GLOBAL CHANGE
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The International Geosphere–Biosphere Programme: A Study of Global Change (IGBP)
of the International Council of Scientific Unions

Editorial

Since the first meeting of the Special Committee for the IGBP in July 1987, the goal has been to develop a numer of research projects to be launched during the IGBP implementation phase lasting for at least 15 years starting in 1990.

During the 30 months since the first SC-IGBP meeting, some 50 international planning workshops have been arranged by the IGBP with the participation of several hundreds of scientists from all parts of the globe. This has been a major international undertaking with the ultimate aim to define core projects on the basis of the research priorities agreed to at the first meeting of the IGBP Scientific Advisory Council (October 1988). Following this meeting, three core projects were established (IGAC, JGOFS and PaGloCha). In November 1989, the SC-IGBP reviewed reports from the planning groups and considered proposals for additional core projects. Seven core projects were proposed for which the SC-IGBP is now developing detailed science plans. Decisions to approve these proposed projects will be taken at the next SC-IGBP meeting in March 1990 (Moscow). In addition, two potential core projects will also be dscussed then.

The identification of these 12 core projects constitutes a major step towards the development of the IGBP science plan, which will be discussed at the 2nd SAC meeting (Paris 3–7 September, 1990). The specific science plans for the core projects will form the substance of the SAC II report, which will be widely disseminated during June 1990.

In parallel to the development of the scientific plans, discussions are also under way to define an implementation strategy for the IGBP. Two consultation meetings have already been held (May 1989 in Washington, DC, and October in Lisbon). The proposed implementation strategy will also be included in the report to SAC II.

Some of the participants at the 5th meeting in Berlin of the Special Committee for the IGBP in front of "the Wall" on the day it opened, November 10, 1989. From left to right: Brian Walker, Dennis Ojima, Marie-Lise Chanin, Luiz Molion, Oliver Arino, Anne Arquit, Jim McCarthy, Hassan, Virji, Vladimir Kotlyakov, Harold Shiff, Bert Bolin, Takahisa Nemoto, Gunilla Björklund.

Established, Proposed and Potential IGBP Core Projects

At its recent meeting (6–10 November 1989 at the Wissenschaftskolleg zu Berlin, West Berlin), the SC-IGBP considered proposals for core projects from its planning groups. Three core projects have already been established. In addition a number of proposed core projects have now been identified. The SC-IGBP also discussed a few potential projects, for which further discussions are needed in order to clarify a possible role for the IGBP in their development. The SC-IGBP will consider the potential projects at its next meeting in March 1990. This NewsLetter contains draft summaries of the core projects. These will be further refined in the near future.

Two key activities have not been designated as IGBP core projects but are essential to the success of the IGBP: (i) The development of global

data and information systems, and (ii) the establ*ishment of Global Change Regiona*l Research Centres.

Established IGBP Core Projects
- International Global Atmospheric Chemistry Programme IGAC (IUGG–IAMAP-CACGP/IGBP)
- Joint Global Ocean Flux Study JGOFS (SCOR)
- Past Global Changes (IGBP)

Proposed IGBP Core Projects
- Land–Ocean Interactions in the Coastal Zone (IGBP)
- Global Ocean Euphotic Zone Study-GOEZS (IGBP/SCOR)
- Biospheric Aspects of the Hydrological Cycle (IGBP/WCRP–GEWEX)
- Global Change and Terrestrial Ecosystems (IGBP)
- Climate Change Impacts on Agriculture and Forestry (IGBP)
- Modelling Global Biogeochemical Cycles (IGBP)
- Geosphere–Biosphere Models (IGBP)

Potential Core Projects
- Stratosphere–Troposphere Interactions and the Biosphere (IAMAP/IAGA/SCOSTEP)
- Global Change and Ecological Complexity (SCOPE/IUBS)

Complementary IGBP Initiatives
- IGBP Data and Information Systems (IGBP Working Group 1)
- Global Change Regional Research Centres (IGBP Working Group 2)

ESTABLISHED CORE PROJECTS

International Global Atmospheric Chemistry Programme IGAC *(IUGG–IAMAP–CACGP/IGBP)*

This Core Project addresses the important biogeochemical interactions between the terrestrial and marine biospheres and the atmosphere. It was formulated by the Commission on Atmospheric Chemistry and Global Pollution (CACGP) of the International Association of Meteorology and Atmospheric Physics (IAMAP) as the International Global Atmospheric Programme (IGAC). Major contributions to the planning are made through the activities of a SCOPE project on Trace Gas Exchange dealing with biological aspects of source-sink relationships of key biogenic trace gases. The Core Project consists of 6 principal research foci including 19 activities which are summarized below. Several research activities are being developed in collaboration with SCOPE and IGBP's Coordinating Panel on Terrestrial Biosphere – Atmospheric Chemistry Interactions. An important additional focus proposed under IGAC deals with international support activities to aid IGACP implementation and coordination.

Natural Variability and Anthropogenic Perturbations of the Marine Atmosphere.

The oceans cover about 70% of the planet and act as both a source and sink of many important atmospheric constituents. In the marine atmosphere chemical species of continental origin are processed without disturbances of new anthropogenic inputs. The marine atmosphere is, therefore, a favorable area to study transformation processes in detail. Three IGAC studies are proposed to address this environment and perturbations to it due to continental emissions:
- North Atlantic Regional Study
- Marine Gas Emissions, Atmospheric Chemistry and Climate
- East Asian – North Pacific Regional Study

Natural Variability and Anthropogenic Perturbations of Tropical Atmospheric Chemistry

Tropical continental areas play an important role in the chemistry of the global atmosphere and its oxidizing power. Large emissions of gases and particles are associated with rain forest, savanna regions, tropical wetlands especially paddy areas and other tropical areas undergoing rapid land use change. Five IGAC studies are proposed to address the tropics and their changes due to human activities:
- Biosphere-Atmosphere Trace Gas Exchange in the Tropics
- Deposition of Biogeochemically Important Trace Species
- Impact of Tropical Biomass Burning on the World Atmosphere
- Chemical Transformations in Tropical Atmospheres and their Interaction with the Biosphere
- Trace Gas Emissions from Tropical Wetlands and Rice Paddy Agriculture

