GLOBAL CHANGE NEWSLETTER

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GLOBAL IGBP CHANGE

Issue No. 49
April, 2002

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

IGBP is sponsored by the International Council for Science (ICSU)

Science features

Tom Edwards starts this edition by describing recent exciting developments in using water isotopes to describe and model past and present precipitation (p2). Two 'marine' articles follow: Robert Duce and Ed Urban give us an excellent summary of the diverse activities of SCOR (p4); and Stephen Smith describes how the LOICZ modelling team are successfully implementing a global approach to collect and use data on C-N-P fluxes in coastal waters (p7). Carbon is highlighted again on page 12, where Peter Cox and colleagues explain the importance of incorporating the carbon cycle into general circulation models in order to increase their accuracy. Finally, Ulrike Lohmann gives us a fascinating insight into how anthropogenic aerosols affect cloud formation and, ultimately, climate.

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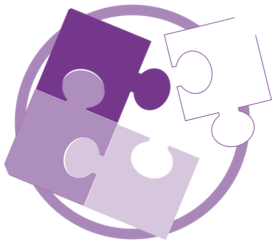
NewsLetter Survey

This NewsLetter now reaches 12000 people! Although it is fantastic that we have such a wide readership, the postage is also a major expense. To try and address this problem, we would like to know if you would prefer to receive the newsletter electronically. At the same time we would greatly value your comments on the content and style. Please take a few minutes to fill in the enclosed survey!

Enclosed

Integration Section



In this Newsletter we introduce a new section; 'Integration'. The evolving IGBP Phase II places a much stronger emphasis on the integration of different parts of Earth System Science, and on the integration between IGBP and other global change programmes. This regular feature will highlight this important development.

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You have probably noticed immediately that this is not the promised 'Phase II Special Edition'! We have decided to postpone the special edition until June, in order to ensure that the articles accurately reflect the complex transition process and the decisions and discussions from the IGBP SC meeting in February.

Instead, then, this is a general issue, with five science features from all corners of IGBP and Earth System Science.

Contents

Mapping and modelling global isotope climate and palaeoclimate

by T. W.D. Edwards

The distribution of the naturally occurring heavy isotopes ^2H and ^{18}O in palaeoprecipitation provides one of our most direct and quantitative links to Earth's past climate and to key aspects of the global water cycle. Palaeoprecipitation isotope data are best known, in the context of global change research, for their use as proxy indicators of palaeotemperature, especially from the exquisitely detailed records of δ^2H and $\delta^{18}O$ measurements (see Box) obtained from the ancient precipitation preserved in polar glaciers. Some of these records, such as the Vostok record of Antarctica, extend more than 400,000 years into the past, chronicling repeated episodes of continental glaciation (Figure 1). Myriad records spanning shorter periods have also been derived from speleothems, tree rings, lake sediments and numerous other natural isotopic archives.

Precipitation isotope data are also widely used in hydrologic studies, exploiting the systematic spatial and temporal variations in the distribution of water isotopes as input functions for investigations ranging from assessment of runoff generation processes to the water balance of major river basins.

A relatively recent and exciting development, fuelling demand for much better characterisation of the present and past global precipitation isotope fields, is the incorporation of water isotope diagnostics into atmospheric general circulation models - "isotopic-AGCMs". These models explicitly account for the slightly differing properties of $^1H^1H^{16}O$, $^1H^2H^{16}O$ and $^1H^1H^{18}O$, and are thus rigorously constrained by the need to conserve both mass and isotopes in the global water cycle. This not only imposes especially severe requirements on the realism with which such climate models must mimic nature, but also affords unprecedented opportunities for direct quantitative comparison of model results with measured isotopic data. The link to the isotopic composition of palaeoprecipitation is particularly important, since it will ultimately permit use of palaeodata directly, without the additional uncertainties introduced by transformation into secondary proxies like palaeotemperature.

Scientists engaged in ISOMAP, an initiative of the IGBP PAGES core project, have

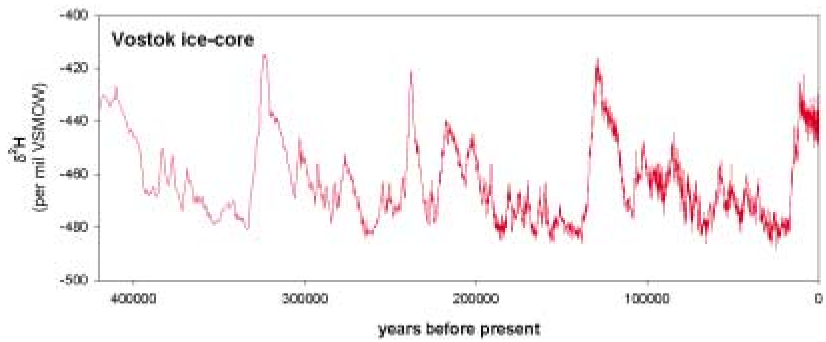

Figure 1. Hydrogen-isotope record obtained from the Vostok ice-core, Antarctica (Petit et al. 1999). The record clearly shows the characteristic saw-tooth pattern of glacial-interglacial cycling, reflecting the gradual onset (progressively declining δ^2H values) and rapid culmination (abruptly increasing δ^2H values) of four major episodes of global continental glaciation, plus many higher-frequency variations. Although this measured isotopic time-series is commonly portrayed as a palaeotemperature history, it actually provides a direct chronicle of dynamic changes in the partitioning of isotopes in the global water cycle, which can be mapped with increasing fidelity by isotopic-AGCMs.

