GLOBAL CHANGE
NEWSLETTER

No. 23 SEPTEMBER 1995

THE INTERNATIONAL GEOSPHERE–BIOSPHERE PROGRAMME: A STUDY OF GLOBAL CHANGE (IGBP)
OF THE INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS

Collaboration: The Very Essence of the IGBP

Chris Rapley, Executive Director, IGBP

Collaboration lies at the heart of the IGBP, whether it is between individual scientists, research groups, institutes or nations. By combining skills and resources, the IGBP sum can be made greater than its component parts at all levels of its activity. However, human collaborations are notoriously susceptible to problems and these can result in reduced overall performance or even serious disruption. Given the special difficulties faced by a highly multidisciplinary, international programme such as the IGBP, particularly as a result of its overlay of scientific and social differences in both culture and language, the basic ground rules of good collaborative practice are worth close consideration.

(i) Complementarity and Capacity: Collaborations are usually only fruitful if the groups or individuals involved draw on a genuine *complementarity* of *skills* and *experience*, and if they have the *resources* to contribute. Otherwise, it is almost always easier and more effective to carry out the work alone.

(ii) Balance: The collaborators should have approximately equal levels of *scientific interest* in the joint activity. It should also be similar in terms of *priority* within the parent organisations involved, and in terms of *benefit* to them. Without such balance, there is a danger that the degree of commitment will prove unequal, especially under pressure of events and other tasks, resulting in a partial or complete default on the part of the collaborators with the least at stake.

(iii) Compatibility: Compatibility is required in *scientific standards, scientific and technical skills*, and *general working practices*. Any differences in attitudes towards aspects of *scientific rigour, documentation standards, reporting and communications*, or *the presentation of results* can result in difficulties. *Technical compatibility* (for example, the use of compatible experimental equipment or word processors) is also highly desirable and should be sought actively at the outset.

(iv) Communication: Effective communication is crucial. Thus attention must be paid to both *language* and *terminology*, as well as to the *technical means* of communication (email and the Internet have revolutionised this aspect), and to *timing* (a 12 hour difference in time zones can present significant difficulties).

(v) Interfaces: These should be as *clean and simple* as possible, whether *technical* or *organisational*. *Single points of contact* should be identified for each key area of interaction.

(vi) Integrity and Trust: It is essential that all involved respect and trust the *integrity* and *behaviour* of those with whom they are collaborating. This extends beyond the interactions within the consortium to interactions with *other parties*, since these can affect the reputations of consortium members by association, and can affect activities unconnected with the collaboration.

(vii) Commitment (Hero / Heroine): The existence of *a strongly committed lead individual* within each of the collaborating groups has a powerful influence on the likelihood of success.

(viii) Rules and Agreements: Prior to the start of the activity, it is prudent *to agree and*

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write down the *basis* of the collaboration. The document can be very brief, but should address the *goals and objectives* of the work, the *responsibilities of those involved*, the *internal and external deliverables* (in terms of form and content) the *schedule* including any *milestones*, the *scientific, technical, and organisational interfaces*, *rules* regarding the *publication/presentation/authorship* of results, and the form of *acknowledgement* to be used. Also, *ground rules and procedures* in the event of difficulties or dispute should be agreed and recorded.

Circumstances will dictate the extent to which it is necessary or possible to follow all these guidelines, and the degree of formality involved, but past experience provides ample evidence of their value. A high degree of collaborative success will not only contribute directly to the scientific productivity of the IGBP, but also to the level of satisfaction gained by those who participate.

Mea Culpa: In the editorial "Beyond the Endless Frontier" in NewsLetter #22 the publication date of Vannevar Bush's report was given as 1947 rather than 1945. In addition, I omitted to acknowledge Tom Malone's summary of the Bush report given in "Sustainable Human Development: A Paradigm for the 21st Century" a White Paper for the US National Association of State Universities and Land-Grant Colleges (1994).

Those who wish to read Vannevar Bush's original paper should access
http://snorri.chem.washington.edu/ysnarchive/articles2/VBush1945.html
on the World Wide Web, or simply search the Web for "Science the Endless Frontier"

Chris Rapley, Executive Director, IGBP, and Armando Rabuffetti, Executive Director, IAI, at the IAI workshop in Belem (Brazil). The Workshop addressed the IAI's science agenda, and topics such as collaboration with the three international global change programmes.

Global Analysis, Interpetation and Modelling

Current Modelling Experiments

Global Analysis, Interpretation and Modelling (GAIM) is the over-arching activity of the IGBP which aims to link the data output of different components of Earth system research into a holistic picture. Three modelling tasks address the contemporary era, the fossil fuel era, and the palaeo era.

The Contemporary Era

The Coupled Atmosphere-Land-Ocean Carbon System for the Period 1980-2000

This experiment is designed initially for the target period 1980-1990, paralleling the time period under consideration by the Atmospheric Model Intercomparison Project (AMIP). As new data sets become available this target period will be extended, eventually spanning the 20 year time frame 1980-2000. This experiment will serve as a pilot project which may serve also as framework to evaluate models of other biogeochemical cycles besides carbon. The experimental approach employs a description of the physical-climate system, carbon cycle model components, and validation data sets.

Since the experiment is designed to be validated against synoptic observations, the most realistic meteorology and oceanic circulation during the simulation period is needed. For the atmosphere, the stored output fields of atmospheric model intercomparison simulation runs are being used in a first phase. In a second phase the data from the re-analysis project currently planned at the European Centre for Medium Range Weather Forecast and the National Meteorological Centre will be used. In order to obtain the time-dependent oceanic circulation, the Ocean Carbon Cycle Model is being driven by observed sea surface temperatures and surface buoyancy fluxes.

In the first stage of implementation, the terrestrial biogeochemical model and the ocean carbon cycle model are being run to equilibrium with prescribed atmospheric CO_2 concentration and a constant climatology, assumed to represent pre-industrial conditions.

In the second stage both models (terrestrial and ocean) will be run each through the industrial period up to the end of the year 1975, forced with prescribed:

- globally averaged atmospheric CO_2 concentration,
- globally averaged atmospheric $^{13}C/^{12}C$ isotope ratio,
- globally averaged atmospheric $^{14}C/^{12}C$ isotope ratio, and
- anthropogenic land-use change scenario.

In this stage, either a constant climate or a climate scenario as developed within the Fossil Fuel Era project, "Changes in Terrestrial Carbon Storage", will be prescribed.

In the third stage the three-dimensional atmospheric transport model will be coupled to the terrestrial biogeochemical and the ocean carbon cycle models. The atmospheric transport model is initialised with uniform concentration and isotope fields representing globally averaged conditions for January 1976. The three coupled carbon models are run through the four years 1976-1979 and then through the target period 1980-1990. This stage also requires the specification of the spatio-temporal distribution of the CO_2 emissions, both from fossil fuels and from land-use and land-use change.

Dynamics of the Coupling between the Hydrological Cycle, Carbon Cycle, and Terrestrial Biomes

One of the expected consequences of climate change from increasing greenhouse gases over the next century will be changes in distribution of biomes and rates of carbon pool cycling. These changes will in turn modify the climate changes. Present model simulations of climate change from greenhouse warming assume prescribed distributions of biomes and non-interactive scenarios for changing atmospheric carbon dioxide. Two-way coupling between climate change on the one hand and

he effects of biome distribution and carbon fluxes, on the other hand, will eventually be tackled.

The role of terrestrial ecosystems in modifying regional climate, soils, and nutrient exchanges is acknowledged but not quantified. At regional scales, vegetation exerts a feedback with the climate of the planetary boundary layer, changing humidity, temperature, momentum transfer, and CO_2 concentrations. This GAIM project complements the Project for Intercomparison of Land-surface Schemes in conjunction with World Climate Research Programme, and builds upon other intercomparisons such as the SCOPE (Scientific Committee on Problems of the Environment) project on forest succession models.

In sum, the purpose of this experiment is to understand better the relationships between climate and terrestrial ecosystems by focusing upon changes (natural and human-imposed) to terrestrial ecosystems and their feedback to regional climate.

The project is being conducted in three phases:

- sensitivity of regional climates to prescribed ecosystem changes;
- sensitivity of ecosystem models to imposed regional climate excursions;
- sensitivity of coupled ecosystem and climate models to imposed disturbances (e.g. trace gas increases, land-use change).

The First Phase, sensitivity of regional climates to terrestrial ecosystem changes, comprises a detailed analysis and interpretation project in which groups who have (or will soon have) conducted similar land-use change experiments will inter-compare experiments and results. The aim is to identify common sensitivities and increase understanding of the sensitivity of regional climates to terrestrial ecosystem changes.

In Phase Two, sensitivity of ecosystems to imposed regional climate excursions, advantage will be taken of the fact that the complex land-surface schemes which are being incorporated into general circulation models are now beginning to include biogeochemical dynamics as well as predictive components relating to shifts in the distribution of terrestrial ecosystems. In this Phase, a hierarchical series of intercomparisons will be undertaken. These will begin with a community-wide intercomparison of ecosystem changes in response to different initialisation assumptions and different imposed meteorology.

Phase Three, sensitivity of combined ecosystem and climate models to imposed disturbances, cannot be successfully completed until there is agreement from Phases One and Two. The plan is to obtain one or more pairs of climate and ecosystem models which together provide a representative range of sensitivities. The experiment(s) must depend upon the availability of adequately resolved parameterisations and input and evaluation data. One possibility is to use the observational data to be provided by the Large scale Biosphere experiment in Amazonia, one of the primary activities of the IGBP Core Project Biospheric Aspects of the Hydrological Cycle for the near future, or the basin-scale experiments of Global Energy and Water Experiment in the WCRP.

The Fossil Fuel Era

Terrestrial Carbon Storage

The broad objective of this project is to develop more realistic, generalised ecosystem element cycling models for analysing global responses over decades and centuries and to gain more consistent understanding of past changes in atmospheric CO_2 concentration and the carbon cycle. Through a series of model sensitivity tests and comparisons, this activity seeks to improve our understanding of terrestrial ecosystem contributions to fossil fuel era increases in atmospheric CO_2 concentration.

Thus far, analyses of past changes in terrestrial carbon storage have relied on models with simplistic representations of ecosystem carbon dynamics. Some studies have used purely empirical representations of terrestrial exchanges with the atmosphere. This was largely because more detailed and realistic ecosystem models were specific to certain sites where they were developed or, at best, to limited areas. There are now, however, a number of more mechanistic terrestrial element cycling models that seek wide applicability and need to be used in global carbon cycle studies. This activity will analyse the carbon cycling response characteristics of selected ecosystem models within a common framework of calibration data, land-use forcing functions, climate histories, and atmospheric CO_2 increase.

The Palaeo Era

Climate-Vegetation Interactions: A 6000 Year BP Experiment

A key issue is the extent to which vegetation distribution modifies itself through feedbacks to climate, through mechanisms such as increased evapotranspiration leading to increased precipitation inland. Investigation of this issue requires atmospheric and vegetation model coupling. A coupled model, run to equilibrium, should naturally be able to reproduce present vegetation patterns (assuming that the vegetation is at equilibrium). A more stringent test is whether such a model can also reproduce vegetation patterns at a time when the atmospheric circulation was substantially different.

Data from the millennium around 6,000 yr. BP provide an opportunity to "observe" the equilibrium state of the coupled vegetation-atmosphere system at a time when orbital changes, affecting the seasonal and zonal distribution of insolation, caused a substantially different global pattern of temperature and precipitation than present. In many subtropical regions the climate at 6,000 yr. BP was even more different from the climate at 18,000 yr. BP because of the major expansion of northern-hemisphere summer monsoons, which brought moisture to areas such as the Sahara that are extremely dry today.

Data from the past vegetation for 6,000 yr. BP (mainly inferred from pollen records) can be used to check the performance of climate models forced by a different orbital configuration. It has already been observed that the degree of monsoon expansion simulated by atmospheric general circulation models is not enough to explain the near-disappearance of the Sahara desert at 6,000 yr. BP as shown in the palaeovegetation record unless the land-surface conditions are also changed to be consistent with the palaeovegetation record. In this light, a purpose of this experiment is to use the palaeovegetation record as a means of testing the equilibrium performance of a coupled climate-biome model. Note that the aim of the experiment is not to seek a direct analogue for global warming, but rather to test the linked models under a climatic regime substantially different from present.