The Role of Polar Regions in Changing Atmospheric Composition

The Arctic and Antarctic regions play important roles in atmospheric chemistry involving long-range transport of anthropogenic pollutants, exchange of trace gases between the atmosphere and snow/ice surfaces, atmospheric chemistry in a seasonal light/dark atmosphere and the concentration and storage of atmospheric constituents in ice. These regions have a special sensitivity to anthropogenic emissions (e.g. ozone destruction by halocarbon decomposition products, albedo changes due to soot particles). The polar regions are especially important because the expected greenhouse warming of the Earth is predicted to be most pronounced at high latitudes during the winter half year. Two IGAC studies are proposed for these regions:
- Polar Atmospheric Chemistry
- Polar Air-Snow Experiment

The Role of Tundra and Boreal Regions in Changing Atmospheric Composition

An understanding of the cycling of trace gases between the atmosphere and ecosystems of the forested, the wetlands, and the tundra areas in the boreal region is of special importance for assessing the impact of a climate change on these cycles and how fluxes from this region alter climate (e.g. through positive feed-back mechanisms). This arises because these regions both contain major carbon reservoirs that may be very sensitive to the effects of future climate change and are predicted to experience very large effects of a change in the climate. Two IGAC studies are proposed for these boreal and subantarctic regions:

- Northern Wetlands Study (Boreal and Tundra regions
- Boreal Forest Study

Natural Variability and Anthropogenic Perturbation of Middle-Latitude Trace Gas Fluxes and Atmospheric Chemistry

The mid-latitude regions, especially in the northern hemisphere, has undergone dramatic perturbation to the atmospheric chemistry, due to anthropogenic activity. These changes in atmospheric chemistry influence rates of net fluxes of biogenic trace gas by altering nutrient availability and pH in various ecosystems.

Mid-latitude ecosystems have been greatly altered as well, through changes in land use and agricultural practices. Management practices of irrigation, fertilization, residue placement and cultivation have all altered environmental factors which control sites of trace gas production and exchange.

Two IGAC studies are proposed:

- Influence of intensive agriculture on trace gas fluxes
- Influence of pollutants and forest harvest of trace gas emissions from forest ecosystems

Global Distributions, Transformations, Trends and Modelling

The differences in the composition of the atmosphere over the globe and the short- and long-term variations in this composition reflect the net effect of all the relevant atmospheric processes: emissions, circulation, transformation and removal. The global distributions and trends of chemically and radiatively important species are signatures not only of atmospheric changes but also of the fundamental processes underlying them. The IGAC Programme has five studies addressing this important globally integrating research area, involving a ground-based network, aircraft-based surveys, experimental studies, and relevant theory and modelling:

- Global Atmospheric Ozone Network
- Global Atmospheric Chemical Survey
- The Chemical and Physical Evolution of Cloud Condensation
- Nuclei as Controllers of Cloud Properties
- Development of Global Emission Inventories

International Support Activities include setting of internationally agreed measurement standards to be achieved via instrument intercalibrations and intercomparisons, educational and research result communication activities related to atmospheric chemistry, biogenic trace gases, etc. Three major activities proposed are:

- Education in atmospheric chemistry and global change
- Communication (IGAC Newsletter)
- Intercalibration and intercomparisons

IGBP CP1 has formed a subcommittee to write a companion report which will further develop the biological issues. This report will draw on the SCOPE Dahlem conference (Feb. 1989) and the upcoming SCOPE/IGBP conference in Sweden (Feb. 5-9, 1990). The report entitled "IGAC: The Terrestrial Biological Component" will be completed early in March, 1990.

There was a meeting of representatives of CP1, CP2, JGOFS, and IGAC in San Francisco in December, 1989 to determine the mutual interests in participation in this Core Project and to suggest other activities that should be added. It is hoped that a report entitled "IGAC: the Marine Biological Component" will follow from this meeting.

Joint Global Ocean Flux Study JGOFS *(SCOR)*

In late 1987, the Scientific Committee on Oceanic Research (SCOR) established a major global ocean research programme known as the Joint Global Ocean Flux Study (JGOFS). The major goal of JGOFS is:

"to determine and understand on a global scale 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 the continental boundaries."

The International Science Plan for JGOFS is now being finalized and a Pilot Study in the North Atlantic involving at least seven countries and six research vessels was successfully carried out between March and October 1989. It is expected that JGOFS will require about a decade to achieve its objectives.

The central question for JGOFS is to understand the oceanic role in the uptake of the CO_2 produced from the burning of fossil fuels. About half of the 5 to 6 gigatons produced annually can be accounted for in the increasing levels of carbon dioxide in the atmosphere, while the fate of the remaining 2 to 3 gigatons, presumably absorbed by the ocean, is not well understood. It is imperative to increase our knowledge of the role of the ocean in moderating or buffering the greenhouse effect and what the limits on these processes may be. 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 $(35+10) \times 10^9$ 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). To achieve an assessment of the capability of this 'biological pump' our ability to estimate new production should be improved by at least one order of magnitude.

Many of the fundamental equations and parameters involved are unknown or poorly understood. The JGOFS Science Plan must, therefore, provide an objective analysis of the basic scientific information required in order to successfully obtain the data sets needed to fulfill these goals. It will establish the scientific rationale for the overall programme, enlarge upon its stated goal, define detailed objectives for that goal and discuss various strategies for addressing those objectives. These strategies fall into three categories:

- a sequence of process studies to elucidate the connections between various biogeochemical processes and distributions
- a large-scale global survey activity and time series stations to improve basic descriptions of the biogeochemical cycle
- a systematic set of model studies to identify critical processes and variables, to assimilate observed parameters into basin and global scale fields and to predict the future state of the ocean.

This international plan defines a minimum essential set of process studies and ocean surveys for achieving the JGOFS goals, gives guidance for the integration of remotely sensed data and for the optimal use of modelling to express JGOFS results on a global scale. Another function of the international plan is to encourage efficient use of resources by identifying redundancies in national plans and opportunities for coordination of activities in various oceanic regions. Due to the complexity of the studies, it is intended to forge strong links to the various core projects of IGBP and to other international programmes such as WOCE.

Past Global Changes PaGloCha *(IGBP)*

The core programme on Past Global Changes (PaGloCha) will be made up of two distinct yet related streams of effort, guided by separate international, multidisciplinary advisory panels. The first will concentrate on the fixed period of most recent 2000 years, the second on the particulars of the glacial–interglacial cycles that have dominated Earth system history in the late Quaternary epoch. The two streams were chosen to fill critical gaps in our understanding of the most basic processes of Earth system behavior. They promise, as well, to provide the most reliable data for validating the Earth system models that will be needed to anticipate the effects of accelerated greenhouse warming in the next 100 years. Modeling exercises should help define the range of possible climate forcing factors consistent with the available data, and should improve our understanding of how the Earth system has responded to them. In addition, records of past global changes will be used in modeling experiments to investigate the relative stability of the earth system; that is, its potential to shift into other quasi-stable states that may be inferred from information obtained from proxy records.

