5 to 6 gigatons of carbon produced annually from the burning of fossil fuels. About half of this can be accounted for in the increasing levels of carbon in the atmosphere, while the fate of the levels of carbon in the atmosphere, while the fate of the remaining 2 to 3 gigatons, presumably absorbed by the ocean, is not well understood. The relative importance of physical processes (transport from the surface layer by deep water renewal) and biological processes (new production in the surface layer and subsequent removal by sinking in detritus and faecal pellets) is a subject of debate in the scientific community. Current estimates indicate that (35+/-10) x 10^9 tons of carbon are removed annually from the euphotic zone by physical transport processes while new production accounts for about (20+/-10) x 10^9 tons/yr. Given these estimates and margins of error, it would appear that the importance of the biological and physical processes may be similar, but it must be recalled that the amount of anthropogenic carbon absorbed by the ocean is an order of magnitude less than these figures (i.e. 2-3 x 10^9 tons). Thus, it was agreed that a central goal of JGOFS should be to improve our ability to estimate new production by at least one order of magnitude in order to determine the capability of this "biological pump" to be pathway for a significant fraction of the 2-3 x 10^9 tons of carbon that enter the ocean each year from physical processes will also be required from WCCE in order for the oceanographic community to address questions of global change arising from increasing levels of atmospheric and oceanic CO_2 due to the burning of fuels.

The Committee agreed that this was a scientifically appropriate expansion of the original goal of JGOFS and that this type of approach should be taken in developing the first sections of the Science Plan before strategies for solving such problems are discussed. At its second meeting the Committee approved the following "specific objectives", or expansion of the basic goal of JGOFS:

> To study the biogeochemical processes which control and modify organic and inorganic carbon and associated biogenic elements. This objective implies the quantification of these and other processes involved in the cycles of elements, mainly oceanic transport.
>
> To determine the response of biogeochemical processes to physical and chemical forcing and their perturbations over seasonal to secular time scales. This will be achieved through process studies, large scale satellite and in-situ data acquisition programmes and the development of coupled physical and biogeochemical models of the ocean.
>
> To determine the response of the biogeochemical processes to anthropogenic perturbations. In particular the role of the ocean in moderating the atmospheric increase in anthropogenic CO_2 must be understood. This sets the time frame within which the JGOFS programme should be run. The required observation programme should be achieved during the next decade because it is necessary to describe the present state of the system in order to predict future changes. This also sets the precision to be achieved because of the expected magnitude of the anthropogenic perturbation.

The format of the Science Plan for JGOFS was determined as follows:

(1) Introductory section with historical perspective, rationale and restatement of original goal.

(2) Expansion of the original goal into a series of detailed scientific objectives to be addressed by JGOFS. In addition to the improvement of estimates of new production discussed above, other examples of such problems may be the ways in which carbon is partitioned into various pools in the ocean, the relationships between total production and new and recycled production, the importance of secondary production, bacterial production and grazing in the carbon cycle, the effects of seasonality on grazing in the carbon cycle, the effects of seasonality on fluxes, the effects of boundaries such as the ocean bottom (burial and re-suspension) or continental margins on the global balances of biogenic substances, the effects of advection and mesoscale eddies on chemical cycles, and so on.

(3) The scientific basis for the global survey - this chapter will contain a number of sections on the need for fundamental data, new technologies and the opportunities they present for rapid advances (satellite ocean color scanners, computing, new instrumentation, etc.), the needs for specialized data sets for the establishment of sea truths, a consideration of present modelling capabilities and the problems of assimilation of satellite data, and so on.

(4) The next chapter will address questions of methods and measurement protocols. This will build upon the work of the groups of experts for the twenty "core measurements" of the North Atlantic Pilot Study (see below).

(5) A series of regional descriptions will follow with statements of specific objectives for each, information on other programmes in the region (e.g., TOGA and WOCE), special problems posed for operations there and recommendation for action. This chapter will begin with a statement on the scientific basis for the division of the world ocean into these regions for planning purposes.