(Text from the Annual Report of the GAIM Task Force)

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Where does N_2O Come From? An Aspect of BATGE Research

Biosphere -Atmosphere Trace Gas Exchange in the Tropics: Influence of Land-Use Change

An activity of the International Global Atmospheric Chemistry Project (IGAC)

A Science Feature of IGAC contributed by
Michael Keller
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In many ways, nitrous oxide (N_2O) is a forgotten greenhouse gas. Its rate of increase, 0.3% per year during the 1980's, does not sound terribly shocking. Its sources are poorly known and the prospects for "instant gratification" following possible controls of N_2O emissions are small because of its 150 year atmospheric lifetime. From another vantage, the long atmospheric lifetime of N_2O gives each additional molecule emitted to the atmosphere a large global warming potential. The effects of increasing concentrations of atmospheric N_2O will be with us for a long time.

Our ignorance of N_2O sources and sinks is troubling. The current budget is seriously unbalanced. Sources (14 Tg-N/yr) exceed sinks (10 Tg-N/yr) by 40%. Data from polar ice cores show that N_2O concentrations in the pre-industrial atmosphere hovered around 280 ppb. Today the concentration exceeds 310 ppb. Where does the excess contribution to the N_2O budget come from? Based on numerous measurements, we know that fossil fuel combustion cannot be a major source. Other industrial processes such as the manufacture of adipic acid (for nylon) and nitric acid contribute perhaps one eighth of the imbalance.

Looking to the natural biological sources of N_2O gives us strong hints about where to find the perturbed sources. N_2O is formed by microbial processes. For soil processes which produce about two thirds of the natural N_2O, the "Hole-In-the-Pipe" conceptual model (Figure 1) relates the total amount of N_2O released through "leaks" in the pipe directly to the overall "flow" of N through the pipe. The size of the leaks may be controlled by a number of soil properties, chief among them soil moisture content. From our understanding of terrestrial ecology, we know that most temperate ecosystems are nitrogen poor. In contrast many natural tropical ecosystems are nitrogen rich. And recent budgets suggest that while unmanaged temperate and boreal ecosystems produce about 1.2 Tg N_2O-N annually, unmanaged tropical ecosystems produce 4 times as much: 4.8 Tg annually.

What happens when these ecosystems are disturbed? Disturbance of temperate ecosystems generally does not lead to large releases of N_2O because nitrogen is in short supply. In contrast, large N_2O emissions have been observed following natural (e.g., hurricanes) and anthropogenic disturbances of tropical forest. Figure 2 shows findings from a study of N_2O release from a sequence of pastures representing various times following deforestation. Because forest to pasture conversion is a dominant land-use in tropical America, this effect may account for a tenth of the annual global imbalance of N_2O.

While forest disturbance is important, we need to look for higher flows in our plumbing if we are going to find a big enough leak. Big flows of nitrogen can be found wherever farmers are applying nitrogen fertilizer to fields and also where domestic animals are kindly returning much of what they take in. The annual use of nitrogen fertilizer, about 80 Tg-N, is now greater than natural biological nitrogen fixation. It has been known for two decades that fertilizer use increases N_2O emissions from farm soils. Fertilizer use in the developed world appears to have reached a plateau. In contrast, in the developing world (a near synonym for the tropical world), fertilizer use nearly doubled during

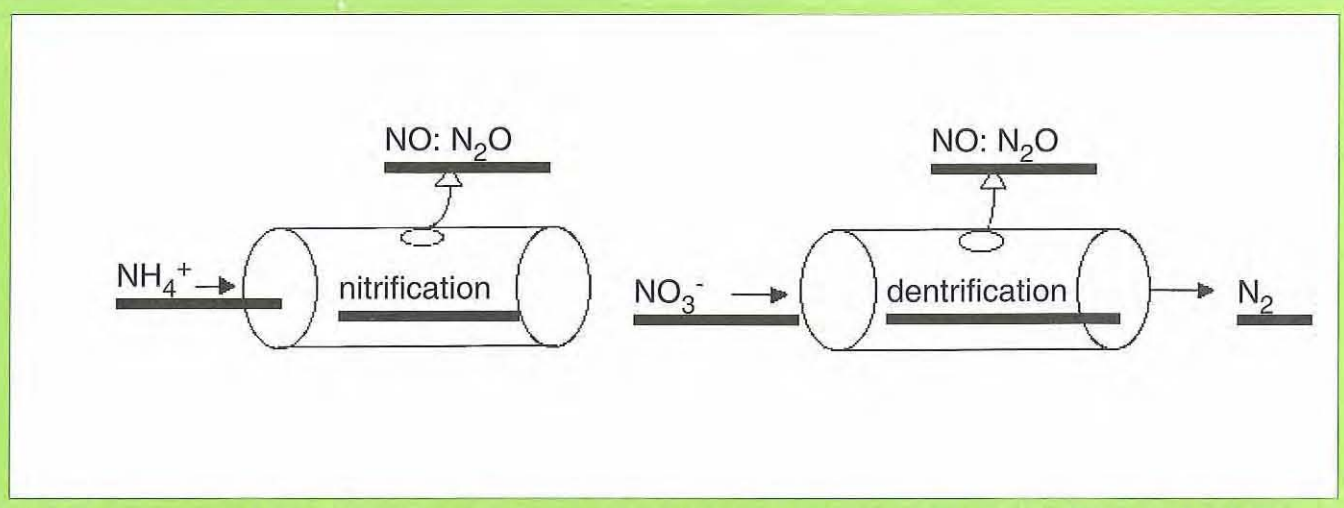

Figure 1. The "Hole-in-the-Pipe" conceptual model indicates the flows of inorganic nitrogen through the microbial processes of nitrification and denitrification. Nitrogen oxides escape through "leaks" in the pipe. (Adapted from Firestone and Davidson, 1989)

the 1980's. Moreover, we have indications that the same amount of nitrogen fertilizer yields more N_2O under tropical conditions than under temperate conditions.

Is the world faced with agonizing decisions pitting food production against atmospheric composition change? Not necessarily. Through improved fertilizer management, we may be able to re-adjust the nitrogen plumbing with the help of plants. We need to design agronomic systems for the tropics that reduce the nitrogen flow through the pipe by directing more fertilizer to the crops and less to the microbes that make N_2O. Results from studies of sugar cane in Hawaii and wheat in Mexico suggest that careful fertilizer management can significantly limit emissions of N_2O while at the same time cutting fertilizer costs and increasing crop yields. Reduced N_2O emissions to the atmosphere may someday be the result of richer harvests by farmers in the tropics

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Bouwman, A. F., K. W. Van der Hoeck, J. G. J. Olivier. 1995. Uncertainties in the global source distribution of nitrous oxide. *Journal of Geophysical Research*, 100, 2785-2800.

Firestone, M. K. and E. A. Davidson. 1989. Microbiological basis of NO and N_2O production and consumption in soil, in: *Exchange of Trace Gases between Terrestrial Ecosystems and the Atmosphere*, edited by M. O. Andreae and D. S. Schimel, pp. 7-21, John Wiley & Sons, New York.

Keller, M. and P. A. Matson. 1994. Evaluating the effects of tropical land use changes on atmospheric composition, R. G. Prinn (ed.) *Global Atmospheric-Biospheric Chemistry*, pp. 103-118 in: Plenum Publishing Company, New York.

Keller M. and W. A. Reiners. 1994 Soil-atmosphere exchange of nitrous oxide, nitric oxide, and methane under secondary succession of pasture to forest in the Atlantic lowlands of Costa Rica. *Global Biogeochemical Cycles*, 8,399-409.

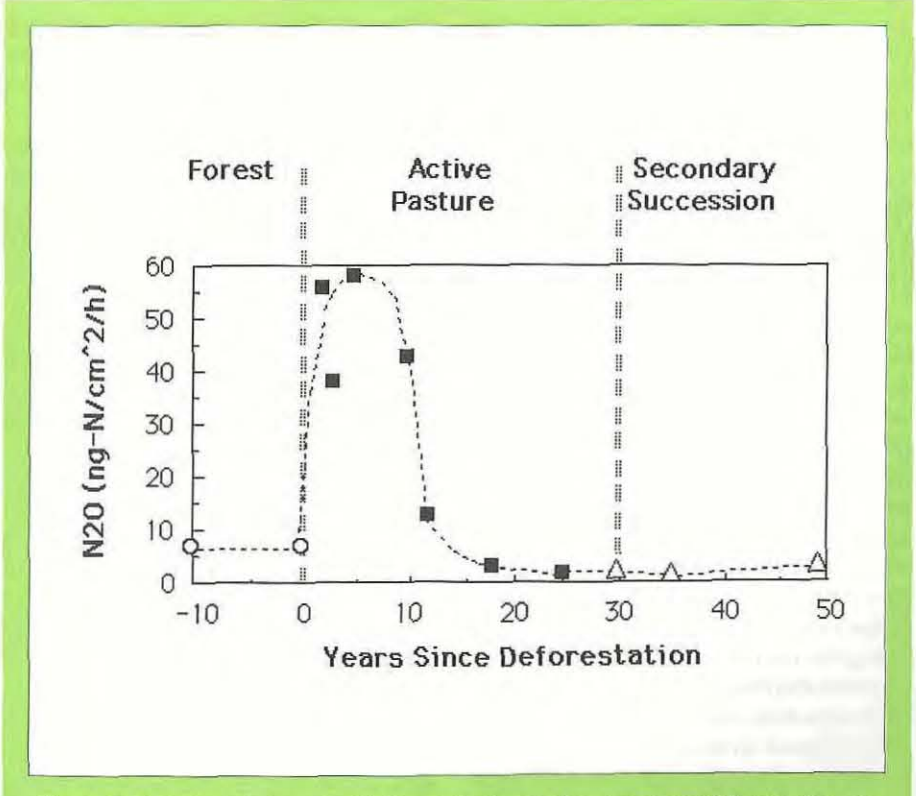

Figure 2. Emissions of nitrous oxide from soils along a chronosequence following the conversion of forest (0 years) to pasture through secondary succession in the Atlantic Lowlands of Costa Rica. (Adapted from Keller and Reiners, 1994).

Update on ACE^{ED}

The Goal of IGAC's Atmospheric Chemistry and Environmental Education in Global Change is to coordinate education activities aimed at promoting understanding of global change in the chemistry of the atmosphere, and its relationship to the biosphere, geosphere and to anthropogenic activities, internationally, both in the developing and developed countries and countries in all climate regions. (see *Global Change NewsLetter* No. 20, December 1994, pp. 7-8; 19)

To promote education and training in this field, scientists in IGAC and the World Meteorological Organisation's Global Atmosphere Watch (WMO/GAW) agreed to join forces with those in START to design and execute an integrated approach to "academic capacity building" in developing countries. The mechanism involves the establishment of a pool of voluntary lecturers recruited from the international scientific community to carry out the educational mission.

Through the coordination of IGAC, START, WMO/GAW and the Inter-American Institute for Global Change Research (IAI), a plan to design and jointly implement a capacity building programme for atmospheric chemistry in developing countries has already begun with a series of workshops.

The goal is to provide an integrated approach to academic capacity building in atmospheric and environmental chemistry in cooperation with multinational research/monitoring/assessment programmes with the participation of the International Volunteer Teaching Corps of scientists. If you wish to become a volunteer teacher, please contact:

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Recommendations for Atmospheric Chemistry Units

The International Union of Pure and Applied Chemistry (IUPAC), Division of Applied Chemistry, Commission on Atmospheric Chemistry has published a new set of recommendations for the use of units in atmospheric chemistry:

Schwartz, S.E., and P. Warneck, *Units for use in atmospheric chemistry (IUPAC recommendations 1995)*, Pure & Appl. Chem., ***67(8/9)***, *1377-1406, 1995.*

Global Change and Terrestrial Ecosystems

Integrative Activities

The early results from GCTE and related research around the world include: (i) the first trends from research on complex multispecies systems under elevated CO_2; (ii) an intercomparison of patch models of vegetation dynamics as applied to global change issues; (iii) rapid progress in the develop of dynamic global vegetation models (DGVMs); and (iv) first results from model intercomparisons in the Wheat and Rice Networks.

Integrating activities, cutting across the thematic division of GCTE foci, have made advances on many fronts. Integration is being achieved by the IGBP transects programme, Crop Networks, an elevated $C0_2$ consortium, and the Long-Term Ecological Modelling Activity (LEMA)

Long-Term Ecological Modelling Activity (LEMA)

A major aim of LEMA is to facilitate model and database exchange across GCTE and to undertake model intercomparisons at appropriate stages in the development of various Tasks.

Evaluation of the application of patch models of vegetation dynamics to global change issues.

An excellent example of a long-term ecological modelling activity was the workshop in Apeldoorn, Netherlands, organised around a sensitivity analysis, in which 13 research groups from around the world presented results from existing patch models using a standard set of climate change scenarios. Although the predicted ecosystem responses varied considerably from model to model, all of the models predicted significant changes in ecosystem structure as a result of climate change.