Stream I: Earth History During the Past 2,000 Years

Stream I will endeavor to improve, significantly, our understanding of the history of the Earth system over the past 2,000 years, through the documentation of changes in climate, air and ocean chemistry, vegetation and land use. The chosen periods is that of man's greatest impacts on the planet, and the era of significant overlap between the written record and the data stored in natural archives. In addition, the rapid climatic fluctuations (such as the Medieval Warm Period and the Little Ice Age) that occurred during this period may provide important insight into the rates of regional- to global-scale changes that can be expected to occur within the Earth system, and with which human beings may have to contend in the near future. A clearer illumination of global and regional changes in this epoch has many potential pay-offs: it can extend – by a factor of about five – the period of the most reliable climate history of the Earth; it can (i) establish a more extensive global record of land use changes in order to assess the effects of past human impacts on the Earth system, (ii) provide a well-documented background of natural change against which anticipated anthropogenic impacts can be calibrated, and (iii) provide a "Rosetta Stone" for the interpretation of data from the natural archives of the much more distant past by focusing on the period of overlap between written history and natural records.

The goal of Stream I activities is to reconstruct the detailed history of climatic and environmental change for the entire globe for the period since 2,000 BP, with temporal resolution that is at least annual and, ideally, seasonal. Results of Stream I research will provide a baseline of natural change against which human impacts can be measured, and against which environmental signals from the more distant past can be calibrated and quantified; elucidate the connections and phase relationships between biogeochemical and climatic changes in the most recent period of Earth history; and provide a data base for testing numerical models of the Earth system.

Stream II: Glacial and Interglacial Cycles in the Late Quaternary

The focus of Stream II is on under-

standing the dynamics that caused glacial/interglacial variations, as well as the interactive feedbacks among various components of the Earth system that dictate the overall response of the system to such large-scale climatic fluctuations on a global scale.

Stream II is designed to reconstruct a continuous history of climatic and environmental change through the last full glacial cycle in order to improve our understanding of the sequence of events that control epochs of major global climatic changes. The goal is not only to understand the way the Earth system functions during times of glacial maximum and minimum conditions, but also to document the onset and nature of the transitions from warm to cold and cold to warm periods.

PROPOSED CORE PROJECTS

Land–Ocean Interactions in the Coastal Zone (IGBP)

Factors of global change, e.g., climate and land use, will alter the rate of weathering and erosion on land, and fluvial transport of sediment and dissolved nutrients to the coastal zone of the sea. These same factors may alter the amount and distribution of aeolian dust. Changes in erosion patterns on land will have profound consequences for soil properties and, thus, on anaerobic conditions that are of particular importance for production of biogenic trace gases.

Climate change is expected to result in sea level rise. This will profoundly affect coastal ecosystems, incursion of salt water to groundwater aquifers and tidal and storm surges up riverine and estuarine systems.

These relationships represent a continuum of phenomena that is of global extent around the coasts of the world and are thought to be important for the functioning of the global ecosystem. Similarly, development of predictive understanding of these phenomena and their linkages requires an interdisciplinary approach that focusses on the continuum of interactions and fluxes.

A potential core project that would focus on these interactions among processes involved in transport between land and sea is in the early stages of exploration. One key component has been proposed:

Coastal zone and resource studies (IGBP)

The coastal region and continental shelf waters represent only about 10% of the total ocean area. However, they exhibit rates of biological productivity per unit area, on average, 2–3 times higher than oceanic waters and they act as a transformation and depository zone for dissolved and particulate carbon via river water and atmosphere from land masses.

The contribution of the coastal waters to fluxes of carbon and atmospheric trace gases (CO_2, N_2O, DMS) is still uncertain. However, the continuing urbanization and industrialization of the coastal plain, where 70 % of the world people live, and heavy exploitation by man of the natural resources of the coastal seas are thought to be significantly affecting exchanges of materials between the coastal ocean, land and atmosphere.

Another grave concern is the pollution and physical disturbance of coastal systems. Many pollutants are a threat to the health of marine organisms and, in turn, limit their exploitation by man. Coastal engineering practices and erosion can cause extensive loss of habitat. Enhanced inputs of nitrogen and phosphorus are associated with frequent phytoplankton blooms, which may cause damage to fisheries and on mariculture, through the production of toxic substances and anoxic waters.

The scientific problems in coastal and estuarine systems have been dealt with as matters of local regional interest. However, recent studies have revealed the importance of studies on the interactions between land/sea, ocean/atmosphere, coastal sea/open ocean etc.

In this context, inputs and feedback of regional domains such as coastal waters to the atmosphere, open ocean and even to the terrestrial zones should be addressed within the framework of the IGBP.

The formulation of a coherent global strategy for studying the coastal zone in the context of the objectives of the IGBP is more difficult than for the land and ocean on either side because of the physical complexity and high biological diversity of this boundary zone. However, several general considerations point to the overall importance of the coastal ocean for understanding the Earth system:

(1) The large inputs of terrestrial carbon (particulate and dissolved) to the coastal ocean and high rates of *in situ* productivity indicate that this region plays an important and as yet largely unquantified role in the global carbon cycle.

(2) Through exploitation of the coastal ocean for natural resources (living and non-living) and for waste disposal, man is causing significant chemical modification of the environment which is affecting the cycling of elements such as C, N, and S and, in turn, is likely to influence the trace gas composition of the atmosphere.

(3) The sensitivity of coastal ocean ecosystems to the influence of man and to the predicted effects of changes in sea level and climate has led to an urgent need, especially in less developed countries, for scientific guidelines and policies relating to a variety of socio-economic and management issues. At present there is no research programme dealing with the coastal oceans at the hemispheric or global scale.

The objectives of the core activity will be:
(1) To describe quantitatively the physical, chemical and biological properties of the coastal ocean that affect global climate through modification of the biogeochemical coupling between terrestrial and oceanic ecosystems and through direct exchange of biogenic trace gases with the atmosphere.
(2) To develop and apply objective methods for measuring and predicting change in the coastal ocean ecosystem due to variations in global climate and to the effects of man's activities so that rational policies for maintaining biological diversity, productivity and habitability of the coastal zone can be maintained.
(3) To determine the direction and significance of feedback effects between global climate and the coastal ecosystem that are the result of chemical modification by man of the atmosphere and of coastal waters.