Data archived at the World Data Centre for Paleoclimatology, Boulder, CO, USA: http://www.ngdc.noaa.gov/paleo/data.html

Box : What are δ values?

The relative abundances of the rare heavy isotopes ^2H and ^{18}O or, more correctly, the relative abundances of the water isotopomers that contain them, $^1H^2H^{16}O$ and $^1H^1H^{18}O$, in relation to common light water, $^1H^1H^{16}O$, are usually expressed as "δ" values, reflecting differences in ^2H or ^{18}O concentration from that of Vienna Standard Mean Ocean Water. VSMOW approximates the isotopic composition of the world oceans, the primary source of atmospheric moisture and a logical "starting point" in the global hydrological cycle. Rain-out and distillation of moisture during transport to higher latitudes causes progressive heavy-isotope depletion (more negative δ values) because of mass-dependent differences in the behaviour of the water isotopomers.

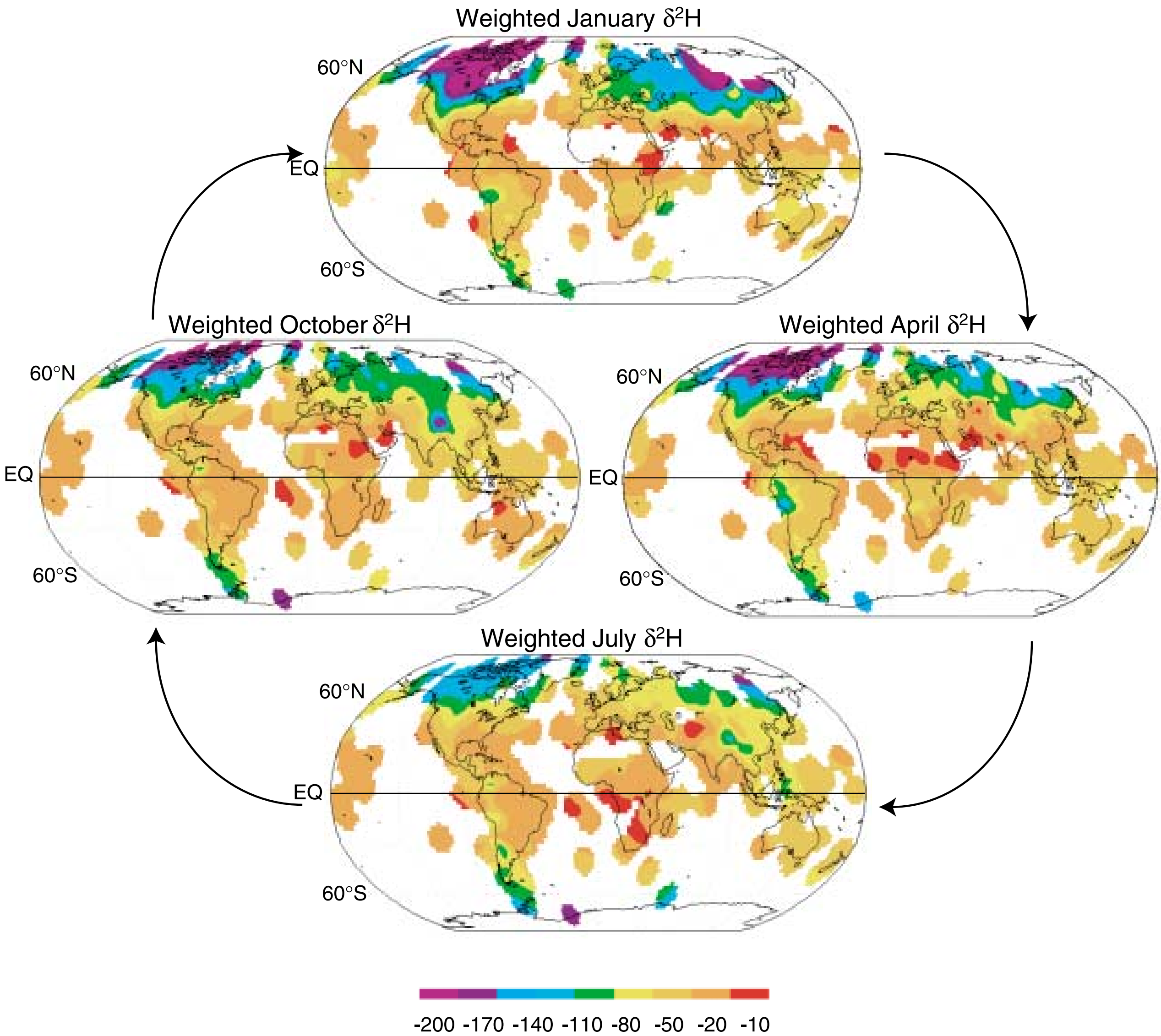

Figure 2. Contour maps of the modern global precipitation δ^2H field for January, April, July and October, based on the IAEA/WMO GNIP database (see IAEA 2001 for the full set of global and regional maps and animations). These maps represent our current best approximation of the average "climatological" δ^2H fields for these months over the past 40 years. Key aspects of seasonal water isotope cycling are evident, including the marked deepening in winter and shallowing in summer of the degree of ^2H depletion in Arctic precipitation, which is the analogue at annual time-scale of glacial-interglacial signals like those recorded in the Vostok ice core (Figure 1).