One of the most impressive outcomes of the workshop was the versatility of patch models in many aspects of global change research. The development of multi-life form patch models, for example, is a promising means of studying global change impacts at sensitive ecotones (e.g., the forest-grassland boundary), and the development of linked structure-function patch models will greatly assist research on global change impacts on ecological complexity and its relationship to ecosystem function. Also, modules based on patch models will likely be a key component of dynamic global vegetation models.

The workshop identified a number of areas, usually involving other components of the GCTE Core Research Programme, in which additional work is needed to overcome current limitations of patch models. These include: (i) improved modelling of soil processes; (ii) better understanding of mortality and recruitment processes; (iii) research on the effects of environmental factors such as temperature on whole-plant growth and mortality; (iv) experiments involving mature trees in natural stands under elevated CO_2; (v) incorporation of the spatial and temporal effects of disturbance regimes; and (vi) inclusion of the effects of animals and pathogens on patch dynamics.

The Vegetation/Ecosystem Modelling and Analysis Project

A GCTE Core Research Project, this is another excellent example of a long-term ecological modelling activity. In this project the outputs of three biogeochemistry models and three vegetation distribution models for the USA under present-day and future climate and CO_2 levels were compared. A doubled atmospheric CO_2 level was assumed, and the corresponding equilibrium climates from three general circulation models were used as scenarios. Thus, there were 27 possible combinations of climate scenario, biogeochemistry model and vegetation distribution model. When the outputs of the biogeochemistry models alone were compared, changes in the simulated net primary productivity and terrestrial carbon storage from present to future ranged from a 2% to a 35% increase for net primary productivity and from a loss of 33% to a gain of 16% for carbon storage. The variability in carbon cycle responses occurred because the hydrologic and nitrogen cycles as represented in the models have different sensitivities to increases in temperature and CO_2. When the effects of changing vegetation distribution were also included, the change in net primary productivity varied from no change to an increase of 56%, and the change in carbon storage ranged from a decrease of 39% to an increase of 56%. The variation here was due primarily to either decreases or increases in projected forest area as simulated by the vegetation distribution models, combined with temperature induced effects on water status and nitrogen cycling as simulated by the biogeochemistry models.

This well-designed and executed project demonstrates the power of model intercomparisons and appropriate model linkages, two activities which LEMA wishes to promote further. The Vegetation/Ecosystem Modelling and Analysis Project which involves investigators from 11 institutions, is sponsored by NASA, the Electric Power Research Institute, and the United States Department of Agriculture Forest Service.

TIGER

The strong progress made in the development of dynamic global vegetation models is exemplified by the UK consortium studying the influence of changes in climate and carbon on biome distribution. The strategy employed by this consortium, which is part of the Terrestrial Initiative in Global Environmental Research (TIGER) funded by the UK Natural Environmental Research Council, is shown in Figure 1. The core of the global model is DOLY (Dynamic Global Phytogeography Model), which uses a water balance approach along with information on soil carbon and nitrogen contents to calculate the leaf area index and net primary production for the Earth's terrestrial surface. Several additional features are moving DOLY rapidly towards dynamic global vegetation model status: (i) a module which projects conversion from natural vegetation to agriculture based to changes to the distribution of human population; (ii) the use of functional types rather than species or biome types in modelling vegetation structure; (iii) the development of a patch model based on gap dynamics to simulate changes to biome type; (iv) use of remote sensing to detect and quantify rates of disturbance; and (v) the coupling of DOLY to a general circulation model. The initial coupled dynamic global phytogeography model - general circulation model runs indicate that there is significant feedback from vegetation to climate at the regional scale for temperature and soil moisture, but that the effect averaged over the whole globe is small.

The provision of appropriate data-bases, particularly at the global scale, is becom-

ing an increasingly important component of GCTE's modelling work. For example, GCTE and other groups are working closely with IGBP-DIS to produce a globally consistent soils database designed specifically to support global change research. Disturbance regimes, and their projected variation under global change, are looming as an increasingly important feature in simulating ecosystem dynamics at all scales. The compilation of a global disturbance database is thus a high priority within the Long-Term Ecological Modelling Activity and GCTE generally.

The work described above illustrates the ability of Long-Term Ecological Modelling Activity to facilitate significant advances in scientific understanding across the GCTE research programme. The potential for further model development within GCTE is now great, and the need for a LEMA Secretariat to provide coordinative support for model intercomparisons, modular modelling, and data acquisition and standardisation is acute. GCTE is making a concerted effort to obtain resources to provide support for the rapidly growing number of activities being undertaken in or proposed for the network.

Crop Networks

The report from the 1993 Wheat Model Comparison Workshop caused much interest. The reasons for the marked divergence in the output from the 10 models (2.5 - 8.0 t/ha grain yield), given common initialisation parameters, is still being keenly debated, and will form the subject of two scientific papers in preparation. Particularly surprising was the fact that the use of a common leaf area index development time course for all models did not bring about a marked improvement. A follow-up workshop was held in March 1995 in Reading, UK, to examine in more detail the reasons for the divergence in yield prediction. It proved difficult to establish the exact reasons for the model divergence, but a major factor was the way each model dealt with radiation use efficiency, and how this varied with temperature. Three additional members have been accepted into the GCTE Wheat Network, the formal Network membership now standing at 36. A compilation of the 1993 Wheat Network Model and Experimental Metadata was published as GCTE Report No. 2.

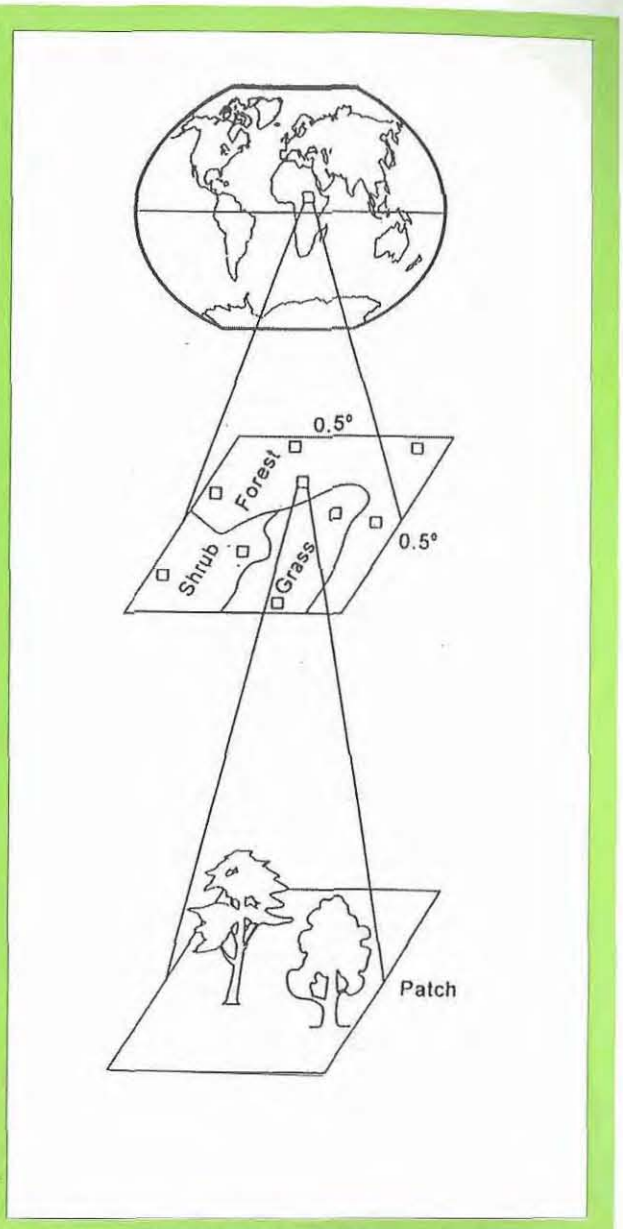
The GCTE Rice Network was formally launched at an international workshop at the International Rice Research Institute, Philippines, in March 1994. A comparison of four major rice growth models was presented, which showed a divergence much less than that of the wheat models. A major proposal for funding the Network's activities (planning and training workshops, exchange visits, research fellowships, field experimentation and coordination) was prepared and discussed with a wide range of donors; partial funding has been secured. The next GCTE Rice Workshop (Bangkok, September 1995, hosted by the Thai National IGBP Committee) will design a multi-site, network-experiment for temperature gradient tunnels and report results from a temperature x CO_2 sensitivity analysis for the major rice simulation models. A GCTE Rice Working Group has been convened to manage the Network.

The proposed GCTE Potato Network was discussed in detail at an international workshop in Wageningen, Netherlands. Although modelling potato growth is relatively well advanced, the participants agreed that a formal GCTE Network, linking experimental and modelling groups worldwide, would be very beneficial. Initial plans for this were prepared with a list of potential members.

The proposed GCTE Cassava Network was formally announced at a Symposium of the International Tropical Root Crops Society in Salvador, Brazil. The GCTE Network was seen as essential to link cassava researchers investigating global change impacts; pests and diseases will play a particularly important role in both experimental and modelling studies for the Cassava Network.

A grant was received from the Dutch Global Change Programme (NOP) to engage a GCTE Crop Networks Research Officer. The position, to be located with Professor Jan Goudriaan, Wageningen, is to help prepare Network datasets and models for model comparison and data synthesis exercises.

The management structure of the individual GCTE Crop Networks has been changed to allow greater specialist input for the given crop. The earlier structure of "temperate" and "tropical" crops has been superseded by crop-specific Working Groups comprising plant physiologists, specialists in pest, diseases and weeds, and modellers. The GCTE Crops Committee, spanning all Crop Networks, continues to provide a general coordinative and management function.



Hierarchy of scales addressed in GCTE research on ecosystem structure/composition

Further achievements of GCTE , relating to the Transects plans, the CO_2 consortium, and the progress of projects under each Focus and Task, can be found in the GCTE annual report for 1994, Canberra: 1995.

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Biospheric Aspects of the Hydrological Cycle:

The Four Foci

Global Circulation Model simulations are sensitive to changes in surface albedo, aerodynamic roughness, soil moisture and evaporation, all of which are influenced by vegetation and snowcover. Nevertheless, the role of the biosphere is not sufficiently described in these models and improvement of the eco-hydrological components in GCMs remains a challenging task. In-depth knowledge of the interactions between the hydrological cycle and the terrestrial biosphere is crucial for assessment of the impact on freshwater resources, and hence the productivity of natural and man made ecosystems, of climate change and other more direct human pressures on the environment.

The understanding of interactions across the diversity of processes and temporal and spatial scales requires collaboration between hydrologists, atmospheric scientists, soil scientists and ecologists to a degree that traditional boundaries between these fields disappear. BAHC is a catalyst in this process as an organisation that stimulates and fosters integrative, eco-hydrological research.

Two basic BAHC objectives are:

- to analyse the biospheric controls of the hydrological cycle through field measurement for the purpose of developing models of energy and water fluxes through the soil-plant atmosphere system at all temporal and spatial scales,
- to develop databases that can be used to describe the interactions between the biosphere and the rest of the physical earth system, and to test/validate model simulations of these.

A range of tasks have been formulated and grouped under four Foci:

One-dimensional Soil Vegetation Atmosphere Transfer models (SVATs)

The main objective of FOCUS 1 is to investigate the vertical exchange of energy, moisture and coupled trace gases at the soil-vegetation-atmosphere interface and their dependence on relevant soil and vegetation parameters as well as climatological, hydrological and other related parameters. Investigations have been carried out at this scale and a number of SVAT models have been developed. Emphasis is on improving SVATs to simulate in a comprehensive way the various eco-hydrological processes, for the full eco-climatic continuum found on Earth.