(6) The final chapter will be on process studies for JGOFS. The basin and global surveys may provide information on specific parameters and on their spatial and temporal variability, but they will not yield an understanding of the rates of transformations of matter and energy, the influence of physical forcing on these rates or of the factors controlling fluxes and biogeochemical cycles. A "general prescription" for process studies is under development for inclusion in this chapter and specific studies and sites will be recommended.

Authors have been identified for all of these sections and the Committee agreed upon a schedule of the preparation of the Science Plan by various drafting groups, under the leadership of the Chairman and Vice-Chairman of JGOFS with coordination and editing being done through the SCOR Secretariat. It is expected that an advanced draft document will be available to all JGOFS Committee members for consideration at the third JGOFS meeting in February 1989.

The JGOFS North Atlantic pilot study

As noted above, the JGOFS Committee has established a Pilot Study Cruise Coordinating Committee which has now held two meetings in preparation for the start-up of the Pilot Study on March 1, 1989. This group has identified the following scientific objectives for the Pilot Study:

The overall objective of the Pilot Study will be to study aspects of the carbon cycle and related biogeochemical cycles with reference to the evolution of the spring phytoplankton bloom and its northward passage along 20° W, with the goals of:

i) Laying the operational basis for a 10 year inter national study of ocean biogeochemical fluxes;

ii) Working towards an essential set of core measurements for biogeochemical flux studies to be made by standardized procedures, thereby improving the compatibility of observations made by different national programmes;

iii) Testing and developing procedures at the international level for data management, archiving and exchange and incorporation of these data into the next generation of models;

iv) Development and testing of techniques for measuring essential biogechemical properties not presently observable by routine methods;

v) Collecting information required to improve assimilation of remotely-sensed data into oceanic biogeochemical flux studies.

The establishment of the Cruise Coordinating Committee with representation of each country participating in the Pilot Study (Canada, FRG, France, UK and USA) is intended to ensure that the Study is a truly coordinated effort rather than a series of loosely linked national cruises. For example there is a specific need for coordination of the NASA aircraft overflights with the cruise schedules, and with those of additional aircraft for remote sensing during the Pilot Study.

Other questions such as data, standards and intercalibration are being resolved amongst the nations participating in the Pilot Study. The North Atlantic Planning Workshop identified "a realistic set of 'core' measurements which would be made by all participating nations". They include:

Meteorology, CTD, CTD O_2 probes, 0_2 - Winkler, Optics, Nutrients, Total CO_2, POC, PON, DOC, Phytoplankton Pigments, Biomass: Bacteria, Cyanobacteria; Mesoplankton; Microplanktion, Primary Production: by ^{14}C; by 0_2, New production, Bacterial production, Grazing: by mesoplankton; by microplankton, Sediment Traps: floating; moored

A group of four or five national experts from the participating nations was established for each of the core measurements. They were charged with defining a standardized protocol and desired precision for each measurement, evaluating the need for intercalibrations and defining a reasonable deadline for the submission of data to the JGOFS database. The reports of these twenty groups were all prepared via telemail exchanges and were considered at the recent meeting of the Cruise Coordinating Committee. Certain issues have been referred back to the groups for elaboration prior to the next meeting in December 1989. It is expected that the protocols for the core measurements will be issued to all Pilot Study participants immediately after that meeting.

The Pilot Study meeting also reviewed and refined the schedule for the 1989, 20° W cruises in order to maximize the spatial and temporal coverage from the onset of the spring bloom. It gave detailed consideration to issue of aircraft remote sensing, racing decisions on the use of the NASA Airborne Oceanographic Lidar during a thirty-six day period in May and June.

Finally, in order to ensure that the best possible use is made of the information gathered during the Pilot Study and that the experience gained is used to best advantage in planning JGOFS on a larger scale, the JGOFS Committee intends to organize a Pilot Study data synthesis and analysis workshop in early 1990, followed by a Pilot Study scientific evaluation symposium later in the year.