Global Ocean Euphotic Zone Study GOEZS *(IGBP/SCOR)*

Given the unequivocal link among biogeochemical processes in the ocean and atmosphere–ocean interactions that are functions of tropospheric temperature, it is important to understand these interrelationships and their role in modulating climate. There is a sense of urgency in this task, since anthropogenic activities are altering some aspects of these biogeochemical cycles, the full implications of which are not yet known for the physical aspects of the climate system.

Continued increases in the atmospheric concentrations of radiatively active trace gases is anticipated with corresponding increase in global air and sea temperature. A new level of understanding of the processes responsible for biological activity in the euphotic zone of the world's oceans will be essential to develop prognostic models to predict consequences of this warming. A global scale study of the ocean's euphotic zone, especially the interaction between physics and biological productivity, with a long-term goal of predicting the potential impact of increasing tropospheric concentrations of radiatively active trace gases in biogeochemical processes in the ocean that are influenced by, and feedback to, climate. The proposed project would build on the results from JGOFS and WOCE.

A Global Ocean Euphotic Zone Study (GOEZS) will require balanced and highly interactive efforts in modelling, in observing ocean properties *in situ* and from space platforms, and in quantifying fluxes for key physical and biogeochemical processes. In addition, it will require new efforts to effect synthesis across physical, conceptual, and disciplinary interfaces.

A number of paradigms will guide the development of GOEZS:
- Role of nutrient limitation in controlling primary production, and therefore the magnitude of the global oceanic sink of CO_2.
- Effect of changing surface radiation balance on the timing of the spring plankton bloom and foodweb processes that together determine the fraction of primary production falling to the deep ocean as detritus.
- Effect of changing physical environment (temperature, salinity, mixed layer depth) on relative contributions of different species of particular significance to global primary production and biogeochemical cycles (e.g. change in contribution of coccolithophores).

Based on these paradigms, the following objectives are proposed:
- To improve understanding of the interaction between circulation and physics of the euphotic zone and primary production
- To develop models of these processes as a guide to understanding
- To develop a global model of gas exchange between the ocean and atmosphere including the ocean biosphere as an interactive source/sink.

The fieldwork of GOEZS will be timed to benefit from the new remote sensing instruments on the polar platform and thus not be implemented until the end of the 1990s. The fieldwork of GOEZS will be timed to benefit from new robotic systems (such as Autosub) now being developed for automatic data collection in the open ocean. There will be a need to develop new instruments to collect extended time series of observations of chemical and biological variables from moored or mobile platforms.

Biospheric Aspects of the Hydrological Cycle (IGBP/GEWEX)

The hydrologic cycle and the land surface are dynamically coupled through the physical processes of energy and water supply, transformation, and transport at the land–atmosphere interface. The biosphere works in concert with these physical processes to strongly modify this coupling. Regional variability of vegetation cover on land significantly influences the hydrologic cycle. Present physically based climate models need refinements that accurately reflect the dynamic coupling in the soil–vegetation–atmosphere system. To understand the dynamics of and the synergisms among soils, vegetation and the atmosphere on the small scale and their integrated effects on the macro or grid scale, there is an urgent need to (i) study the role of the biosphere in controlling these fluxes of energy, moisture and momentum sinks and sources over the land–surface and their seasonal variability, at various scales, and (ii) explore, by experiments and models, whether our understanding of surface hydrology involving vegetation on small scales can be rigorously integrated over space to describe interactions appropriate to scales of global models, and whether such processes can be quantified, individually as well as in their integrated effects, by remote sensing.

Amongst the major biospheric aspects of the hydrologic cycle that deserve attention are:

- Effects of density and structure of canopy and litter on interception of net radiation and precipitation,
- Control of water flux from the soil into the atmosphere by leaf transpiration,
- The feedback role of vegetation in modifying regional and global climates

To quantify these effects, integrated process studies from local to global scales are needed using field experiments, space observations, and a hierarchy of models. The following core activities are proposed:

(i) Small-scale process studies (point, pixel-patch, landscape, catchment) aimed at developing physically based integrated Soil-Vegetation-Atmosphere Transfer (SVAT) models that accurately portray vegetated land-surface information such as surface albedo, roughness, water flux and trace gas exchange to the planetary boundary layer, and can be used to provide boundary conditions for general circulation models.

(ii) Meso-scale process studies (river basin, GCM grid cell) of the role of vegetation in complex hydrological systems, including processes controlling vertical and horizontal water and energy exchanges in the land–atmosphere boundary layer. At this scale, explicit representation of landscape attributes (topography, soils, vegetation) is required.

(iii) Development of large-scale (continental to global) hydrologic models that explicitly include generalized SVAT models defining the role of vegetation in the hydrologic cycle. To produce realistic dynamic models at these scales, satellite observations will be required for definition and long-term measurements of key variables related to vegetation and surface climate.

Important prototypes of critical experiments integrating ground and aircraft measurements and satellite data have been conducted by the ISLSCP-FIFE project in the USA (Kansas grassland) and HAPEX-MOBILHY project in France (complex landscape). Thus close collaboration with ongoing related projects under GEWEX/WCRP is necessary for conducting above activities. A first step in this respect was the establishment of a joint IGBP/WCRP ad hoc coordination group for land–surface experiments. This group will assess the small and meso-scale field experiments that have already been conducted by various groups and recommend a coherent programme of future field experiments designed to achieve the goals of core activities described above.

Global Change and Terrestrial Ecosystems (IGBP)

The objective of this core project is to develop a predictive understanding of changes in the structure, composition and function of terrestrial ecosystems, under scenarios of changing atmospheric CO_2, climate and land-use. This understanding is needed as mankind's welfare depends on these ecosystems and, secondarily, because the feed-back effects of these changes in ecosystems can further exacerbate changes in the global environment.

The project has two main foci: the "metabolism" of ecosystems (the energy, water and biogeochemical fluxes) and the dynamics of land cover. Required inputs are a "local climate simulator" and a boundary layer model, developed under the auspices of the WCRP.

I. Metabolism of Ecosystems

Three core activities related to the metabolism of ecosystems. They are basic research, model development and research which together connect all levels of ecosystem function into the global processes.