taken a lead role in the challenge of mapping and modelling global isotope climate and palaeo climate. A first step in this endeavour is the fuller characterisation of the present global isotope field for comparison with isotopic-AGCM simulations of equilibrium isotope climate under modern boundary conditions (Figure 2), and ongoing work is aimed toward mapping and modelling of both equilibrium and transient global isotope climate for key times and intervals in the past. Such efforts will significantly enhance our understanding of past and present global climate history and dynamics, as well as our ability to simulate and anticipate future change using climate models.

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Further Reading and Web Links

Edwards TWD. (1998). ISOMAP - Reconstructing the Isotopic Composition of Past Precipitation from Continental Archives. PAGES Newsletter 6, 10. (http://www.pages-igbp.org)

Jouzel J, Hoffmann G, Koster RD and Masson V. (2000). Water isotopes in precipitation: Data/model comparison for present-day and past climates. Quaternary Science Reviews 19, 363-379

Petit JR, Jouzel J, Raynaud D, Barkov NI, Barnola J-M, Basile I, Benders M, Chappellaz J, Davis M, Delayque G, Delmotte M, Kotlyakov VM, Legrand M, Lipenkov VY, Lorius C, Pépin L, Ritz C, Saltzman E and Stievenard M. (1999). Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. Nature 399, 429-436

Rozanski K, Johnsen SJ, Schotterer U and Thompson LG. (1997). Reconstruction of past climates from stable isotope records of palaeo-precipitation preserved in continental archives. Hydrological Sciences Journal 42, 725-745

Rozanski K, Araguás-Araguás L and Gonfiantini R. (1993). Isotopic patterns in modern global precipitation. In Climate Change in Continental Isotopic Records. Edited by PK Swart, KL Lohmann, J McKenzie and S Savin. Geophysical Monograph 78, American Geophysical Union, Washington, DC, p 1-37

Schotterer U, Oldfield F and Fröhlich K. (1996). GNIP - Global Network for Isotopes in Precipitation, PAGES, Bern, 48 pp

IAEA (2001). GNIP Maps and Animations, International Atomic Energy Agency, Vienna. (http://isohis.iaea.org)

What is SCOR?

by R. Duce and E. Urban

The Scientific Committee on Oceanic Research (SCOR) promotes international cooperation in oceanography. It was created by ICSU in 1957 as the first of its interdisciplinary bodies, and operates primarily through three types of scientific activities—large-scale research projects, working groups, and advisory bodies and planning groups—supplemented with capacity-building activities.

Global-scale issues related to the role of the ocean in environmental change are tackled through SCOR's participation in planning and guiding long-term, large-scale international ocean research projects. For example, SCOR initiated the Joint Global Ocean Flux Study (JGOFS) and the Global Ocean Ecosystem Dynamics project (GLOBEC; also co-initiated by the Intergovernmental Oceanographic Commission [IOC]). SCOR and IGBP presently co-sponsor four major ocean science activities. In addition to JGOFS and GLOBEC, these include the now-developing Surface Ocean-Lower Atmosphere Study (SOLAS) and the Ocean Biogeochemistry and Ecosystems activity.

In addition to these projects with IGBP, SCOR also co-sponsors the Global Ecology and Oceanography of Harmful Algal Blooms program (GEOHAB), with IOC. Large-scale blooms of phytoplankton that are toxic to marine organisms or humans, or which lead to oxygen depletion in coastal waters, have become

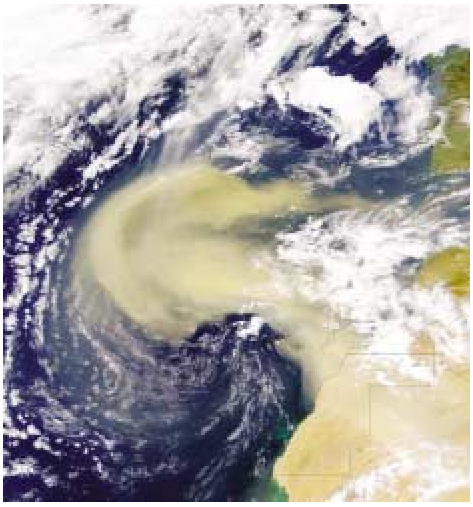

Figure 1. Dust storms deliver materials to the Atlantic Ocean from the Sahara Desert. Photo provided by the SeaWIFS project, NASA/GFSC, and ORBIMAGE.

a major concern for most coastal nations. Blooms of harmful algae are thought to be related to increased inputs of nutrients to coastal waters, but many other factors, including interacting chemical, biological, and physical conditions, influence the initiation and development of harmful algal blooms by mechanisms that are not well understood. SCOR and IOC are planning for a major international research program that will study harmful algal blooms from perspectives ranging from why the biology of certain species makes them harmful to how large-scale oceanographic conditions can either promote or hinder blooms.