SCOSTEP

The Scientific Committee on Solar-Terrestrial Physics (SCOSTEP) was established by ICSU as an inter-union body to promote and coordinate international interdisciplinary programs in solar-terrestrial physics. This discipline deals with the study of the generation, flow and dissipation of energy and the transfer of mass in the solar-terrestrial system (the chain of coupled regions comprising the solar photosphere and corona, solar wind, magnetosphere, ionosphere and atmosphere), and the study of relevant physical and chemical interaction mechanisms and associated effects on the total Earth system.

During the past decade, SCOSTEP has aided the scientific community by organizing many proposed studies of the solar-terrestrial environment into coherent programmes of international scientific cooperation and by establishing special data and information services for these programs. These programs were focused largely on individual regions of the solar-terrestrial system.

Solar-terrestrial research has reached a point in its evolution where it needs a higher level of research organization. A new program is being organized, called Solar-Terrestrial Energy Program 1990-1995 (STEP), which will focus on the solar-terrestrial environment as a complex interactive system whose overall behavior often drastically departs from the simple superposition of its parts. The main goal of STEP is to advance the quantitative understanding of the coupling mechanisms that are responsible for the transfer of energy and mass from one region of the solar-terrestrial system to another. It will involve ground-based, aircraft, balloon, rocket and satellite experiments; theory and simulation studies; and dedicated data and information systems. STEP has been endorsed by the ICSU General Committee at its 1987 meeting in Rome.

The basic framework of STEP consists of five Priority Areas. Of these, three should be of specific interest to the IGBP program. They are listed below, with a brief description of their goals (from Solar-Terrestrial Energy Program: A Framework for Action, SCOSTEP, in press 1988).

The sun as a source of energy and disturbance

To achieve an understanding of the principal source mechanisms for electromagnetic and corpuscular emissions on the sun and in the solar environment, and to formulate physical models to improve the predictability of short-term perturbations (minutes to days) and long-term variability (years to decades).

Middle atmosphere response to forcing from above and below

To achieve and understanding of the response of the middle atmosphere to changes in solar and near-space inputs and to volcanic, tectonic, meteorological, biospheric and anthropogenic activity, and to study the extent to which this response feeds back to the geosphere regions below and above.

Solar variability effects in region adjacent to the earth's surface

To determine the influences of solar variability on the physical and chemical properties and the large-scale behavior of the lower atmosphere, on man-made technological systems, on earth currents and on biota, and to formulate, test and study mechanisms responsible for these effects.

SCOSTEP wishes to collaborate very closely with the IGBP in the planning and implementation of these three Priority Areas of STEP.

Regarding the study of solar variability processes, the emphasis for specific cooperative work could be on "Long-Term Measurements of Solar Output", as described in sections 4.1, 4.2 and 4.3 in STP Newsletter 1986 No. 1. (It should be noted that, quite obviously, this project could not be accomplished during the short span of ISY.)

Regarding the middle atmosphere, the specific cooperative SCOSTEP-IGBP work could be on the topic "The Upper Atmosphere as a Processing Region for Variable Inputs of Solar, Terrestrial and Anthropogenic Origin", as described in sections 3.1 and 3.2 of the STP Newsletter 1986.

With respect to the third Priority Area described above, emphasis for cooperative work could be on the "Global Electric Circuit" as described in Section 3.3 of the STP Newsletter 1986; as well as on a systematic study of, and search for possible mechanisms responsible for, the discriminatory role played by the quasi-biennial oscillation (QBO) in the correlation or anti-correlation between tropospheric parameters in specific regions and solar activity.

SCOSTEP is prepared to establish a Liaison Group between the Working Groups assigned to the three Priority Areas (Drs. Marcos Machado, Marvin Geller and Karin Labitzke, respective Chairmen) and the SC-IGBP.