Core activities:

1. CO_2 manipulation. Integrated experiments on elevated concentration of CO_2 will address basic questions about alteration of ecosystem rates of carbon assimilation and allocation with secondary effects on tissue quality. These experiments will cross scale from a single leaf to a whole ecosystem. They should be conducted in regions that are tempe-

rature and/or water limited, and in regions where neither are limited and which may respond most markedly to elevated CO_2 concentrations. Ecosystem processes expected to respond to CO_2 concentration and climate are primary productivity, carbon partitioning, water use efficiency, decomposition, nutrient cycles, plant competition and herbivory.

2. Carbon storage and biogeochemical cycles. Prediction of change to net storage, flux and allocation of carbon, and biogeochemical cycling resulting from changes in CO_2 concentration, temperature and precipitation, and land use is a major objective of this activity. Basic information about availability, storage and the processes responsible for C, N, P, and S fluxes in ecosystems are necessary. Soil studies to elucidate the dynamics of the active fraction of organic matter in soils and to determine the impact of disruption on biogechemical and carbon cycling through the system. An inventory of the stable and labile fractions of soil organic matter and vegetation is necessary.

Field measurements and laboratory experiments are required to determine the CO_2 fertilization effects on litter quality and quantity in terrestrial ecosystems. Highest priority research areas are tundra/boreal and tropical forest ecosystems.

3. Water and energy fluxes. Critically important information about these processes require research to improve and integrate ecosystem production and decomposition models and then to link the validated ecosystem models at landscape and higher scales to general circulation models (GCM) through the Soil–Vegetation–Atmospheric Transfer (SVAT) models.

Empirical research is required on interception–evaporation, transpiration and soil processes. Infiltration of water, intrasoil water movements and sub-surface run-off must be modeled. These data will provide the link between biogeochemical processes models of CNPS cycles of ecosystem function and climate models.

II Dynamics of Land Cover

Land cover characterization (vegetation structure and composition plus general soil properties) is a structural expression of ecosystems although with functions and dynamics of its own. Activities related to the dynamics of land cover change are represented by four main research efforts.

Core Activities:

1. Documenting land cover and its change: Land cover will change as a result of changes in climate and land use. This activity consists of three parts. First, to develop a contemporary land cover data base, and ancillary data base which would include soil data, topography, and other relevant data, for all land areas of the world and a continuous updating of that data base through appropriate remote sensing and geo-referencing methods. Second, to develop and maintain a data base on changes in land use worldwide. This would need both remotely sensed as well as ground-based data. Third, to develop a capacity to develop scenarios of land use change based on certain assumptions of climate change and socio-economic conditions.

2. Survey of potential impacts: This activity would involve the use of correlative models modified by estimations of change in climate, land use, and socio-economic factors to identify regions and ecosystem types where significant change can be expected. Direct CO_2 effects would be incorporated as separate scenarios based on general understanding of these effects as they mature.

3. Vegetation and landscape dynamics: This activity would involve development of detailed vegetation dynamics and soil models put in the context of landscape variability and disturbance regimes. The landscape models will be deterministic and include a fine degree of detail regarding vegetation and the catenary sequence scale for soils. Besides land cover predictions, this activity would examine the interaction of landscape components in terms of other ecosystem properties such as water and nutrient availability, role of refugia, disturbance regime, and rates of recovery to perturbation.

4. Certain transition zones may exhibit very large changes in ecosystem structure and function with climate and CO_2 concentration change. Examples of such transition zones are boreal forest – tundra ecotone, tropical forest, savanna ecotone, continental grassland–desert transition and tropical elevational geoclines in monsoonal climates. These zones are logical areas for prediction and monitoring of change, as well as for investigating factors which affect the rate of succession and changes of ecosystem composition and land cover. Mixed correlation, mechanistic and landscape-scale models will be used here and field experiments applied as appropriate.

Climate Change Impacts on Agriculture and Forestry (IGBP)

The objective of this core project is to predict the changes which will occur in the quantity and quality of the yield of plant and animal crops. These are feed forward effects only. Given a predicted change in climate or CO_2 concentration, what will be the impact on annual crops, tree crops (horticulture and silviculture) and on animal production from pastures? Some of the most significant effects will be secondary such as pests, diseases and fire regimes. Therefore, it is essential to consider individual pests and other species level changes.

Changes in climate, CO_2 concentration, and other atmospheric change (e.g. acid deposition) will have direct effects on plant production and the distribution of environments appropriate for production of agricultural species.

The balance between crop yield as opposed to plant production may change. Plant vegetative production may be increased with increases of temperature but grain production may decline, while changes in number of frost days will affect fruit set in horticultural crops. What will be the effect on crop yield of change in plant production?

Water use efficiency in respon-

se to CO_2 change at the field level is unknown. Thus there is a need for refined water balance models for the major crops and cropping regions.

Pests and disease distribution will be affected by climate change. For instance the effects of changes in frost frequency on the distribution of insect vectors that do not have a diapause state may cause their expansion into formerly unaffected areas.

Livestock will likewise be affected by these changes. The effects of change in ecosystem function can be expected to change the quality (N content) and quantity of forage available to animal species. Changes in climate may affect fertility of livestock and the change to disease and insect vectors may exclude economic production from their current distribution.

The project would include the following types of agriculture and silvicultural systems:

1. Commercial, large-scale crop production (e.g.wheat, rice, soybeans,...)
2. Perennial crops (horticulture, coffee, viticulture,...)
3. Timber production from plantation forestry
4. Livestock production from native and cultivated pastures
5. Subsistence level farming systems

Empirical, modelling and monitoring research are needed to understand these changes. Empirical research must include investigations of temperature and CO_2 (and their interaction with nitrogen fixation) effects on individual species of plants and animals including pests.

Model development is important for evaluating the scenarios of change and agricultural systems. Generic models for C3 (wheat-rice) and C4 (maize and sugarcane) crops will evaluate the impact of changes to annual crops. Horticultural, viticultural and other perennial crop models must be developed or adapted. All of these models and those appropriate for animal cropping systems must be able to respond to CO_2 and other biogenically active elements, climate change and changes in nutrient availability.

This core project may be developed by IGBP as a joint project with other international bodies with interest in changes to agricultural systems. The project must bring together expertise in all counties and from all varieties of agricultural and pastoral development. An initial meeting in late November 1989, Cameroon, established the priority for investigations of this nature.