Working Groups

More specific ocean science topics are addressed by short-lived Working Groups, the traditional mechanism by which SCOR has operated since its inception. Existing working groups focus on a range of scientific questions:

Biogeochemistry of iron in seawater

In what forms does iron exist in seawater and what are its sources, how does it change among forms, how is it distributed in the ocean, what controls iron's availability to marine organisms, and how should iron best be measured in seawater?

Coastal ocean modelling

What are the weaknesses of coastal wave models, coastal circulation models, and coastal atmospheric boundary layer models operated separately, and how could they be coupled to produce more realistic and useful results?

Fluid flow through coastal sediments

What is the magnitude and distribution of submarine groundwater discharges in space and time, how do such discharges affect coastal nutrient and contaminant concentrations, and how do they contribute to coastal ocean processes? What reactions and transport phenomena are important in different marine environments that contain permeable sediments, for example, beach, inter-tidal, subtidal, and continental shelf environments?

> "What new indicators could be used to study the functional role of species in marine ecosystems and the effects of exploitation and environment?"

Evolution of the Asian monsoon system

What are the key climate proxies necessary for effective comparison of the Indian and East Indian monsoon subsystems in their evolution over different time scales in response to tectonic processes, variations in Earth's orbit, and ocean circulation?

Synthesis of climate records of the past 80,000 years

Are the records of short-term climatic events in marine sediments compatible, as recorded by proxies of isotopic, elemental, palaeontological, sedimentological, and magnetic properties?

The role of marine phytoplankton in global climate regulation

How do environmental factors (e.g., nutrients, grazing by zooplankton) and species-specific factors (e.g., genetic composition and cellular responses to environmental conditions) affect the production of climate-relevant gases, such as the production of dimethyl sulphide by the phytoplankton species *Phaeocystis?*

New methods

- **Surveying plankton:** How can strategies for continuous sampling of phytoplankton and sampling instruments be improved and integrated with direct plankton sampling approaches?

- **Estimating downward carbon flux from the surface ocean:** How do the carbon export fluxes determined by sediment trap and Thorium-234 methods differ, what are the main causes of any discrepancies, and how can they be resolved? Can Thorium-234 serve as a survey tool to determine carbon export fluxes on a global scale?

- **Measuring the status of marine ecosystems:** What new indicators could be used to study the functional role of species in marine ecosystems and the

Figure 2. High-biomass "red tide" caused by *Noctiluca* bloom in New South Wales, Australia.

Photo reproduced with permission from Gilbert PM + Pitcher G (eds) 2001. GEOHAB Science Plan.

effects of exploitation and environment (e.g., output of multi-species models or available time series, satellites, and geographic information systems)? How can such indicators be used in a comparative way to characterise ecosystem states, changes, and functions? What is the utility of these indicators for management purposes and for the sustainable use of renewable marine resources?

- **Observing marine life:** What are the relative merits of different technologies for observing marine organisms and which technologies deserve further research based on their potential for making significant contributions to the detection of marine life?

Planning Groups and Advisory Bodies

The third type of SCOR activity includes planning groups and advisory bodies:

SCOR-IOC Advisory Panel on Ocean Carbon Dioxide—The ocean absorbs approximately one-third of the carbon dioxide added to the atmosphere by human activities each year. Several different national and international programs worldwide make observations of inorganic carbon in the ocean, but questions remain about the spatial and temporal aspects of absorption and release of carbon dioxide by the ocean, how much carbon is exported from the surface ocean to deeper waters, and the effects of increasing carbon dioxide on oceanic biology and chemistry. Key issues that are not routinely handled by individual projects involve how to integrate carbon-observing systems and how to standardise measurement techniques and provide reliable reference standards. This panel is responsible to advise global carbon research and monitoring programs on observations, data management, and modelling needed to understand the ocean component of the global carbon cycle, and to provide an international forum for initiatives to promote high-quality observations of the ocean carbon cycle. SCOR and IOC have maintained joint activities on the topic of ocean carbon since 1979.

Ocean Carbon Sequestration—As interest in tradable carbon credits has been stimulated by the Kyoto Protocol, some commercial enterprises have teamed with ocean scientists to design potential schemes to fertilise the surface ocean with iron or nitrogen to create blooms of phytoplankton, which may sink to the deep sea and remove (at least temporarily) carbon from the surface ocean. Others projects are testing techniques to inject carbon dioxide into the deep ocean with the hope that it will not return to the atmosphere for several centuries. Although much relevant research has been conducted in the past decade, the potential effectiveness and risks of these forms of carbon sequestration in the ocean have not been discussed among ocean scientists as a community recently. SCOR and IOC are currently planning and raising financial support for an international workshop to document what we know and need to know related to the proposals to attempt to sequester atmospheric carbon dioxide in the ocean through fertilisation of surface waters and deep-ocean injection.