Resolution from SCOSTEP council June 26-27, 1986

Taking into account the oral report by Dr. Juan G. Roederer on recent developments in the planning of the IGBP, and having duly examined the written report by the ICSU/Global Change Working Group on Upper Atmosphere and Near Space (UANS), entitled "A Program for the STudy of the Long-Term Behavior of the Upper Atmosphere and Near-Earth Space Environment".

The council of SCOSTEP

- Endorses the recommendations and proposals put forth by the Working Group in said report;

- Expresses concern about the persistent indications that the ICSU ad hoc Planning Group on Global Change may severely restrict the scope of the IGBP by focussing mainly on biospheric processes or systems;

- Urges the ad hoc Planning Group to restore in full the original intention of the IGBP as a programme dealing with physical, chemical and biological interactions that regulate the total earth system; and

- Urges ICSU (1) to accept the recommendations made by the Working Group on UANS; (2) to incorporate the basic scientific questions formulated by the Working Group as an integral part of the scientific goals of the IGBP; (3) to establish a Scientific Working Group structure that reflects the importance of the role of the variability of energy and mass inputs and the role of the outer layers of the geosphere in interactive processes governing the total earth system; and (4) to include representatives from SCOSTEP in the membership of the Scientific Committee on Global Change.

UITA

Conscious of the vital importance of the IGBP objectives for the long term future of the technical development and for the technological options UITA has confirmed its intention to provide specific contributions with its Association Members to the achievement of the IGBP during the 1990 decade. This confirmation has been given by the UITA General Assembly held in PARIS at UNESCO headquarters on 21-24 April 1988.

For this goal, a special working group, chaired by Mr. Joseph Jacquet, has been set up in the UITA Environment Committee in order to define concrete projects of contributions in the IGBP, this task been performed jointly with the Associations Members and in agreement with the ICSU organization board. It is recalled here that one of the major objectives of the IGBP is the study of the impact of all human activities in the operation of the Geosphere-Biosphere system at the scale of the next coming century, mainly the evolution of the planetary climate with the potential influence of man on its dynamics and the assessment of any anthropogenic global impact on the total Earth System.

The present paper introduces the UITA intentions and provides a provisional up to date statement on its proposals of participation in the IGBP for the attention of the IGBP Scientific Advisory Council.

An action has been undertaken with the different International Technical Associations Members of UITA in order to identify the IGBP repercussions in their specific fields of interest and to incite them to participate on its accomplishment by contributing of their technical competence. As a matter of fact the Scientific Community needs information on the technological stakes and the socio-economical consequences of foreseeable changes of the planetary environment. In other respects, it is always in search of reliable data, integrated in planetary scale, on the wastes produced by human activities and spread in the different receiving bodies of the Geosphere-Biosphere System. These data have to be related both to the past and the present ages with projections in the future in order to identify or assess the global impact on the Earth System.

From now on the thoughts of the UITA - IGBP Working Group are focused around two centers of concrete actions corresponding to well identified gaps or insufficiencies:

- On the one hand, in the field of the quantified assessment of global impact of man in his environment;

- On the other hand concerning the diffusion and the transfer of scientific results towards users, like policy and technical decision-makers, managers of planetary resources, etc...

Collection and elaboration of data

The first focus deals with the collection and the elaboration of reliable data of planetary scale to quantify the environmental disturbances brought by human activities - mainly by their waste production. These data affect always an history with its three components: the past, the present and the future as it can be assessed from the different scenarios of development considered for the next coming century, the planetary and prospective dimensions being here essential. Each of these three components includes its proper uncertainties which have to be evaluated taking into account other factors depending on:

- whether industrialized or developing countries are concerned;

- whether the types of sources of wastes: industrial, domestic or agricultural ones - moving or fixed ones - concentrated or diffuse with consideration to the technical development.

The Scientific Community is here in situation of demand towards the technical and technological Organizations able to collect and provide such data with a quality label in their own field of competence. Can be mentioned as examples:

- Data related to the various energy consumption and fuel fossil use scenarios;

- Pollutant rejections from heavy industry (chemical, metal, etc...) and from transportation systems (motor vehicles);

- Data related to fertilizers consumption, carbon release through deforestation and agricultural practices, etc...