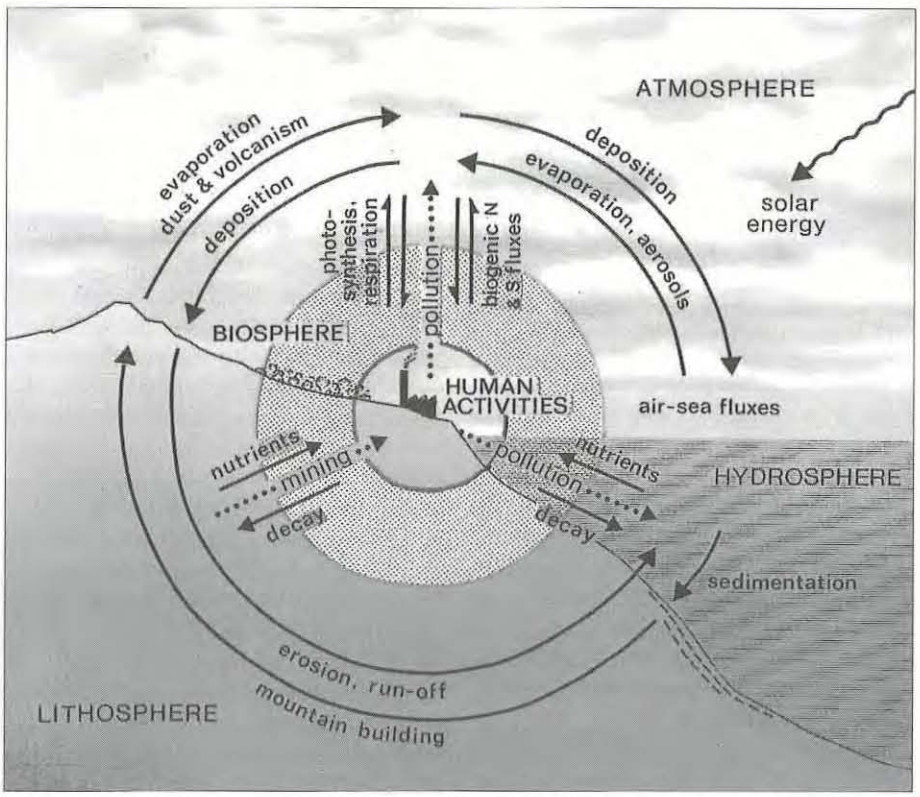
A coordinated network of flux measuring stations for long-term, continuous observations has been established (CO_2 FLUXNET). Eventually this initiative should lead to continuous operation of 10-50 stations, capable of measuring radiation, heat, water and CO_2 fluxes, preferably evenly dispersed over the world's land surface. Such stations drive on technology developed over the past five years in various Land-Surface Experiments. A central data information system will be established at the NOAA-Oak Ridge Data Archiving Center, with input from the Global Terrestrial Observing System (sponsored by WCRP).

BAHC, through Focus 1 and Focus 3, produces global vegetation and land cover mapping. A BAHC priority is to evaluate and compare methodologies, to lead to agreement on a single multipurpose classification. At the same time first attempts at mixture-modelling studies are supported for selected pilot regions.

New 'applications' in SVAT science are underway: these include non-methane hydro-carbon models, biome competition models and wildfire behaviour models.

Regional-scale studies of land surface properties and fluxes

FOCUS 2 extends the investigations under Focus 1 into two and three dimensions. It is oriented towards experiments in different regions, and therefore takes into account the role of heterogeneity in land use, vegetation type, soil, hydrological and other conditions and includes effects of topography and lateral surface and subsurface water flow up to a scale of 10^4 km^2. An important subject in Focus 2 is upscaling, namely the appropriate representation of characteristics of larger areas in models



Earth system cycles: the main mechanisms moving materials between land, air and oceans, and their principal interactions with biological processes and human activities.

which take account of land surface heterogeneity in all its forms.

Outstanding progress has been made in understanding "aggregation" through a mixture of experiment, modelling and a continuous review of methods. A major achievement of recent years is the conclusion that a simple rule can be used for above-ground vegetation parameters, regardless of the scale of heterogeneity.

A common format for Large Scale Field Experiments has been found in close collaboration with the Global Energy and Water Cycle Experiment-International Satellite Land-Surface Climatology Project.

Recently emphasis has shifted from atmospheric advection to eco-hydrological control. This process is accompanied by a refocussing towards below-ground processes, inclusion of carbon exchange and an extension of temporal scales.

Diversity of Biosphere Hydrosphere interactions

FOCUS 3 seeks to develop models that describe long term dynamics of the terrestrial biosphere, and the provision of global, quantitative data on biospheric processes and relevant land surface characteristics.

The first SVAT publications appeared in the early 70s, the first mesoscale experiments were from the mid 80s, but the first climate simulation with a dynamically redistributed vegetation was performed only in 1994. So the Focus 3 agenda is very young, and can only mature to full scale as the scientific foundation for the first two foci develops.

Recent developments show evidence that vegetation distribution and physiology can have large effects on climate. However, most studies have been simplistic and unidirectional, whereas the opposite is true: vegetation distribution and physiology are sensitive to climate. The prediction of vegetation distribution and understanding the difference between potential and actual distribution has progressed dramatically.

The Weather Generator

FOCUS 4 was initially conceived to develop data bases to describe the interactions between the biosphere and the physical Earth system, and to test and validate models of such interactions. In practice, this meant the provision of high-resolution meteorological data for climate and climate-change research for the BAHC and GCTE core projects. FOCUS 4 has now entered a second phase where it is possible to identify different types of downscaling approaches, assess the uncertainty of their results, and the applicability of any approach for ecological and hydrological modelling.

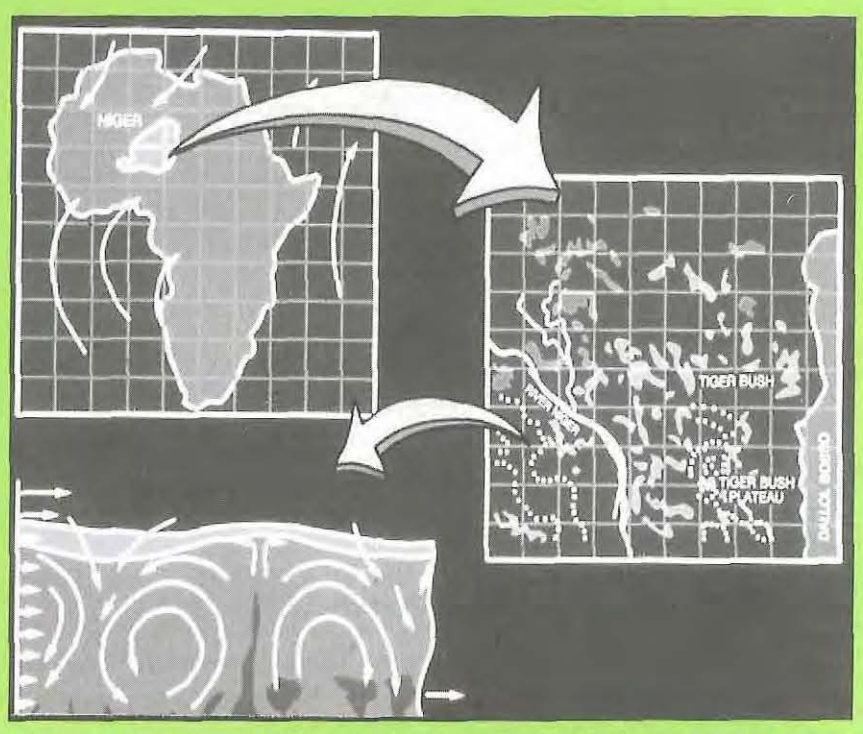
The dynamic and stochastic approaches to downscaling need to be evaluated with different data sets, but also both should be integrated in a single, Bayesian framework. Study areas for calibration and evaluation of the different downscaling algorithms have been chosen, partly in collaboration with projects under Focus 2: the HAPEX-Sahel, the North China Plain project, the Little Washita Basin in Oklahoma, and in the future the Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA).

In the near future the preparation of standardised data sets needed for coordinated reference runs with various downscaling models will be finalised and distributed among the relevant groups. Another continuing focus will be on the analysis of the effects of uncertainties in application programs. Of particular concern is the systematic analysis of the impacts of uncertainty in simulation models such as the SVAT's which are at the core of Focus 1.

The central role that data uncertainty plays in the quality of model output, requires policy makers and other end-users of model results to provide feedback on the acceptable level of risk. This awareness may provide a bridge to HDP (Human Dimensions of Global Environmental Change Programme) and the GCOS (Global Climate Observing Programme) initiative on the socio-economic benefit of climate forecasts.

Focus 4 started the exploration of using satellite data. The optical properties of clouds can eventually be transformed to produce daily values and drought extremes. This can be useful in many areas of the world where adequate observations are not available.

There are plans to apply the Weather Generator in the North China Plain in cooperation with GCTE but also with BAHC Focus 1, the relevant foci in IGBP-DIS and the HDP, and in collaboration with existing Chinese programs or institutes involved in climate impact assessment and adaptation research.



Aggregation Modelling in HAPEX-SAHEL is a project under BAHC Focus 2, and it is a study area for BAHC Focus 4.

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CO_2 FLUXNET Implementation
Creating an Open Discussion

What happens to CO_2 produced by human activities? It is not yet possible to close the contemporary global carbon budget because of the inability to estimate the quantity of excess carbon taken up by terrestrial ecosystems. From various CO_2 measurements and model studies of the carbon cycle (e.g., Ciais, et. al., 1995; Denning et. al., 1995), the fractions remaining in the atmosphere and absorbed by oceans are relatively well-bounded estimates. The difference, or a "missing component," is thought to be taken up by terrestrial systems, but firm quantitative estimates are elusive. Recent research suggests a strong mid latitude Northern Hemisphere terrestrial sink roughly equivalent to half the fossil fuel emissions for 1992 and 1993, and emphasise the need for research on processes responsible for absorbing such large quantities of CO_2. Systematic CO_2 flux measurement is one possible approach for sharpening the estimates of terrestrial carbon change.

A workshop at La Thuile, Italy recently reviewed flux measurement approaches for quantifying annual net carbon gains by terrestrial ecosystems (Baldocchi, et. al., submitted), and a "CO_2 FLUXNET" has been proposed to obtain worldwide systematic data on CO_2 exchange between the atmosphere and terrestrial biosphere (IGBP, 1995). A clear conclusion of this Workshop was that eddy co-variance* is one very attractive approach for measuring carbon flows into and out of an ecosystem in order to quantify a "missing" component of the excess carbon budget. Technological readiness exists, as do sound scientific approaches. The scientific community is excited about implementing a network of measurements, and in producing coordinated measurements and a more comprehensive data base. The ideas from La Thuile have gained support from IGAC, BAHC and GCTE Projects of IGBP; however, commitment to long-term systematic observation would still be a bold step because most experiences to date stem from relatively short-term campaigns.

What is even less clear is the dimension of institutional support and availability of funds to develop and sustain a global network of measurements. The fact that scientific and technical capabilities and interest exist does not necessarily ensure financial support for an emerging venture. Funding for developing a network of systematic measurements is not a trivail matter; up-front investment costs estimated in U.S. dollars are ca. $100,000 per site. Annual operating expenses– for flux and collateral atmospheric measurements; for quality control and archival of data; for studies of ecosystem processes and controls, and for measurement of site biological parameters; for analysis and modeling – could cost $100,000 or more per site.

It has not yet been determined what would constitute an optimal number of network sites, but it was learned at La Thuile that scientific capability to run equipment and interpret results exists at 20 to 25 locations worldwide. Systematic CO_2 flux data will be needed from 25 more locations to provide required global coverage, where an "ideal" set of locations would depend on a strategy to sample globally the ecologically significant biomes. Initial costs to implement a global measurement-monitoring network would be at least $5 million, and would increase by $0.1 to $0.2 m. for each station added to the network.

In view of the non-trivial financial requirements, and the fact that many governments closely scrutinize support for research, it would seem that parallel to the development of scientific plans there should be a discussion of how a CO_2 flux network can be financed, especially since a worldwide network would likely involve scientists and sources of support from many countries. Mechanisms for planning and coordinating funding may in fact already exist since a flux network simply augments other global ventures such as satellite observations and general climate modeling.

Given the diversity of philosophy and financial practices of different countries (and their respective science agencies) in supporting research, it would seem prudent to explore and understand possible approaches for securing and coordinating various sources of support. Assuming that flux measurements would need to be taken continuously, and that a flux measurement/monitoring network would need to operate for a decade or longer, is it possible to get assurances/commitments for long-term support? Moreover, is it possible for the scientific community to define clearly the funding requirements needed to sustain a long-term program that would make it palatable to governments willing to invest? Finally, there may be lessons to learn from experiences of developing and sustaining other networks of measurement, e.g., the atmospheric CO_2 measurements made over the past four decades, which has had its share of frustrations. These are just a few of the logistical and financial questions that might be discussed prior to implementation of a "CO_2 FLUXNET."

To explore some of these issues, an open discussion is proposed of financial-institutional-coordination-logistical aspects of "CO_2 FLUXNET." It would be especially helpful if Program Managers/Research Directors could bring their perspectives to the discussion.

Those having views on these issues should send them to the IGBP Secretariat (see address on p. 19 in News Letter box). Please identify message subject as "CO_2 FLUXNET," and include your Internet address.