Modelling Global Biogeochemical Cycles (IGBP)

The IGBP core projects that address the questions regarding the atmosphere, the oceans, terrestrial vegetation and soils include the development of process models and sub-system models, both for the definition of observational needs and for analysis and interpretation of the data being collected. The IGBP must also consider the total Earth system, i.e. the mutual interactions of the subsystems referred to above. The core project on Modelling Global Biogeochemical Cycles is designed to foster and coordinate the development of global biosphere models of the major biogeochemical cycles. The model development should emphasize and focus on improvement of our understanding of the major biogeochemical cycles and initially particularly consider the global carbon cycles which in any case have to be the core element of any future truly Global Geosphere–Biosphere Model.

These models of global biogeochemical cycles will make use of the General Circulation Models for the atmosphere and the oceans as being developed within the aegis of the World Climate Research Programme. Close contact must be established between the Scientific Steering Committee of this core project and the appropriate committee(s) of the WCRP. It has been repeatedly stressed by other IGBP research planning groups that the ecosystem response to climate depends on extremes and their frequency in addition to the slow changes of mean climatic conditions. An obvious responsibility of the Scientific Steering Committee would be to clarify inter-relationships of this and other kinds, that are of importance for the further development of Global Geosphere–Biosphere Models.

The specification of data needs that are related to model development is an integral part of any core project and will accordingly be done as part of the development of sub-system models. It is, however, clear that there will be special data requirements association with the integration of such sub-system models into global models. These are of two kinds:

i) observations of the interactions between subsystems, particularly the exchange of key elements

ii) observations that can serve as integral constraints in the process of validating models, which is particularly the case for rare isotopes of key elements (C, N, O, S).

Geosphere–Biosphere Models (IGBP)

The development of advanced Geosphere–Biosphere Models must be a central core project of the IGBP, as such models are needed to synthesize our understanding of the interactions of the various components of the biogeochemical, hydrological, and physical aspects of the climate systems, including the coupling with vegetation systems. The aim of this core project is to design comprehensive quantitative prognostic models of the Earth system, which will become feasible on super-computers available early in the 21st century with expected computing rates exceeding those available today by several orders of magnitude. Such models will simulate the detailed events with sufficient spatial and temporal resolution and permit explicit treatment of the strong non-linear interactions between physics, chemistry and biology that occur on small scales (e.g. plankton patchiness in the sea and plant communities on land). As a preliminary guideline, one of the aims should be to achieve a horizontal resolution of about 20 km. The project should pay special attention to parameterization of the important processes occurring in the spacial interval 1–10 km, which will probably not be resolvable in global models even in the 21st century.

The output of the project will be a strategy for the design of integrated high resolution global models, but the project will not be concerned, at least not for the first ten years, with the implementation of such models. The emphasis will rather be on developing a balanced approach, in which relative allocation of computing power to simulating the various sub-systems (ocean biosphere, terrestrial biosphere, atmospheric and oceanic circulation, etc.) reflects the relative importance to the global cycles being modelled. As the model design becomes clearer, attention will have to turn to the specification of data needed to run and to test such advanced models.

The practical task of designing an integrated model will provide a guide to the relative priorities of IGBP core projects and it may lead to the identification of gaps in the IGBP research strategy.

POTENTIAL CORE PROJECTS

Stratosphere-Troposphere Interactions and the Biosphere (IAMAP/IAGA/SCOSTEP)

The main objective of the project is the dynamic, radiation and chemistry coupling between the stratosphere and the troposphere, insofar as it may affect the troposphere climate and/or influence the biosphere.

Research Priorities

1. Tropospheric–stratospheric exchange:

The transport of energy, momentum and matter through the tropopause provides the coupling between those regions. Such transfer is also responsible for the global distribution of trace gases in both Hemispheres. Its relevance to IGBP can be summarized under the following topics:

- Transport of trace gases (H_2O, O_3, CH_4, N_2O, CFCs, halogens, etc.) which impact on the stratospheric composition and radiative budget and, for some of them, are responsible for the ozone depletion processes.
- Transport of stratospheric aerosols of volcanic, anthropogenic and aeolian origins which affect the Earth's radiation budget. Aerosols and long-lived species also provide tracers for the atmospheric circulation.

2. Atmospheric changes and U.V.-penetration

Both natural and anthropogenic effects are changing the distribution of atmospheric ozone. As O_3 is the main absorber of solar ultraviolet radiation, these changes in both tropospheric and stratospheric ozone affect the penetration of the U.V.-flux through the atmosphere. Two aspects are relevant to the objectives of IGBP:

- The effect of altered U.V.-flux on tropospheric chemistry and, therefore on its composition
- The penetration of U.V.-flux down to the biosphere. Both monitoring and modeling programmes should be encouraged to quantify the extent of this change. Such a knowledge is needed by other IGBP programmes to evaluate the impact on human health and on ecosystems.

3. Stratospheric changes and climate

Changes in stratospheric composition (O_3, H_2O, aerosols) result in changes in stratosphere temperature and transport which, in turn, affect the temperature structure of the troposphere. Combined with the greenhouse effect, these changes in temperature profiles can significantly affect climate. The following issues need to be addressed:

- The influence of ozone depletion on the temperature structure of the stratosphere and the troposphere and on the horizontal and vertical transport
- The coupling between changes in

stratospheric ozone and the greenhouse effect, using models which explicitly include the stratosphere
• The study of the aerosols and water vapour on the radiative budget and on the heterogeneous chemistry which is responsible for the ozone depletion.

4. Natural variability and detection of anthropogenic effects

Changes in solar U.V.-radiation are known to affect the atmospheric structure (T, d) and therefore may affect transport and composition (O_3). In order to unambiguously separate natural solar effect from anthropogenic effects, the sun's radiation must be monitored as well as the atmospheric parameters. Models of solar effects on the atmosphere (firstly stratosphere and stratospheric-tropospheric exchange) must be also refined.

Recently, a significant statistical relationship between the quasi-biennial oscillation / solar variability and tropospheric / stratospheric processes has been demonstrated. Research to understand these relationships should be encouraged. If solar causes are established, the mechanisms for this to take place must be elucidated. This is a necessary step to permit an early detection of changes due to anthropogenic effects.

Coordinated action is needed for establishing:
1) Long-term monitoring of critical parameters
2) Modeling studies, and
3) Field measurement campaigns on crucial issues (i.e. chemistry, volcanic aerosols)

Implementation

The proposal is mostly based on earlier proposals by the IUGG Association (IAGA / IAMAP, i.e., MARC and MACS) but more emphasis is given to coupling between the stratosphere and the troposphere and between dynamical, radiative and chemical processes not covered by IGAC. A project initiated by SCOPE on UV effects on the biosphere is now underway to study what is known about the effects of changing UV on biological processes. A core project in this area would benefit from existing and planned programmes related to the ozone issue. Close interaction with WCRP, mainly on the modelling issue, should be established in order for both programmes to benefit from a coordinated efforts.