An application of this proposal could be tried on some specific atmospheric pollutants in cooperation with the International Union of Associations for the Prevention of the Atmospheric Pollution (UIAPAP).

It is very important that one should make sure that this UITA proposal does not overlap activities undertaken within existing data banks or other organizations interested, or at least UITA should act in total concert with these structures. Human and financial means have to be found to perform on the statistical collected data critical inventories, necessary representativeness appraisement, and coherence tests of sets : the problems of extrapolation and integration versus space and time will be considered with a special attention combined with the definition of local and regional indexes to guide the operations. It has to be stressed that such a participation of UITA Associations members is a matter of long term involvement implying continuity of action at least for the decennial duration of the IGBP.

Communication topics

The implementation of such an ambitious programme as IGBP implies that immense efforts should be made to establish permanent communication during its achievement:

- First within the Scientific Community in order to overcome "disciplinary" compartimentations and converge the studies on the transdisciplinary objectives defined;

- and also in a "downstream direction", that is to say towards engineers, technicians, practicions, decision-makers and managers, so that a constructive dialogue may be establish between "fundamental" scientists and users of research results facing particularly the climatic challenge which is acknowledged as characterizing the century to come.

The second UITA proposal refers to the communication topics with the setting up of a permanent cell of scientific information intended for political and/or technical decision-makers concerned by "the long-term". The project consists in establishing a perennial structure, serving as a "node" of direct relationships between the scientific community and the decision makers responsible for global environment protection, and being in charge of very precise missions as:

- Regular updating of scientific knowledge synthesis highlighting the attainments and uncertainties in the different subject areas of the program, the reliability of the available simulation tools for assessing the impact of human activities, for instance on the global climate;

- Promotion of the dialogue between scientists, technicians and/or decision-makers on precise themes related to the taking into account of the impact of human action on the global environment, its long term practical consequences, and the political and technological decisions to be taken;

- Dissemination of information, considered as having an objectivity (or independence) label by a wide audience in the general public, following the development of the research work.

- Ability to meet all requests for information relating to the carrying out and stakes of the program;

- Organization of interdisciplinary meetings between participants involved in the program.

Such a list is only indicative and a consultation with the international organizations involved in the Global Change programme is of the highest importance to determine accurately the structure and attributions of such a cell which is to be a living organism rather than a more documentation conservatory or a new bureaucratic realization. The scope at stake here is important since the UITA proposal is aiming at establishing a permanent structure (of the same duration as that of IGBP), of international purpose, of non governmental nature to protect its independence, mastered by some personalities selected and recognized of by both parties and in charge of missions that must be clearly distinguished from those of already existing bodies such as SCOPE, the emphasis being put on the specifically global dimension of the problems mentioned.

As above mentioned, these proposals are given here as an indication and require careful critical investigations, in one hand, to define accurately the corresponding needs and, on the other hand, to ensure the adequacy of the project to real needs identified by all the concerned parties. From this point of view, the UITA - IGBP working group remains at the disposal of the IGBP Executive Committee and Scientific Advisory Council, in particular of its "Data and Information Systems" Working Group, in order to put in concrete form the UITA hoped participations for the IGBP accomplishment.

WDC

Background

The ICSU World Data Center (WDC) System is a dynamic international network of active groups, many of them closely associated with research activities, collecting, cataloging and, in many cases, reformatting, geophysical information; many of the Centers produce higher level information products of use to the research community. The WDC System consists of three complex Centers, i.e., comprising all or nearly all of the disciplines of the IGY and new areas added since then: WDC-A, USA; WDC-B, USSR; WDC-D, China. In addition, there are specialized discipline Centers in give countries in Europe (WDC-C1) and in Japan (WDC-C2). At present, the system comprises 27 active Centers in full operation, and the 9 Centers of WDC-D just getting into operation. WDC-D includes a Center on Environment and Renewable Resources, of particular importance to IGBP and the first such Center in the system.