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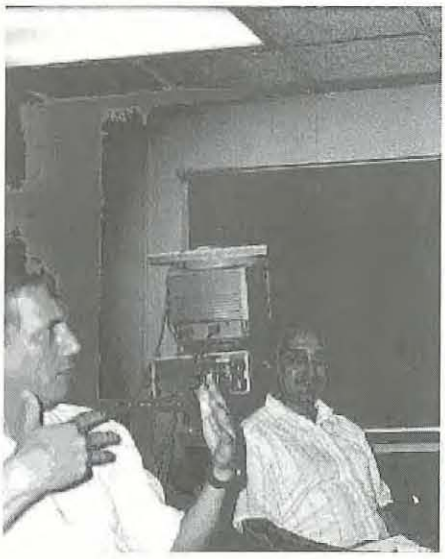
*Eddy-covariance, also eddy correlation, is a measurement technique in which atmospheric fluxes are derived from covariances of the vertical wind speed and temperature, humidity, or CO_2 concentrations.

Corrigendum: The last issue of the Global Change NewsLetter failed to mention that the US Department of Energy sponsored the La Thuile Worshop. Our apologies (Ed.)

Spreading the Web : The IGBP-DIS-START 1995 Summer School

In order to increase the knowledge of electronic networking and its utility in global change research, IGBP-DIS and START (the IGBP Global Change System for Analysis, Research and Training Framework Activity) organised a Summer School on electronic networking and Data and Information Systems (DIS). The workshop was a three week summer school given by instructors from the University of Maryland, IGBP-DIS and START at the University's Department of Geography. The major objective of the summer school was to gather scientists from developing countries within START regions and develop a prototype World Wide Web data and information system to act as a seedbed for the development of a fully functional START-DIS.



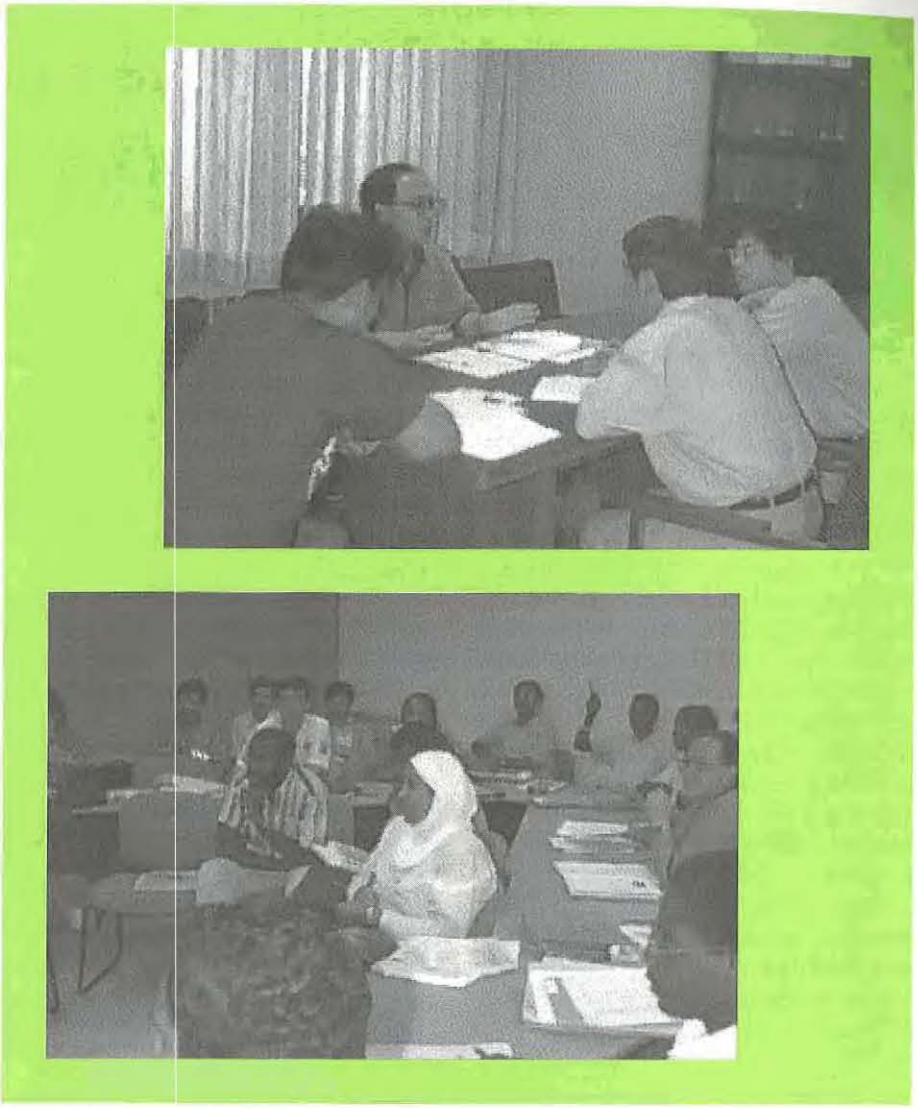
Funding was provided through the International START Secretariat via an NSF grant. The Workshop ran from 17 July 1995 through 4 August 1995 and included 24 scientists from around the world. In the 15 instructional days participants created a functioning data and information system using World Wide Web technology. These participants returned to their countries with reference materials, teaching materials and relevant software.

Classes ran for three weeks in the University's UNIX laboratory. Participants were introduced to the UNIX operating system along with various existing network services in a three day preliminary session. Participants then began designing and implementing the START-DIS in earnest. In only three weeks these participants had developed a working version of the system that was later demonstrated to the START Standing Committee at their meeting in Washington, DC, on 11-14 September, 1995.

By the conclusion of the course, the twenty-four scientists at the summer school had learned how to develop a working Data and Information System and had set up their own system in only three weeks. Participants developed plans for future implementation of similar systems within their own regions. Most importantly, they developed human networks with scientists all over the world that will serve themselves and the START Secretariat for years to come.

These scientists have become an important asset to START and IGBP in the development of a wide area based Data and Information System. Continuation of similar workshops within the regions is a basic step towards fruition of the START data and information systems.

Plans also include the creation of the START-DIS CD-ROM which will contain the entire START-DIS system, WWW client applications, and other relevant software to assist those regions with limited network access. The CD-ROM should be available by Spring of 1996.



Teachers and students at the IGBP-DIS-START Summer School at the University of Maryland

For more information, please contact the **International START Secretariat**, Suite 200, AGU building, 2000, Florida Avenue, NW, Washington, DC 20009, USA, Tel: (+1-202) 462 2213, Fax: (+1-202) 457 5859,
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Land-Ocean Interactions in the Coastal Zone Achievements and Future Plans

A network of over 1,000 coastal scientists from 124 countries was involved in the development of the LOICZ Implementation Plan (IGBP Report No. 33), which details the manner in which the scientific issues and uncertainties surrounding the role of the coastal domain in the functioning of the Earth system need to be addressed.

The Second LOICZ Open Science Meeting, convened in April 1995 at the Marine Science Institute of the University of the Philippines, was attended by 203 natural and social scientists from 45 countries. This provided a forum in which to explore the mechanics of how to implement the project.

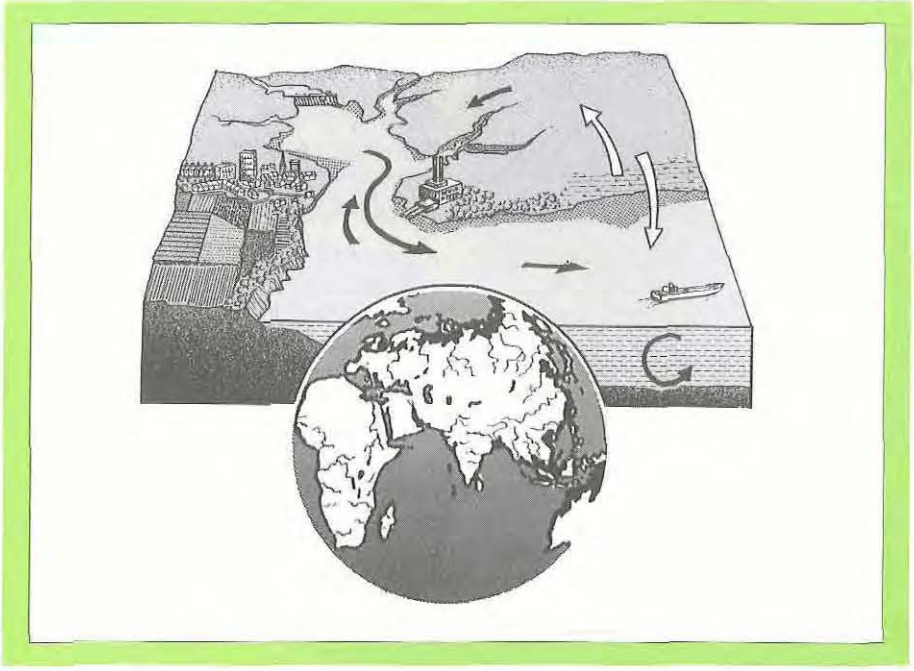
Both regional and topic-oriented discussions were convened, resulting in the identification of potential core research nodes and initiation of specialised networks upon which the future success of LOICZ will depend. The meeting was supported by a number of international agencies with interests in coastal science including the Intergovernmental Oceanographic Commission of UNESCO, IUCN-The World Conservation Union, and the Commission of the European Union with whom the LOICZ Project maintains strong collaborative links.

There are significant differences between LOICZ and those Core Projects of the IGBP that address processes in comparatively distinct compartments of the Earth system such as the atmosphere, or the oceans. In comparison with the relatively uniform environment of the sunlit zone of the open ocean, or the rapidly mixed environment of the atmosphere, the spatial and temporal heterogeneity of the world's coastal zones is considerable. As a consequence there are considerable methodological problems associated with developing global perspectives of the role of the coastal sub-system in the functioning of the Earth system. This issue is being tackled through the development of a coastal typology that will be used as a framework for preparing regional and global syntheses and to identify coastal areas and types for which more empirical data are required. A draft document outlining the strategy for developing such a typology has been produced and circulated throughout the network of corresponding scientists and this will be further elaborated in collaboration with the Food and Agriculture Organisation of the United Nations and the Netherlands Geological Survey.

Recognising that considerable bodies of empirical, *in situ* data already exist in the literature for a number of areas of interest to LOICZ the project has initiated, in collaboration with the World Health Organisation and the Global Environment Monitoring System (GEMS) of the United Nations Environment Programme (UNEP) the compilation of data relating to riverine discharge to the coastal zone. A draft document *River Discharge to the Sea: A Global River Index* was published and circulated by LOICZ in April 1995. Further amplification and expansion of this database will be undertaken over the next biennium. Plans are in hand to evaluate the feasibility of producing such a synthesis in the case of groundwater discharge.

A programme of activities in four countries of the Southeast Asian Region was approved as Core Research at the Fourth Scientific Steering Committee meeting held in the Philippines. Executed by coastal zone researchers on the staff of four institutions in the region, this is a collaborative programme funded by the Netherlands Foundation for the Advancement of Tropical Research through the Southeast Asian Regional Committee for START (SARCS) and coordinated by the LOICZ Core Project Office on behalf of the LOICZ-SSC. The research objectives are primarily focused on social and economic impacts of global change in coastal systems (LOICZ Focus 4) but involve quantification of land-ocean fluxes and modelling (Focus 1) and the role of biota in coastal geomorphology (Focus 2).

To provide a framework for future national and regional research, and to ensure that data generated through such research are comparable and compatible, two sets of guidelines are currently under development through LOICZ. The first of these, guidelines for coastal resources assessment are nearing completion and lay out the alternative methods which can be applied in LOICZ research concerned with economic analyses of pressures driving change in coastal areas. The second set of guidelines, currently under development by a consortium of LOICZ-SSC members concern coastal modelling to be used in developing different forms of coastal models of carbon and major nutrients for coastal areas. Another component of this framework, the LOICZ data system plan is under active development in collaboration with the IGBP-DIS. When completed this will document the expectations of the LOICZ project and its component researchers in terms of data compilation, management, access and exchange.



The report of the ad hoc Joint JGOFS/ LOICZ Task Team was published in 1994 and subsequently a Joint Task Team was established, charged with developing a strategy for Continental Margin Studies which form the major point of interface between these two Core Projects. Procedures for the submission of national and regional research are being finalised and despatched to the National IGBP and LOICZ committees. Execution of such research will commence in 1996. At the present time LOICZ is establishing a firm basis on which to build future activities. This foundation, in terms of initial networks, researchers and activities will be in place by the end of this year and full scale execution of project activities is envisaged over the subsequent biennium.