Global Change and Ecological Complexity (SCOPE/IUBS)

The manner in which biological systems maintain certain number of species within a typical community structure, the role gene pool size on species adaptability to changing environmental conditions, and the consequences of land use on habitat size relative to maintenance of community composition and ecosystem processes are all related to the study ecological complexity. The interplay between global change and ecological complexity is not well defined. As an initial step is recommended that SCOPE and IUBS investigate how changes in biodiversity, sizes of community units, and genetic variability will be affected by global change and what, if any, might be their feedbacks to global changes.

The major impact of global change on biological ecological diversity is fragmentation of habitats. It is the combination of this existing pressure and the expected very rapid climate change that is potentially deleterious to ecosystem function. In some cases (e.g. stranded mountain top relicts under a warming trend) the effect is obvious. However, in most cases, the likely effects are not clear and the ramifications of these effects on the global system are not well established.

There are two research questions of interest to IGBP:
i) what kind of diversity, singly or in combination, in which kinds of ecosystems are ecologically sensitive to changing environmental conditions?
ii) what will be the likely effects of global change (land-use and climate) on diversity in those ecosystems where diversity is important?

An initial analysis of existing information is needed to examine these questions in detail and to better define the research problem. Depending on the outcome of the SCOPE-IUBS analysis, the project may then develop into a second phase of active research.

COMPLEMENTATY IGBP INITIATIVES

IGBP Data and Information Systems (IGBP Working Group 1)

At the core of the IGBP there must be a systematic effort to document and to understand the causes of the significant changes on a global scale over the coming decades. To support these activities a data and information system to deal with multiple user needs and the variable data input and sources must be developed. The system needs to have easy access, data certification and documentation, and a workable protocol for data input and output with special consideration of data format.

The initial plan for a data and information system is designed to allow a user to refer to an IGBP data directory which would identify the source location and other pertinent information regarding the data. The data would then be requested from the appropriate data "clearing house". The mechanism for populating the data clearing house with appropriate data sets and for certifying and documenting the data will be largely the responsibility of the institution handling the data. For example, ocean data may be maintained at the ICSU World Data Centres, certain land data at GRID, soil data certified by ISRIC at GRID, and so on for the various data sets necessary for the IGBP core projects.

The IGBP Global Environmental Data Directory (GEDD) will contain summary information to describe data sets. The description will be simple and brief, but with enough information to allow the user to locate data by location, time period, and parameters. The intent is to allow the user to search for the appropriate Global Change data set. The centre, or contact institution for the data, will provide the user with inventory information such as a detailed description of the data, formats, and exact location and time parameters. Access to the data would then be possible from the identified source.

Directories for environmental data exist at international and national levels. At the international level, examples are the World Meteorological Organization's INFOCLIMA, the International Oceanographic Commission's MEDI, and the United Nations Environment Programme INFOTERRA systems. In the United States examples are the National Oceanic and Atmospheric Administration's (NOAA) National Environmental Data Referral Service (NEDRES), and the National Air and Space Administration's (NASA) Master Directory. These data bases enable the user to search for a desired category of environmental data in a specific location.

Future data needs for IGBP will be defined by the scientific community associated with the IGBP core projects. The data will be collected through ground-based networks and space-borne instruments. Despite the lack of explicitly defined data sets, it is possible to see where data gaps exist or will potentially exist in the near future. For instance, remote-sensing of ocean chlorophyll data exists for the 1980s, but current plans for satellite deployment of EOS will not provide coverage until the late 1990s. A potential gap of 5 to 7 years exists in this important global parameter. However, current discussions are underway to alleviate this gap by launching SEAWIFS before 1995 which would shorten the gap. Other important areas of global change research need to be addressed for current status of data and future capability of data collection to insure that the goals of the IGBP can be met.

The land cover data set – a case-study.

A global data set which is urgently needed by a number of IGBP core projects is a data set that includes parameters and measurements needed to evaluate land cover change. It is planned to use as a case-study the land cover pilot study. The plan is to use existing data to quantify various land cover parameters which would be related to a simplified classification scheme reflecting land surface characteristics and related vegetation characteristics (e.g., physiognomy, phenology, etc.). Observations and analyses will be made from AVHRR satellite-derived data. A common methodology for developing digitized land cover data sets will be developed to be used globally. Current pilot study areas identified are: Brazilian tropical forest region; North American central plains region; West African savannah region; Australia; sites in the USSR characterizing boreal forest, steppe; dry steppe, and semi desert regions; and tropical forests in Thailand.

The current plan is to utilize existing AVHRR data for the Brazilian tropical forests. The objective for the study in Brazil is to develop a well documented methodology for discerning forested and deforested areas in the Legal Amazon for the period 1985–1990. The Brazilian scientists in collaboration with scientists from the European Space Agency and the USA will produce a geo-referenced digitized map of existing land cover using high resolution satellite imagery (LANDSAT and SPOT) and a more coarse-scaled integrated 1 km data set using AVHRR. Initial results for forest–non-forested areas of the Legal Amazon for 1988 will be ready by September 1990.

Parallel to the land cover pilot study, development of global data sets to be used as research and educational tools are underway. The first data set compiled and being distributed is a 16 km, 4 week NVDI composite of the African continent. The South American data set is near completion. These data sets are being distributed on floppy discs with a simple GIS.

Global Change Regional Research Centres (IGBP Working Group 2)

A network of Global Change Regional Research Centres will be designed to promote and instigate research on a regional basis in the IGBP. These centres will focus on interdisciplinary aspects of global change research. The number of RRCs will probably be small (about 10) and be located in different areas of the world in response to the scientific questions, geographic representation, the existence of institutions of appropriate nature, political considerations as to national commitment, stability, access etc. The selection of a specific site within a region should be based on the following major criteria:

i) the existence of a scientific institution or "nucleus"
ii) interest of local scientists and of governments of the region
iii) availability of logistical support, and
iv) access to the RRC for visiting scientists and technicians

The RRCs should provide regional institutions with possibilities of expanding present interests towards global understanding and convenient access to global data sets. RRCs will be continental or subcontinental centres with strong links to satellite stations within the region and even to appropriate local stations. They would be especially involved in analysis, interpretation, synthesis and modelling of global change phenomena and use this information for assessments and predictions at the regional level. Training and exchange programmes will be established in the RRCs, especially in the use of new technologies and in data synthesis and modelling in interdisciplinary areas. Each RRC would develop differently according to site specificity, scientific questions and other considerations, but common to all will be a minimum structure that assures that they can meet the general objectives.