> "What do we need to know before we attempt to sequester atmospheric CO_2 in the ocean through fertilisation of surface waters and deep-ocean injection?"

Southern Ocean Research Coordination—Many nations support oceanographic research in Southern Ocean areas, but most programs tend to focus on single disciplines, with little integration among the disciplines. This can lead to overlaps or gaps among activities that can waste research resources or hinder our understanding of how the Southern Ocean works as an integrated system. SCOR is leading a planning activity among international organisations and research projects to coordinate ongoing and planned research in the Southern Ocean.

Capacity-Building Activities

In addition to its scientific activities, SCOR conducts an active program of capacity building for developing nations and nations with economies in transition. Such nations conduct significant ocean research programs on national and regional scales, but are often under-represented in major international ocean research projects. SCOR attempts to increase the involvement of scientists from such countries by awarding travel grants for their scientists to participate in ocean science meetings. SCOR also participates in a fellowship program designed to promote ocean observations (led by the Partnership for Observations of the Global Ocean).

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More information

Additional information about SCOR and the activities described above can be obtained from the SCOR Web site (www.jhu.edu/~scor) or from Ed Urban.

Carbon-nitrogen-phosphorus fluxes in the coastal zone: the global approach

by S.V. Smith, on behalf of the LOICZ Modelling Team

Carbon is generally considered to be the "major currency" within the IGBP, and the nitrogen and phosphorus cycles are intimately linked to carbon. The role of the coastal oceans in global carbon-nitrogen-phosphorus cycles is one of the major and most challenging questions that LOICZ is evaluating. Unlike much of the IGBP, the "domain" of LOICZ (nominally 200 m below sea level to 200 m above sea level, with emphasis on the reactions within the marine portion of the strip) is tremendously difficult to describe in detail. Because the zone is relatively narrow (visualise a strip of coastal real estate that is about 500,000 km in length but only averages about 50 km in width), it is not well represented in gridded global data bases. Further, the zone is heterogeneous both along the length of this strip and across its width.

Arguments can be made that both the large load of materials from land and the human influence along the seashore cause much of the net reaction of this zone to occur in bays and estuaries along the landward margin of the strip. The region is not well represented as an extension of oceanic processes up onto the shelf and into the bays and estuaries, because the influence of both bottom chemical reactions and terrestrial inputs (including especially those associated with human activities) render this region very different from the open ocean. Much of IGBP deals primarily with vertical fluxes: land-atmosphere, ocean-atmosphere. While LOICZ is concerned with these vertical fluxes, it also deals heavily with the horizontal flux of material from land, largely through lateral flow of water to the shoreline, and then lateral transport away from the shoreline.

Analytical Methods and a Strategy for Progress

Within the limits of these considerations, the LOICZ project set up a "globally applicable" method of estimating fluxes within the coastal ocean, especially the bays and estuaries of the inner coastal zone. It was necessary to erect a methodology that could depend largely on secondary data, because, within the time span of LOICZ, funding was not likely to be available for collecting significant amounts of new data. Secondly, if the methodology were to be useful for most of the coastal zone, the data requirements had to be minimal. Thirdly, in order to allow effective comparison among sites, the methodology had to be widely applicable and uniform, rather than tailored to specific sites. Finally, it was deemed desirable that the method be informative, at some level, about processes influencing carbon-nitrogen-phosphorus (CNP) fluxes.

The LOICZ approach [1, 2] is based on one of the most fundamental concepts of the physical sciences: conservation of mass.

Briefly, the procedure is as follows. Water volume and salt content in the system remain constant over time, as water flows through the system and mixes with adjacent systems. The net flow of water can be described by a water budget. Information about mixing can be deduced from a salt budget of non-reactive materials. The data to establish at least crude water and salt budgets can be found for many sites around the globe.

Nutrients not only move with the water but also undergo reactions within the system. Nutrient data (especially data on the dissolved inorganic forms of phosphorus and nitrogen, here termed DIP and DIN) can be found for many of these same sites and used to establish nutrient budgets. These nutrient budgets include the water flow and mixing, as defined by the water and salt budgets, and an additional term that describes net uptake or release of these nutrients within the system. In the jargon of oceanography, these are termed "nonconservative fluxes," because the nutrients do not exactly follow the flux pathways of water and salt.

The nonconservative flux of DIP can be used as an approximation of net uptake of phosphorus into organic matter during primary production or release from organic matter by respiration. The DIP flux is scaled to an estimated carbon flux via a scaling ratio (typically a molar C:P ratio of 106:1, representing the so-called "Redfield Ratio"). While it would be desirable to have direct measurement of carbon uptake into organic matter, such data are not available for most locations. Therefore, the flux of DIP becomes a proxy for net carbon flux. The primary shortcoming of this proxy is that systems with high amounts of suspended mineral material (e.g., from turbid rivers) may show evidence for DIP adsorption onto the particulate materials or desorption from them.