The Future Path

The physical and biological heterogeneity of the world's coastlines, combined with the variety of social, cultural, and economic conditions driving change in these areas, results in a complex interplay of processes such that conditions and the ensuing dynamic equilibrium in any one area of the world's coast can be considered unique. Developing models, scenarios and syntheses that allow a wider spatial or temporal view of these dynamic systems is a significant scientific challenge. In order to develop regional and global syntheses of any single flux from land to ocean (sediments, freshwater, or nutrients for example) this diversity of natural and human conditions must be filtered in such a way that the dominant factors controlling present fluxes can be identified, and quantified. The effects of global change on these factors, whether positive or negative, must then be determined if future conditions are to be adequately described via scenarios, or built into more dynamic models for producing forecasts.

Developing fully predictive models of the dynamics of coastal systems, which adequately incorporate even the dominant natural science components of such systems, is probably not possible within the life-span of LOICZ. The development of fully coupled models describing the dynamics of the natural and human environment of coastal areas also requires a significant investment of intellectual and financial resources, resources that are unlikely to be made available to the project in a co-ordinated manner. Nevertheless, significant advances towards these longer term goals can be made.

In the short term, regional and global syntheses of existing empirical data can be produced to provide a basis for expansion of the temporal and spatial scale of various types of coastal models. Catchment basin models that adequately describe the driving forces controlling discharge from catchments of different types to the coastal ocean can be constructed, allowing extrapolation from catchments of known to unknown characteristics. Once fully validated, coastal ocean carbon budgets and flow models, can be used in conjunction with the coastal typology to provide better estimates of the role of the coastal ocean in the global carbon cycle.

The majority of the work of the Core Projects to date has been undertaken through national research activities co-ordinated by the CPO's and SSC's. Research results are compiled, data exchanged and regional and global syntheses produced, which assist in clarifying the scientific uncertainties surrounding different aspects of Global Change and the functioning of the Earth system. As noted in the LOICZ Implementation Plan, LOICZ is a project that addresses the effects of cumulative changes to the world's coastal zones, the effect of these changes on the functioning of the earth system as a whole, and on the human populations of coastal areas. The complexity of the project in terms of the scientific issues and uncertainties which need to be addressed in achieving the LOICZ goals will necessitate meticulous compilation and analysis of data from individual, national and regional studies.

Whilst LOICZ must, understandably, invest considerable effort during the initial phases of its development in the science and hence the understanding of the dynamic processes occurring in the coastal zones of the world, linking with the other elements of the IGBP must be seen as a pressing need at the programmatic level if IGBP is to achieve its own overall goals and objectives. Integrating LOICZ issues with those of the other Core Projects will not be easy. Many of the scientific questions and issues that are part of LOICZ goals and objectives relate to solving land-ocean flux problems in the horizontal plane. In contrast, JGOFS modelling of carbon and BAHC modelling of water for example, have in the past, largely concentrated on the vertical component of flux. Resolving these apparent incompatibilities presents a significant intellectual challenge to the IGBP. It is a challenge paralleled by that of LOICZ in integrating research over a wide range of natural science disciplines and attempting to integrate such research with that of the social sciences.

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LOICZ Research Goals For The Future

The LOICZ Science and Implementation Plans identify the long-term goals of LOICZ as

(i) To determine at global and regional scales:

(a) the fluxes of materials between land, sea and atmosphere through the coastal zone

b) the capacity of coastal systems to transform and store particulate and dissolve matter, and

c) the effects of changes in external forcing conditions on the structure and functioning of coastal ecosystems.

(ii) To determine how changes in land use, climate, sea level and human activities in the coastal zone alter the flux and retention of particulate matter, and affect coastal morphodynamics.

(iii) To determine how changes in coastal systems, including responses to varying terrestrial and oceanic inputs of organic matter and nutrients, will affect the global carbon cycle and the trace gas composition of the atmosphere.

(iv) To assess how the responses of coastal systems to global change will affect the habitation and usage by humans of coastal environments, and to develop further the scientific and socio-economic bases for the integrated management of the coastal environment.

To achieve these long-term goals three types of basic scientific research are required concerning key aspects of coastal system dynamics:

(i) Intensive process studies and related models designed to achieve an understanding of how coastal systems behave with respect to changing environmental conditions

(ii) The acquisition of extensive observational data for key environmental parameters to establish the significance of coastal processes in determining the global distribution of those parameters

(iii) Simulation and prognostic modelling of coastal systems in order to simulate and forecast over a range of space and time scales the effects of global change on the land ocean interface.

Overview of the Joint Global Ocean Flux Study

by J.G. Field, Chair JGOFS

The JGOFS Science Plan was published in 1990 with a goal and objectives relating to CO_2 and biogeochemical cycles. These were narrowed in the Implementation Plan (IGBP Report No. 23, 1992) to concentrate on CO_2 with studies on other elements only insofar as they affect the understanding of processes of CO_2 fluxes between atmosphere, upper ocean and deep ocean. This has helped to focus JGOFS activities.

Scientific Highlights

JGOFS has stimulated international co-operation that would otherwise not have occurred. Some examples include:

North Atlantic Bloom Experiment

Following the "green carpet as it unrolls northwards" from low to high latitudes with the coming of spring was an important initial JGOFS activity which stimulated the development and publication of a set of protocols for observing the ocean. JGOFS provided the co-ordination that allowed multi-ship inter-calibration exercises to take place resulting in new international standards and method protocols being established. The fact that the spring bloom sediments out in a rapid event that can be detected in bottom sediments is a significant finding. Further work is planned in a second phase of North Atlantic activity from 1997-2000 to study seasonal changes in both the formation of North Atlantic Deep Water at high latitudes, and biological and chemical CO_2 exchange processes.

Time Series stations

The Bermuda (BATS) and Hawaii (HOTS) time series stations have provided an invaluable time series of observations relevant to JGOFS with which to calibrate models. The BATS data, for example, have shown that a large part of carbon transport out of the photic zone is by seasonal mixing of refractory dissolved organic carbon down into deeper water. The development and testing of new high temperature catalytic oxidation techniques for measuring dissolved organic carbon was due to JGOFS stimulation and needs in this area.

Equatorial Pacific Study

This study was planned because of the vast area of upwelling that occurs in the Equatorial Pacific, with accompanying outgassing of CO_2, and the important role of ENSO (El Niño Southern Oscillation) in these processes. Initial results confirm the importance of ENSO in affecting rates of primary production and CO_2 flux in the Equatorial Pacific, and they confirm the Bermuda findings of dissolved organic carbon being an important component of carbon flux out of the photic zone. Furthermore, the High Nutrient Low Chlorophyll (HNLC) paradox of the region has given rise to the first large scale in situ Iron Fertilization Experiment, with JGOFS participation. This experiment showed enhanced primary production with iron fertilization, but the question of altered rates of CO_2 flux remains unresolved owing to subduction of the fertilized water mass.

Southern Ocean:

The first phase of the JGOFS Southern Ocean study (1991-1995) put a new unity of purpose into various national Antarctic research plans, as they re-orientated previously-planned cruises to meet JGOFS objectives. The larger ships used in this region have permitted more exchanges of scientists than in other areas and many ships have accommodated scientists from other countries, promoting close international collaboration. Preliminary results have been exciting and unexpected: the mosaic of water masses, fronts, seasonally moving marginal ice zones, and areas of subduction and upwelling have been intensively studied from a carbon flux angle. The first winter measurements of primary production and carbon flux have been made in the Southern Ocean, and the British results of 1992-3 suggest that in the areas encompassed by their cruises, the Southern Ocean was a net sink for CO_2, whereas summer oceanic conditions were expected to provide a net source in the Southern Ocean. The southern summer of 1992-3 was an anomalous year, however (post-Pinatubo eruption, El Niño) and it remains to be seen whether these results are the norm or not.

Arabian Sea

This region was chosen because of the massive seasonal changes in upwelling caused by monsoonal reversals of wind and current. This had been dramatically demonstrated by the Nimbus Ocean Colour satellite images, and unfortunately the delayed launch of SeaWiFS has hampered the work in this region. Early observations confirm that NO_3-rich waters throughout the study region during the NE monsoon in January were depleted by March-April, with oligotrophic conditions prevailing during the most recent cruises. Thus promising initial results were presented at the Villefranche Symposium.

Continental Margins

This joint work with LOICZ is only just getting off the ground, but has served the purpose of getting many new countries, which are unable to get significant funding for "blue water" research, involved in JGOFS. Thus scientists in Taiwan, Chile and South Africa, for example, have tailored their national research programmes to JGOFS objectives. This work is stimulated by the importance of continental shelves and slopes as regions of enhanced primary production and massive carbon sedimentation, and the need to study the dynamics of coastal upwelling as both a source and a sink for CO_2. It seems from initial models that the intervals between and duration of upwelling pulses, and the degree of subsequent stratification are important factors in assessing the relative importance of outgassing and biological uptake of CO_2. Further work on estuaries, cross-shelf transport, and other aspects of carbon flux are being planned for continental margins.

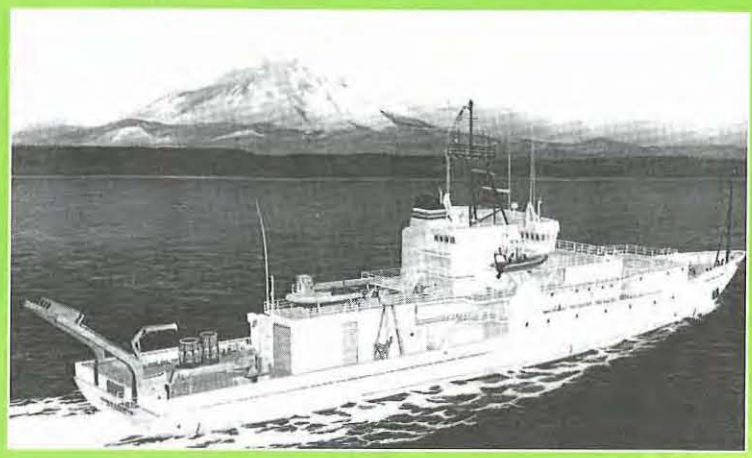
JGOFS has involved physical oceanographers, chemists, geochemists and biologists in planning and executing its research. These scientists would probably not all have co-operated without JGOFS. The disciplines have brought with them a range of techniques ranging from stable-isotope and radio-isotope methods, to physiological uptake experiments, to sediment traps, satellite remote sensing and ocean optics. Models range from geochemical box models to ecological models and to coupled ecological 3-D ocean general circulation models. The resulting interaction has promoted vigorous and healthy debate on issues such as the relative importance of physical, chemical and biological processes in carbon flux on scales ranging from the thermohaline circulation to coastal upwelling. JGOFS has caused scientists to view a range of processes in very different ocean regions from the common perspec-

tive of carbon flux. I believe that as a result, there have been paradigm shifts in areas such as understanding the role of dissolved organic carbon, in the importance of physical processes which drive the "biological pump" and in the "iron hypothesis" in high nutrient-low chlorophyll regions. These ideas are now being tested further as hypotheses in the next phase of JGOFS. Many scientists have been stimulated to work on JGOFS science as a result of the excitement it has generated.

Links to other IGBP Core Projects

JGOFS has had good links with other marine Core Projects, or those being planned. A JGOFS scientific steering committee representative was on the Core Project Planning Committees for both Land-Ocean Interactions in the Coastal Zone and Global Ocean Ecosystem Dynamics. JGOFS is also heavily involved in planning for a potential successor project, tentatively called the Global Ocean Euphotic Zone Study which would link upper ocean physics and biology using Global Ocean Observing System technology to understand and predict climate and weather patterns. There has been good collaboration with the International Global Atmospheric Chemistry project in the Biogeochemical Ocean-Atmosphere Transfers workshop (BOAT) and with IGBP-DIS in compiling a global database of CO_2 measurements. Although there has been little initial marine activity in the IGBP task force for global analysis, interpretation and modelling (GAIM), some marine modellers with JGOFS links have been involved with this task force and more JGOFS links are planned. There has been only limited contact with the Core Project on Past Global Changes (PAGES) hitherto, but more is envisaged with the new IMAGES research initiative organised jointly by the Scientific Committee on Oceanic Reearch and PAGES. New multi-ship work in the North Atlantic (1997-2000) is being planned jointly with the potential Core Project, Global Ocean Ecosystem Dynamics.

We have co-operated well with the World Ocean Circulation Experiment, in the World Hydrographic Programme-JGOFS CO_2 survey in which ships working on the ocean circulation experiment have had at least one berth for CO_2 measurements. This survey of CO_2 provides extensive 3-D global ocean cover to complement the intensive regional process and time series studies on one hand and the satellite remote sensing of the ocean surface on the other. The Panel sponsored by JGOFS jointly with the Intergovernmental Oceanographic Commission is strongly involved in the CO_2 survey and has published a handbook of analytical protocols to measure carbon compounds in sea water. It organised the 1994 international inter-calibration exercise to measure pCO_2 at sea. An Atlantic database for pCO_2 field data is being established in conjunction with IGBP-DIS and this is being expanded to a global CO_2 database under the supervision of a sub-committee of the CO_2 panel. These activities of the Panel are central to one major goal of JGOFS: to quantify the capacity of the oceans to absorb atmospheric CO_2.