Some of the Centers are network together through computer-to-computer linkages, enabling easy production of joint catalogs and file sharing. As part of the efforts to make the Centers more useful to each other and to researchers, possibilities are being investigated of increasing such linkages throughout the system, especially among the Centers engaged in solar-terrestrial work and those that will support the IGBP.

WDC-A is actively involved in publication of large data sets on Compact Disk Read-Only-Memory (CD-ROM), which hold up to 670 Megabytes of data, with very low error rates. Access software can provide for display and manipulation capabilities of the data, as well as for corrigendum, read out automatically whenever the file to be corrected is addressed.

Comments on Global Change Report No.4

This Report contains a section on Data Management and Information Systems, stemming from the August 1988 Moscow Study Conference on Data Management for IGBP. The WDC Panel co-sponsored this conference, assisted in the organization and logistics, and assured that many data technology experts attended. The Panel and the representatives of the WDC Centers who attended are enthusiastic that the WDC system be involved in data planning for IGBP, for at least two reasons: (i) the IGBP scientists who plan observational programmes may not be aware of the resources, and their limitation, available in the Centers, which will be the ultimate repositories of the IGBP data sets; and (ii), the Centers, by being involved early in the planning process, may be able to strengthen their resources and budgets using early knowledge to be more effective partners to the research community in the IGBP studies that will take place over the next several decades. Financial and adequate data budgets are of great concern to be WDC system, and will be discussed in somewhat more detail below. Following are some comments based on programmatic sections of the Report. These are not intended to be exhaustive but mainly illustrative of the kinds of data problems that IGBP must solve if the next generation of research scientists will carry out the modeling and analyses needed to document and understand global change. It is important to remember that a programme such as IGBP has rather long-term objectives. Individual scientists to asses the information bases being started under IGBP. These data bases will outlive many of the scientists who plan them, and in some cases even those who will be assessed, corrected and formatted for use and archiving, it will be too late to go back and retake any of them "correctly." It is the task of the program planners, assisted by data experts and technologists, to do it as right as we know how, from the very beginning.

Atmospheric Chemistry

The proposed IGBP activities include monitoring many chemical species in the troposphere. In this regard, the WDC system needs strengthening. The UNEP Global Environmental Monitoring System (GEMS) sponsors an international network of stations making a variety of measurements. The WMO, in collaboration with GEMS, coordinates an activity called Background Pollution Monitoring (BAPMON), the stations of which are operation under national auspices. However, BAPMOM provides a mechanism for standardization of calibrations, inter-comparisons, and discussion of techniques. It does not, however, provide for adequate collection, merging and regional and global analyses of the data, i.e., no specific

tropospheric chemistry data center activity nor any post-observational quality control are in existence, although some data surely flow into both the ICSU and WMO Data Center Systems. This needs to be remedied for the IGBP.

As an additional insight into this problem, the USA National Oceanic and Atmospheric Administration has a rather broad activity called Global Monitoring for Climatic Change (GMCC). It is the experience of this program that much of the data are not being analyzed early enough in the collection process to provide good quality control checks. The best QC occurs when a scientist tries to use data other than his own for analysis and then finds the calibration inconsistencies, etc., that often creep into routine monitoring data.

The best example of how the system of how the system works very well concerns the measurements and analyses of the atmospheric concentration of carbon dioxide, where research scientists use the information regularly and thus provide an independent check on the quality of the monitoring procedures. This kind of scientific scrutiny needs to be extended to the rest of the BAPMON and GMCC programmes, if the time-series are to have optimal future value. Thus, it would seem that a more collaborative relationship should be fostered between data collection systems and data users (scientists) to provide a crucial feedback into the data management process, to assure adequate quality control: either error correction where possible, or at least error flagging.