In the open ocean DIN is often scaled in exactly this manner to carbon. That scaling in general does not work well in the coastal ocean, for a reason that contains a great deal of information itself. Nitrogen fixation and denitrification are important metabolic processes in bottom-dominated systems and can account for most of the observed nonconservative flux of DIN. Therefore, calculations derived from the budgets use DIP flux as a proxy to calculate how much net carbon uptake or release has occurred, scale this to expected nitrogen flux (typically using the Redfield N:P ratio of 16:1), and then use the deviation between the observed DIN flux and the expected flux to estimate the net of nitrogen fixation and denitrification. As is true with carbon, it would be desirable to have "direct measurements" for these important nitrogen fluxes—and the global data are extremely limited. As is also true in the use of DIP as a carbon proxy, the mineral reactions involving DIP are probably the greatest shortcoming of the DIP proxy for nitrogen metabolism. Despite these limitations, semi-quantitative insight is gained into the rates of the processes of primary production minus respiration (abbreviated [p-r]) and nitrogen fixation minus denitrification [nfix-denit].

To implement this process globally, a two-part strategy has been used to acquaint the scientific community with the budgeting procedures:

- A web page has been set up [2] that summarises and updates the budgeting procedures, provides tools for implementing the procedures, provides various forms of teaching materials, and posts existing budgets as they are developed.
- A series of workshops has been held around the world in order to teach people how to do the budgets and to get them to prepare budgets that can be used by LOICZ.

As a result, about 200 site budgets have now been developed (Figure 1) by nearly 180 people and posted on the web pages.

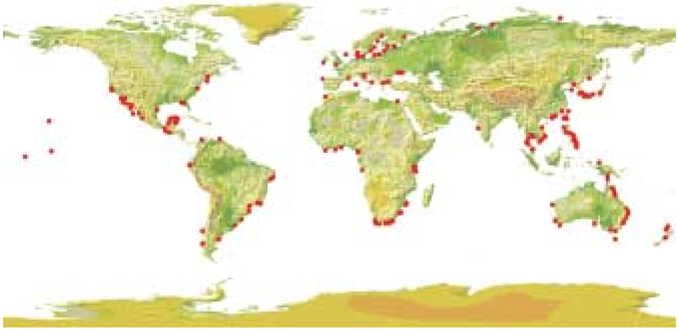

Figure 1. The Global Network of LOICZ budget sites, January 2002. Coastal zone researchers from around the world now represent some of their nutrient budgeting results within a common conceptual framework.

Beginning to Synthesise the Results—Spatial Scaling of Available Budget Data

This article considers some spatial scaling issues with respect to nutrient fluxes in the coastal zone. The budget sites (Figure 1) vary dramatically in their characteristics: from lagoons and estuaries less than 1 km^2 in area, to the 106 km^2 East China Sea; from sites that are decimetres deep to sites that are hundreds of metres deep; from sites that are virtually devoid of loading from land to sites that receive heavy loads of inorganic nutrients derived from human wastes, agriculture, and other sources; from sites that are river-dominated estuaries to hypersaline embayments; from tropical to arctic climate zones. For some sites data quality and quantity are both high; other sites suffer in the quality and quantity of information available.

Such a wide diversity of site descriptions and data quality poses significant challenges to comparison, and that comparative effort is presently underway. For the present analysis we have set aside systems for which the basic data are incomplete, open shelf systems, and systems with an average depth >100 metres, in order to facilitate comparisons among sites. This parsed data set includes about 80 systems. The remainder of this section is devoted to a brief overview of material loads from land to the coastal zone, exchange between the inner coastal zone and offshore waters, and some characteristics of net biogeochemical fluxes.

Figure 2 illustrates frequency distributions of the apparent rates of production minus respiration [p-r] and nitrogen fixation minus denitrification [nfix-denit] as calculated from the nonconservative nutrient fluxes for these systems. Note that these are net rates, the difference between storage and release processes. These net rates are more relevant than gross rates to evaluating the role of coastal systems in carbon-nitrogen-phosphorus exchange. The rates cluster near 0 for both [p-r] and [nfix-denit]. Further analysis will be required in order both to extrapolate from these individual site measurements to estimates of net metabolism for the global coastal zone and to evaluate the regional distributions of these rates. In the meantime, further insight into comparisons can be derived from these data.

> "...the LOICZ project set up a "globally applicable" method of estimating fluxes within the coastal ocean."

Figure 3 illustrates terrestrial nutrient loading to the budget sites. In order to allow comparison across sites, the data have been normalised to the budgeted area of the receiving water bodies. Two important aspects emerge from this figure. First, the area-normalised loading spans 3-4 orders of magnitude. Nutrient loading at the low end of the range is roughly equivalent to upward mixing of nutrients from the deep ocean to the oligotrophic mid-latitude gyres of the surface ocean. At