The Research Vessel Thomas G. Thompson

JGOFS has established links with the Global Ocean Observing System through several individuals associated with JGOFS serving on the observing system committees. Nevertheless, there is a general feeling amongst the JGOFS scientific steering committee that JGOFS should have more direct and formal links with the Global Ocean Observing System. For example, we should be asked to comment on proposals or to submit proposals with plenty of lead time to enable meaningful discussion to take place the scientific steering committee, or to set up special sub-committees for this purpose.

Links to National Research Programmes

These are generally informal through JGOFS scientific steering committee members and other science leaders also serving on National Committees. The Chair of the JGOFS scientific steering committee and other committee members are frequently asked to review proposals to national committees for funding. This informal mechanism appears to work, in that most major national programmes provide important input to the overall JGOFS effort and these efforts have been fairly well co-ordinated. The publication of protocols for JGOFS measurements has helped maintain standards and compatibility of data amongst the national programmes. Another more formal mechanism is that Chairs of National Committees are always invited to steering committee meetings, and there are usually several non-steering committee members present as a result of these invitations. Several such individuals have later been invited to join the leading body of JGOFS. The publication of JGOFS "White Reports" has also greatly assisted national programmes in tailoring their activities to JGOFS.

JGOFS Legacy

As stated in the Implementation Plan, JGOFS plans to leave a legacy for marine Global Change research after the JGOFS sunset date in 2005. This legacy includes:

- an assessment of large-scale carbon fluxes, obtained from a greatly increased network of observations
- a set of models that express our understanding of processes controlling large-scale carbon fluxes
- a procedure for observing the ocean in a routine, synoptic manner to detect changes in the ocean carbon cycle in response to climate change
- a well cared-for data set comprising observations made to standard protocols and a system for making subsets of these data easily available to researchers
- knowledge and understanding of fluxes across continental margins to provide reliable boundary conditions for global ocean models
- an increased number of countries with an interest and skill in JGOFS-type activities and making appropriate measurements and global scale inferences.

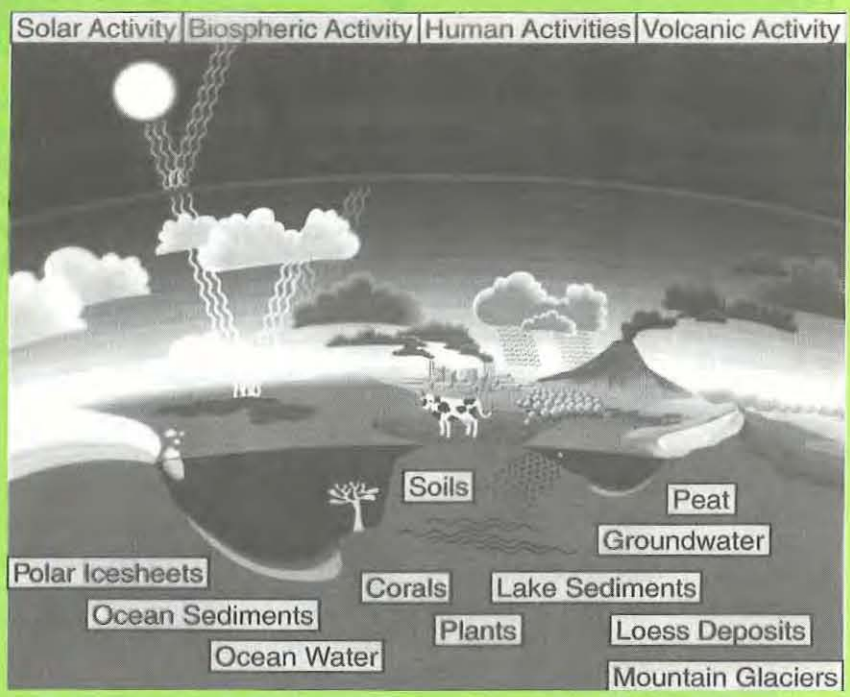
John Field, *Zoology Department, University of Cape Town, 7700 Rondebosch, Cape Town, South Africa, Fax: (+27-21) 650 3726, E-mail: jgfield@uchthpx.uct.ac.za*

Picture of Research Vessel courtesy of *Sea Technology,* Compass Publications, USA

Coral Records Offer Long-Term Perspective on Tropical Climate Systems

Julia E. Cole, Dept. of Geological Sciences, University of Colorado, Boulder CO, USA
Robert B. Dunbar, Dept. of Geology and Geophysics, Rice University, Houston TX, USA

Climate variability in the tropics has important consequences for climate worldwide. Coupled ocean-atmosphere systems originating at low latitudes have global impacts on climate and society: the El Niño SouthernOscillation (ENSO) includes a far-reaching system of teleconnected climate anomalies, and billions of people live in countries where the Asian and African monsoons govern food supplies. Our current insights into tropical climate variability, including our state-of-the-art predictive models, are based on an understanding gained from instrumental records that rarely span more than the past several decades. Yet most climate systems appear to contain significant decadal-centennial as well as interannual modes of variability. Such a long-term mode has only recently been identified from instrumental data for ENSO, following nearly two decades of anomalous conditions in the Pacific. Understanding the long-term dynamics of the tropical ocean-atmosphere is a critical prerequisite to predicting future changes.



The study of corals is part of PAGES core research to answer questions on Past Global Changes

Coral records of past tropical variability

Instrumental records limited to the past few decades cannot provide the insight needed to characterize long-term climate variability fully. To understand the natural range of behavior and sensitivity of tropical systems, we must tap the information preserved in high-resolution paleoclimatic archives from the tropics. Recent paleoclimatic studies on long-lived corals have demonstrated that these records offer a high-quality source of information on subseasonal climate variability that can span several centuries. Also promising is the development of floating subseasonal-annual records from fossil corals recovered from reef cores. Such corals can be dated to an accuracy of 11% and offer potential "windows" onto seasonal-centennial variability during the past one to few hundred millennia.

The massive scleractinian corals primarily used for recent paleoclimatic reconstruction can reach 200-800 years in age and several meters in diameter. These very large corals usually grow in (and thus provide records of) the uppermost 10-20m of the ocean. Annual density bands and/or geochemical variations offer a strong basis for precise geochronology at most sites. Because the coral skeleton grows outward at a rate that can reach 2 cm/yr, millimeter-scale sampling of the skeleton enables resolution of subseasonal phenomena.

The aragonitic (calcium carbonate) skeleton incorporates many geochemical tracers of specific surface ocean parameters, including temperature, salinity, and nutrient content. The isotopic content of skeletal carbonate and the skeletal trace metal content have proven especially useful in tracing past surface ocean variability. Growth parameters (e.g. thickness of annual density bands) also hold promise for providing environmental reconstructions. Records of coral skeletal radiocarbon, reflecting the radiocarbon content of local water masses, offer one of the few means to reconstruct seasonal-centennial variability in ocean circulation. The multivariate archive of climatic information available from corals thus holds great promise for expanding our knowledge of the natural variability in many aspects of the tropical ocean-atmosphere. This new baseline of information will provide a key test for numerical models that seek to predict the evolution of tropical systems.

Regional coral records

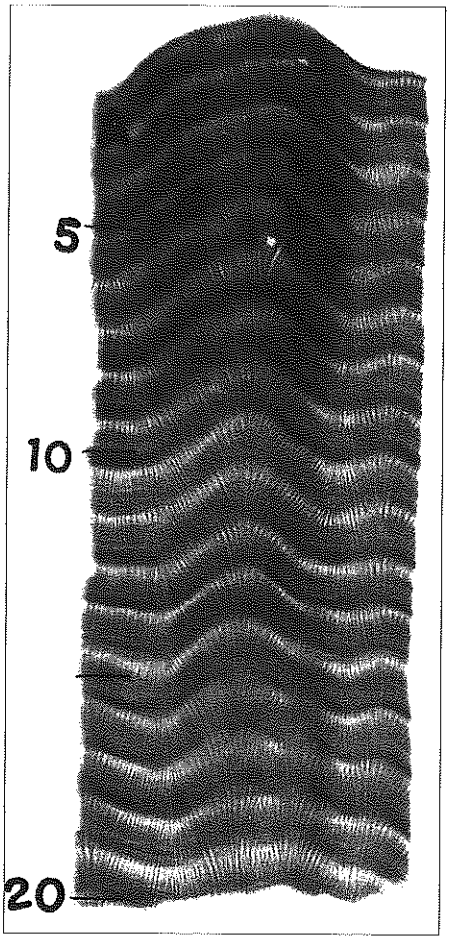
Ongoing research efforts in many countries seek to extend the record of tropical climate variability using corals. Significant additional effort is being directed at the refinement of calibrations for geochemical and growth-related tracers. Coral records are just beginning to play a role in under-

standing tropical ocean dynamics, but they offer perhaps the only means by which we can extend our perspective back over the past centuries to characterize the natural variability of the marine tropics.

The tropical Pacific has seen perhaps the most intensive coral paleoclimatic efforts, motivated largely by the drive to understand long-term ENSO variability. New coral records from the equatorial Pacific reveal previously unrecognized shifts in the seasonal cycle of the tropical Pacific over the past century and in the interannual variability associated with ENSO over the past 4 centuries. In the eastern Pacific, a suite of coral records suggests that decadal shifts in ENSO-related SST's may be coupled to long-term displacements of the Intertropical Convergence Zone (ITCZ; Dunbar et al. 1995). In the western Pacific, recent increases in rainfall associated with a Pacific-wide shift in the late 1970's appear unprecedented over the past 100 years (Cole et al. 1993). The existence of such decadal variability in ENSO is only beginning to be acknowledged from limited instrumental data. Coral records can thus document the degree to which recent changes are unprecedented and the behavior of the decadal-centennial modes of ENSO through time.

Along the Great Barrier Reef, paleoclimatic studies using long-lived corals have identified past changes in river discharge linked to ENSO (Isdale 1984) and modes of long-term temperature variability consistent with tree-ring evidence (Cook 1995). A radiocarbon record from a Great Barrier Reef coral indicates decadally varying circulation changes that may provide an intermittent connection with the eastern Pacific and ENSO (Druffel and Griffin 1993).

In the tropical Atlantic and Indian oceans, new coral records demonstrate the potential to address questions related to the role of the tropical ocean in generating rainfall extremes on adjacent continents. In the Atlantic, tropical SSTanomalies on either side of the equator are linked to drought in Brazil and in Subsaharan Africa. In the Indian Ocean, strong seasonality in many parameters results from the Asian/African monsoon, and the tropical ocean itself may drive interannual variations in monsoon intensity. In both regions, short coral records demonstrate the ability to track regional variability in surface ocean temperature and/or rainfall. Variability in the tropical Atlantic and Indian Oceans may also be coupled to changes in the Pacific: the Atlantic responds to strong ENSO extremes, and both precursory and responding roles have been postulated for the Indian Ocean with respect to ENSO. In both the Indian and Atlantic tropical oceans, our understanding of seasonal-multidecadal variability is relatively poor and would benefit from a long-term analysis involving proxy records.



X-radiograph of the top section of a coral core from Malindi National Marine Park, Kenya. Distinct annual density bands such as those in this coral provide accurate annual chronologies for many coral studies; this core is clearly banded over its 200-yr length. Numbers along left side indicate scale in centimeters.

ARTS: A PAGES focus on tropical climate variability

Within the IGBP, a new PAGES activity has been approved that focuses on developing and synthesizing reconstructions of tropical ocean-atmosphere variability. Goals of the Annual Records of Tropical Systems (ARTS) program include the development of high-quality reconstructions of past tropical variability and the integration of these records with instrumental and modeling studies such as those recommended and supported under the CLIVAR (Climate Variability and Predictability) initiative of the WCRP (World Climate Research Programme). An organizational ARTS workshop will take place in early 1995.

The ARTS activity will include any proxy records contributing insight to seasonal-interannnual variability in the tropics, especially those showing how such variability changes over decade-century scales. Climate reconstructions from corals are expected to form the backbone of this effort, due to their broad distribution in the tropical oceans, their high-fidelity climate reconstructions, and their chronological precision. ARTS will also incorporate the available tree-ring and ice core reconstructions from tropical latitudes and the active participation of tropical climatologists and climate modelers. Integrating the climatic information available in proxy records with the observational and modeling approaches offers a synergistic path towards a predictive understanding of long-term variability in tropical climate.