Depending on the selected scientific priorities of field research and monitoring at each RRC, they will by necessity have direct links to the coordinating offices for relevant IGBP core projects. However, special links will have to be developed with the IGBP Coordinating Panel on Global Analysis, Interpretation and Modelling, as they will be the regional focal points for this IGBP research activity. The RRCs will also be the regional focal points for the activities planned by the IGBP Working Group on Data Information Systems. The RRCs will enhance existing endeavors, taking into account the goals and decision-making processes of existing institutions in the region as well as the governmental and non-governmental organizations responsible for networks and programmes.

Planning meetings 1990

22–24 January	Washington DC	Meeting of IGBP National Committee Chairmen and funding agencies
23–26 January	Villach, Austria	Meeting of the Scientific Steering Committee on Past Global Changes
25–26 January	Wallingford, UK	Ad hoc IGBP/WCRP group on land surface processes
29 January–2 Feb	Washington, DC	Meeting of the WG1 (Working Group on Data and Information Systems
2–4 February	Cambridge, UK	CP4
5–9 February	Berlin West	SAC-II Report Meeting (Planning Group Chairmen, Senior Research Fellows, Post Docs.)
19–23 February	Sigtuna, Sweden	Trace Gas Exchange in a Global Perspective, SCOPE / CP1 Workshop
5–10 March	Sao José dos Campos Brazil	Regional IGBP Meeting for South America
12–13 March	London, UK	Modelling the Physics, Biology and Chemistry of the Upper Ocean and its Interaction with the Atmosphere, JGOFS / IGBP Workshop
13–14 March	Lomé Togo	Planning Meeting for Regional IGBP Workshop for Africa
19 March	Leningrad, USSR	3rd Meeting of the ICC-IGBP
20 March	Leningrad, USSR	**5th Meeting of the EC-IGBP**
22–24 March	Moscow, USSR	**6th Meeting of the SC-IGBP**
17–21 April	Stockholm, Sweden	SAC-II Report Editorial Committee
30 April–2 May	Bellagio, Italy	Regional Research Centre Meeting
5–10 June	Vadstena, Sweden	IGBP/IAHS/IHP Plant-Water Interactions in Large Scale Hydroclimatic Regions
June		Past Global Changes Open Meeting
16–27 July	Snowmass, USA	OIES Summer Institute CP5 / SSC Meeting
29–30 July	Snowmass, USA	**6th Meeting of the EC-IGBP**
24–25 August	Yokohama, Japan	Global Change and Terrestrial Ecosystems Open Meeting
1–2 September	Paris, France	**7th Meeting of the SC-IGBP**
3–7 September	Paris, France	**2nd Meeting of the SAC-IGBP**
8–9 September	Paris, France	**8th Meeting of the SC-IGBP**
26–30 November	India	Regional Meeting for Asia

List of IGBP Correspondents

The Special Committee for the IGBP has decided to invite each ICSU scientific member, to nominate a correspondent to the IGBP, if they so wish. Until now the following have been nominated:

CASAFA	F. W. G. Baker
IGU	V. M. Kotlyakov
IMU	J. L. Lions
ISSS	H.-W. Scharpenseel
IUB	H. Kornberg
IUGG	J. Dooge
IUGS	K. Hsü
IUPAC	M. Williams
IUPHAR	K. J. Netter
SCOPE	F. di Castri
SCOR	E. Tidmarsh
SCOSTEP	J. G. Roederer
TWAS	C. Ponnamperuma

IGBP Secretariat Staff News

Dr Gunilla Björklund, Programme officer with responsibilities for SSC Past Global Changes and proposed Core project for Land–Ocean Interaction in the Coastal Zones and as editor for the Newsletter, will leave the secretariat 1 February 1990 to work as project leader for environmental education issues at Swedish Television.

Congratulation – Correction

We are sorry to have missinterpreted the Seligman Crystal award that Professor Hans Oeschger has received. The award is the highest award in glaciology given by International Glaciological Society. The paragraph should read:

"We congratulate Professor Hans Oeschger, a member of the Special Committee of the IGBP and the Chairman of the Scientific Steering Committee for Global Changes of the Past, on receiving the Seligman Crystal of the International Glaciological Society, the highest award in glaciology. It has only been awarded 13 times previously. He received the award in 1989 for his important work on ice cores."

National IGBP Committees

Countries:	**Chairpersons:**
Argentina	Dr. J. Aumedes
Australia	Prof B.G. Thom (Acting)
Austria	Prof S. Bauer
Bangladesh	Dr. S.D. Chaudhuri
Belgium	Prof. O. Vanderborght (Acting)
Bolivia	Dr. J.Argollo
Brazil	Prof. A. Azevedo Pacheco Leão
Canada	Prof. W.R. Peltier
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China (Academy in Taipei)	Prof. Jong-Ching Su
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Israel	Prof Z. Reiss
Japan	Prof. Y. Oshima
Kenya	Prof. S.O. Wandiga
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South Africa	Prof. P. Tyson
Sweden	Prof. B. Bolin
Switzerland	Prof. H.R. Thierstein
Thailand	Dr. T. Pyakanchana
United Kingdom	
USA	Prof. H.A. Mooney
USSR	Academician G. I. Marchuk
Venezuela	Prof. F. Pannier
Zimbabwe	Dr. G.R. Chimonyo

IGBP Reports

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)

2. A Document Prepared by the First Meeting of the Special Committee, ICSU Secretariat, Paris 16—19 July, 1987 (1987)

3. A Report from the Second Meeting of the Special Committee, Harvard University, Cambridge, MA, USA 8—11 February, 1988 (1988)

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)

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).

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).

7. Report from the First Meeting of the Scientific Advisory Council for the IGBP, Stockholm, Sweden 24—28 October, 1988 (1989).

8. Report from a Meeting of the IGBP Working Group on Data and Information Systems held at WMO and UNEP/GRID, Geneva, Switzerland 11—13 January 1989. Compiled by S. I. Rasool and D. Ojima (1989).

9. Southern Hemisphere Perspective of Global Change: Scientific Issues, Research Needs and Proposed Activities. Report from a Workshop held in Mbabane, Swaziland 11—16 December,1988. Complied by B. H. Walker (1989).

GLOBAL CHANGE
NEWSLETTER

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