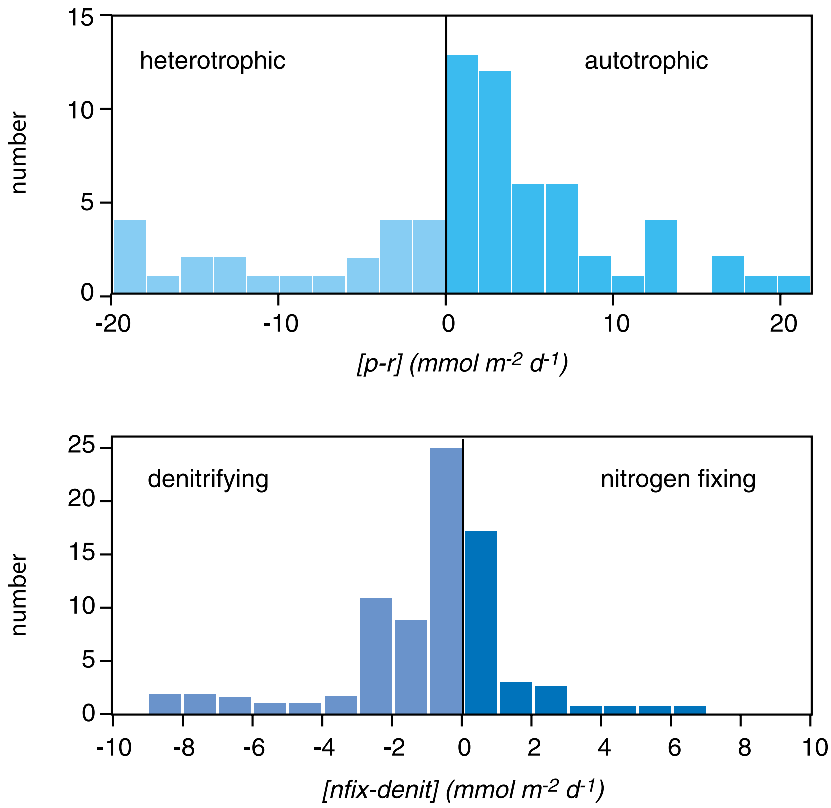

Figure 2. Frequency distributions of [p-r] and [nfix-denit] at the budget sites.
[p-r] is primary production minus respiration
[nfix-denit] is nitrogen fixation minus denitrification.

the other extreme, the high loads are roughly equivalent to direct waste discharge from one person for every 30 m^2 of area budgeted! Clearly this range of conditions imposes dramatic differences on the water bodies receiving these loads.

A second important aspect of this loading pattern is that the DIN:DIP loading ratio changes by a factor of about 4 over the loading range. This changing loading ratio represents a change from both low loading and high N:P loading ratio for oligotrophic systems not dramatically influenced by human activities, to both higher loading and lower loading ratio under the influence of human waste discharges. DIN:DIP flux ratios of around 30:1 typify discharge from relatively pristine river systems, while values near 10:1 typify domestic waste discharge.

Net nutrient reactions in coastal ecosystems clearly respond to nutrient load. The upper panels of Figure 4 demonstrate that in general, as nutrient load goes up, the absolute values of nonconservative fluxes increase. DIP and DIN behave somewhat differently. At low DIP loads nonconservative flux is near 0; at loads in excess of about 0.01 mmol m^{-2} d^{-1}, nonconservative DIP flux may become either positive or negative, reflecting either uptake or release within the systems. Nonconservative DIN flux also responds to loading; as DIN loading increases above about 1 mmol m^{-2} d^{-1} systems tend to take up DIN.

> "...high nutrient loads are roughly equivalent to direct waste discharge from one person for every 30 m^2 of area budgeted!"

Coastal ecosystems not only receive inputs from land but also exchange water with the adjacent ocean. The ocean water may have a range of nutrient levels, but these levels typically approximate natural oceanic nutrient concentrations. Usually this water is low in both DIN and DIP, relative to the terrigenous load, and has an N:P ratio of <10. Water exchange time is a measure of the time it takes for the coastal water body of interest to exchange its volume with the adjacent ocean. Exchange time is expressed as the ratio of water volume in the system of interest to the sum of water flow through the system plus mixing between the system and adjacent water. The budgeted systems have exchange times ranging from <1 day to several years. The lower panels of Figure 4 demonstrate that water exchange times of <100 days generally promote more rapid nonconservative DIP and DIN fluxes.

Where to from here?

These sorts of scaling analyses are useful for generalising loading, internal reaction, and exchange of materials in coastal ecosystems. However, the data are inevitably biased by the availability of sites for which budgetary analyses are possible. The next challenge of the analysis is to extrapolate these site-specific results to the global coastal zone. Towards this end, the budgeting group is working closely with the typology group in LOICZ [3] in order to accomplish this extrapolation. The combined typology and budgeting studies have led to an initial "global synthesis