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Cole, J. E., Fairbanks, R. G., and Shen, G. T. (1993). *The spectrum of recent variability in the Southern Oscillation: results from a Tarawa Atoll coral.* **Science**, 262, 1790-1793.

Cook, E. R. (1995). *Temperature histories from tree-rings and corals.* Climate Dynamics, in press.

Druffel, E. R. M., and Griffin, S. (1993). *Large variations of surface ocean radiocarbon: evidence of circulation changes in the southwestern Pacific.* **Journal of Geophysical Research**, 98, 20,249-20,259.

Dunbar, R.B., B. K. Linsley, and G.M. Wellington (1995). *Eastern Pacific corals monitor El Nio/Southern Oscillation, precipitation, and sea surface temperature variability over the past three centuries.* In. Climatic Variations and Forcing Mechanisms of the Last 2000 Years, P.D. Jones, R.S .Bradley, and J. Jouzel, eds. Springer-Verlag Berlin, in press.20

Isdale, P. (1984). *Fluorescent bands in massive corals record centuries of coastal rainfall.* **Nature**, 310, 578-9.

Note:
Further information on ARTS activities can be requested from the organizers: Julia Cole, University of Colorado (Email coleje@spot.colorado.edu) and Robert Dunbar, Rice University (Email dunbar@rice.edu).

The World Data Centre-A for Palaeoclimatology, established by the NOAA National Geophysical Data Center, Boulder, Colorado is closely tied with the PAST Global Changes project, with much more information on corals. This WDC works closely with scientists to prepare their data for use in the public domain. The Web site: *http://www.ngdc.noaa.gov/paleo/paleo.html*

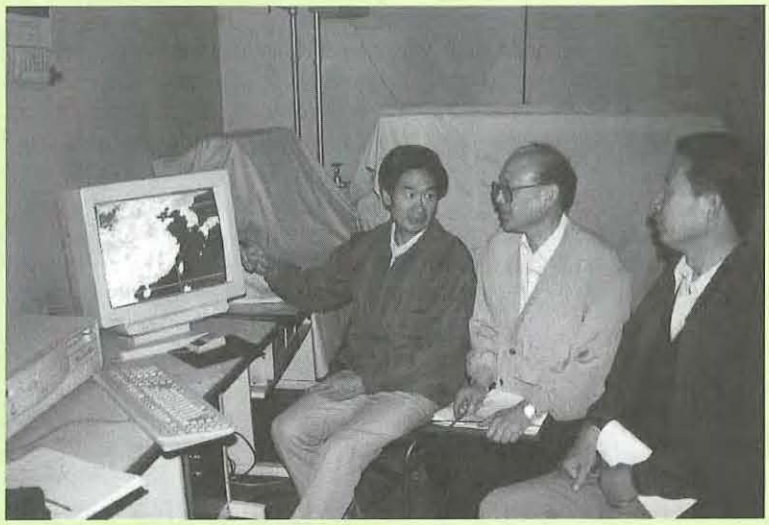
People and Places

Fellows announced at the American Geophysical Union

On August 22 the AGU congratulated the thirty-three distinguished scientists who were selected by a committee of their peers to become AGU Fellows in 1995. This selection was based on the individuals' attainment of acknowledged eminence in a branch of geophysics.

The number of Fellows selected annually is limited to no more than 0.1% of the AGU membership.

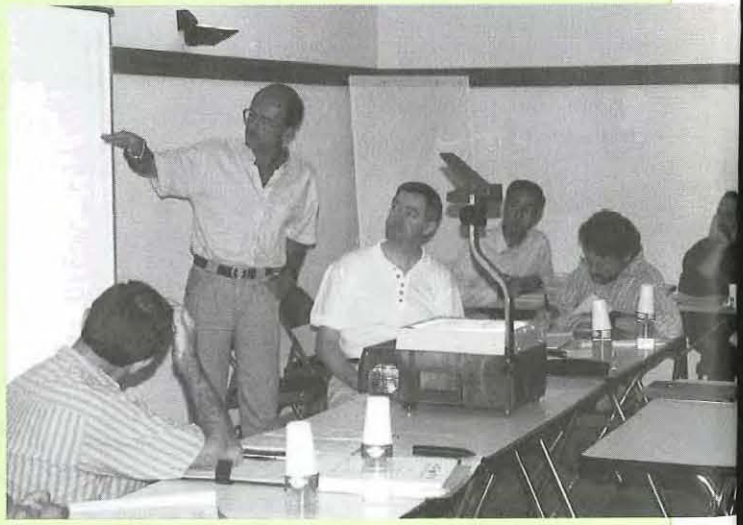
Amongst the new Fellows is Ann Henderson-Sellers, member of the Scientific Committee for the IGBP. She was selected for leadership and extensive and creative research accomplishments on a wide range of climate system topics.



A recent modelling workshop in Beijing

Ann Henderson-Sellers

JGOFS participants at the Fourth International CO_2 Conference in Carqueiranne, France



At the Core Project Officers Meeting at the Royal Swedish Academy of Sciences in Stockholm

Open Science Meetings

9-14 October 1995, Beijing, China
WMO/IGAC Conference on the Measurement and Assessment of Atmospheric Composition Change. Third science conference of the International Global Atmospheric Chemistry Project (IGAC). *John Miller, Environment Division, AREP, World Meteorological Organisation, 41 Ave. Giuseppe Motta, CH-1211 Geneva 2, Switzerland. Fax: (+41-22) 740 0984, E-mail:. john-milton.miller@itu.ch*

22 October 1995, Beijing, China
ICSU Global Change Forum on Earth System Research

23-27 October 1995, Beijing, China
SAC IV: The Fourth Scientific Advisory Council for the IGBP
IGBP Secretariat, Box 50005, S-104 05 Stockholm, Sweden. Fax: (+46-8) 16 64 05, E-mail: sec@igbp.kva.se.

30 October-4 November, 1995, New Delhi, India
Asian Workshop & Training Course on Measurement Techniques and Inventories of Greenhouse Gases

16-17 November, 1995, Zurich, Switzerland
IGBP/BAHC ProClim-Alpen Forum Symposium. The Role of the Hydrological Cycle in Mountain Ecosystems. *ProClim-Forum for Climate and Global Change, Swiss Academy of Sciences, Bärenplatz 2, CH-3011 Bern, Switzerland. Tel: (+41-31) 312 21 14, Fax: (+41-31) 312 55 37, E-mail: proclim@sanw.unibe.ch*

28 November-1 December, 1995, Tsukuba, Japan, Open Meeting on the IGBP Northern Eurasia Study
Dr Gen Inoue, Head of Global Warming Research Team, National Institute for Environmental Studies, Japan Environment Agency, 16-2, Onogawa, Tsukuba, Ibaraki 305, JAPAN, Tel: (+81-298) 51-6111, Fax: (+81-298) 51-4732, Email: inouegen@nies.go.jp

8 December, 1995, Bern, Switzerland
Climate Change: The IPCC Second Assessment Report. *ProClim-Forum for Climate and Global Change, Swiss Academy of Sciences, Bärenplatz 2, CH-3011 Bern, Switzerland. Tel: (+41-31) 312 21 14, Fax: (+41-31) 312 55 37, E-mail: proclim@sanw.unibe.ch*

29 January-1 February, 1996, Amsterdam, The Netherlands
First Open Science Meeting of Land Use and Cover Change (LUCC)
The Royal Dutch Academy of Sciences, Trippenhuis, Amsterdam
Louise Fresco & Rik Leemans, Department of Agronomy, P.O. Box 341, 6700 AH Wageningen, The Netherlands, Tel: (+31) 8370 83040, Fax: (+31) 8370 84575, E-mail: luce@sec.agro.wau.nl

17-21 June 1996, Washington DC, USA.
GEWEX: Second International Scientific Conference on the Global Energy and Water Cycle Experiment, at the US National Academy of Sciences. Scientific interests involve the climate feedback associated with clouds, radiation, and the hydrologic processes. Papers invited. *Contact: GEWEX Project Office, 409 Third Street SW, Suite 203, Washington, DC, 20024, USA.*

26-30 August 1996, Helsinki, Finland
Fourteenth International Conference on Nucleation and Atmospheric Aerosols. M. Kulmala, Department of Physics, University of Helsinki, PO Box 9, FIN-00014, Helsinki, Finland.
Tel: (+358-0) 191 8308, Fax: (+358-0) 191 8680, kulmala@phcu.helsinki.fi

2-6 December 1996, Melbourne, Australia
First SPARC General Assembly (Stratospheric Processes and their Role in Climate). David Karoly, SPARC 96, CRC for SH Meteorology, Blg 70, Monash University, Clayton, VIC 3168, Australia.
E-mail: sparc96@vortex.shm.monash.edu.au

Publications

IGBP Report No. 34

BAHC-IGAC-GCTE Science Task Team. Report of First Meeting, Massachusetts Institute of Technology, Cambridge, Massachusetts. USA, 10-12 January, 1994 (1995). Stockholm: IGBP, 45 pp.
The Science Task Team discussed and developed recommendations for multi-Core Project collaboration within the IGBP under three headings: process studies in terrestrial environments, integrated modelling efforts, and partnership with developing country scientists. Three interrelated themes considered under process studies are: transects and large-scale land surface experiments, fire, and wetlands. Methods for implementation and projects are identified.

Write to: IGBP Secretariat, The Royal Swedish Academy of Sciences, Box 50005, S-104 05 Stockholm, Fax: (+46-8) 16 64 05, E-mail: sec@igbp.kva.se

IGBP announces its new home page on the World Wide Web

The IGBP Home Page URL:
http://www.igbp.kva.se/igbpint.html/

Core Projects

Global Change and Terrestrial Ecosystems (GCTE)

Climate and Vegetation Change. The Influence of Changes in Climate and Carbon Dioxide on Biome Distribution. Interim report of the consortium led by Professor F. I. Woodward, December 1994 (1995). Project 3b of Tiger IV: a NERC community research programme, a Core Research Project of IGBP Global Change and Terrestrial Ecosystems. 24 pp.
M. A. Beran, Programme Manager of Terrestrial Initiative in Global Environmental Research (TIGER), Institute of Hydrology, Crowmarsh Gifford, Oxfordshire OX10 8BB, UK. Fax: (+44-1491) 692430

Land-Ocean Interactions in the Coastal Zone (LOICZ)

The Dynamics of Global Change and the Coastal Zone (1995). Second LOICZ Open Science Meeting, The Marine Science Institute, University of the Philippines, Quezon City, The Philippines, 24-27 April 1995. 107 pp. (LOICZ Meeting Report No. 9)
LOICZ Core Project Office, Netherlands Institute for Sea Research (NIOZ), PO Box 59, 1790 AB Den Burg, Texel, The Netherlands.

National Committees

Canada

Global Change Research Themes. A report of the Canadian Global Change Program Research Committee, prepared by Deanna McLeod (1995). 30pp.
Jeffrey Watson, CGCP Director, 225 Metcalfe, #308, Ottawa, Ontario K2P 1P9, Canada. Fax: (+1-613) 991 6996, Fe-mail cgcp@rsc.

Japan

An Interim Report of IGBP Activities in Japan 1990-1994, edited by Isamu Kayane. (1995). Japan National Committee for IGBP. Science Council of Japan, 265 pp. Proceedings of the 4th IGBP Japan Symposium, 26-27 January, 1995.
Isamu Kayane, Institute of Geoscience, University of Tsukuba, 1-1 Tennodai, Tsukuba, Ibaraki 305, Japan.

UK

International Directory of Global Environmental Research (GER). Initiatives, Programmes and Organisations (1995). Swindon: UK GER Office, 84 pp.
Christine Rowland, UK GER Office, DP 1002, Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1EU, UK.

USA

A Review of the U.S. Global Change Research Program and NASA's Mission to Planet Earth/Earth Observing System (1995). Committee on Global Change Research, Board on Sustainable Development, Policy Division, National Research Council. Washington: National Academy Press, 96 pp.
Copies are available in limited supply from: The Board on Sustainable Development, National Research Council (FO 2080), 2101 Constitution Avenue, NW, Washington, DC 20418-0001, USA.

General Interest

The Blue Planet. An Introduction to Earth System Science, by Brian J. Skinner and Stephen C. Porter (1995). New York; Toronto: John Wiley & Sons, 493 pp, appendices and index.

GLOBAL CHANGE NEWSLETTER

Edited by Suzanne Nash
NewsLetter requests and change of address information should be sent to:
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The IGBP Report series is an annexe to the Global Change News Letter

ISSN 0284-5865

IDÉOLUCK AB/PRINTING: BERGS GRAFISKA, STOCKHOLM