Ocean Chemistry

Physical oceanographers have for a long time collected data on the chemical constituents of sea water, but they have done so mainly for such objectives as tracing water masses and relating to only some aspects of marine biology. However, the IGBP programme now calls for extensive studies of oceanic cycles of important chemical species. Such programs could effectively involve the oceanographic data centers to help decide what special IGBP data sets need to be prepared for archiving, and what higher-level information products, or indices, the data centers could provide.

Hydrology

The present ICSU WDC System does not include explicit a Center for Hydrology. Perhaps the new Chinese Center for Environment and Renewable Resources will include some hydrological data. Some limited hydrological data are collected as part of landsurface/atmosphere interaction studies, and the WCRP Global Energy Water Balance Experiment (GEWEX) may produce some useful large-scale data sets to be submitted to the WDC system.

Some hydrological data related to atmospheric data do flow into the WMO meteorological centers. In addition, under WMO auspices, a new Center for River Runoff has been established at Offenbach, FRG. This Center is an experiment to see if data from several representative river basins can for the basis of useful generalizations on regional scales.

Hydrological data seems to be sensitive, both nationally, and from the viewpoint of the individual hydrologists, at least in many countries. The IGBP programme will have to provide some good international motivation to get these data released, perhaps smoothed into larger scales, for studies of global change.

Role of national committees

The IGBP programs and activities will be contributed by nations. This includes the establishment and operation of the ICSU WDCs. The National Committees can help the WDCs situated in their countries by calling attention to the sponsoring national agencies the need to think about data early in planning for any major, and long-term program such as IGBP. It is an unfortunate fact that "data" per se is usually at the lower end of budget priorities in the planning processes; or, if data management is included in program budgets, it often falls victim to being raided to cover cost over-runs in equipment (especially satellite programs) or field expenses. Inadequate attention to budgets for data management in the early stage of programme planning means that the laborious details of data management are often left to the researcher, who would rather not spend time and effort on such matters that do not bring scientific credit

from colleagues or home institutions. The Data Centers, in such cases, are then usually unprepared to allocate the human and technical resources needed to assure that data sets are given the needed quality control, formatting, merging, and cataloging desirable to make the data as accessible and useful as possible to future generations of workers, to say nothing of the lack of ability to process the data into higher-level information products.

Role of the ICSU's WDC

While the resources of the WDCs are limited, there is much enthusiasm among the relevant Centers to support the IGBP. Inviting representatives of such Centers to assist in data management planning will enable them to go to their national sponsoring agencies to try to get the resources needed to provide the long-term support needed, and their expertise and experience will often be of great assistance in planning realistic data management schemes.

Data coming from scientific experiments, usually limited in time, often goes through good quality control procedures from the participating scientists, who expect to use the data to publish papers - their main sources of public and institutional "credit." Routine data from monitoring, however, is usually not subject to this kind of direct usage control, or if so, it usually is much later when some scientists wants to look at a particular time series. It is then often too late to identify and correct, or sometimes even to flag, such errors.

It is the present experience of some of the ICSU WDCs that older data being reformatted (e.g., put into modern computer data bases) provides a mechanism for inspection of instrumental or station artifacts in the time series. Many cases have been found, usually undocumented or the documentation has been lost or separated from the data, when instruments were changed, when stations were moved, or when observers simply made mistakes in observation or transcription, causing "change" that really was an artifact, not real. Even if such "change" cannot be corrected ex post facto, warning flags can be inserted into the data base. A regular routine QC program at the relevant data centers, especially for routine data, could be a significant contribution to IGBP, for it will be much harder later to deconvolve such artifacts from the real data base.

National resources will be needed for such contributions. They may be modest, in overall terms of the cost of an IGBP program, but they will be significant in terms of the present funding level of the WDCs. We call attention to such needs to the respective National Committees.

IGBP Reports

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)

No. 2. A Document Prepared by the First Meeting of the Special Committee, ICSU Secretariat, Paris 16-19 July, 1987 (1987)

No. 3. A Report from the Second Meeting of the Special Committee, Harvard University, Cambridge, MA, USA 8-11 February, 1988 (1988)

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)

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)

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)