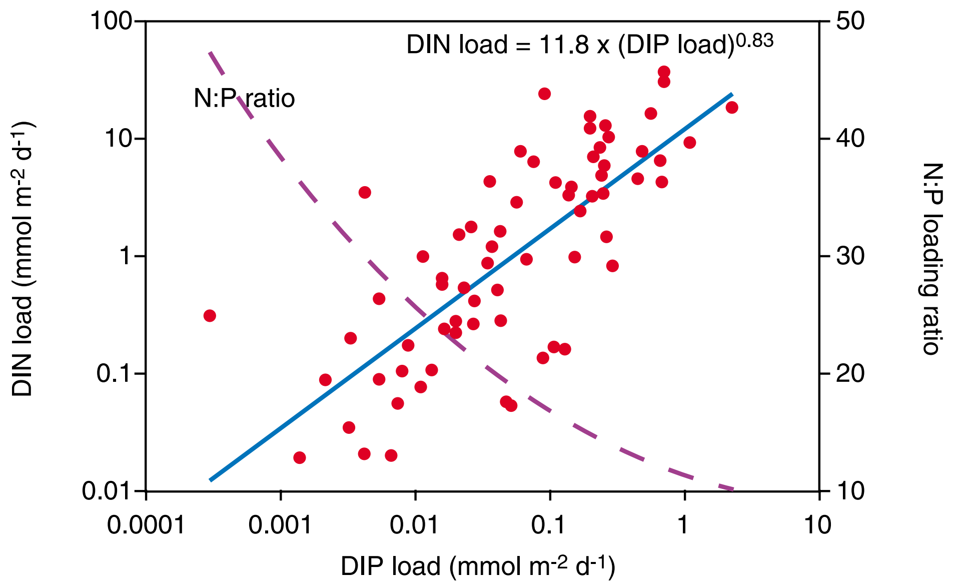

Figure 3.
Area-normalized DIP load versus DIN load to the budget sites. The N:P loading ratio diminishes as total load increases

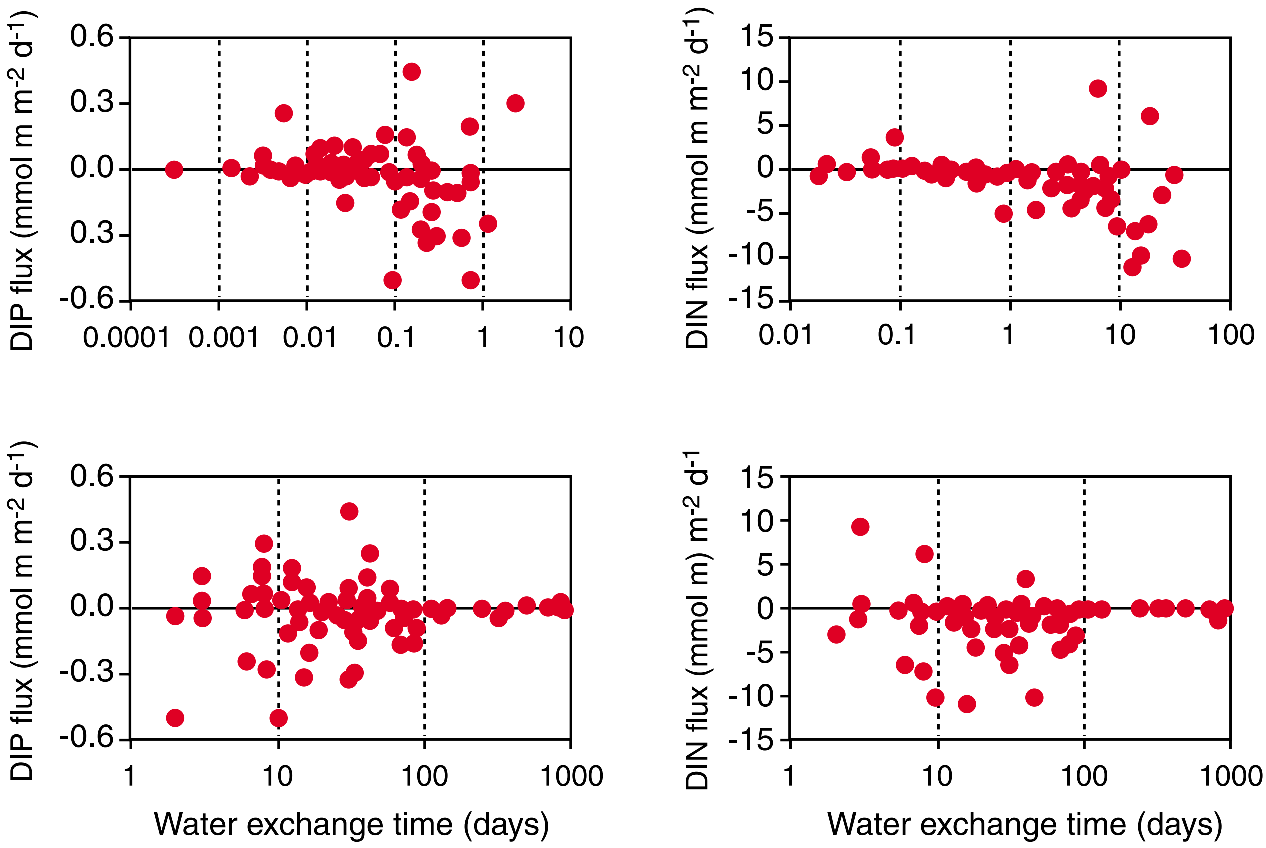

Figure 4. Non conservative nutrient fluxes in response to nutrient loading (top panels) and water exchange time (bottom panels). Absolute rates of nonconservative fluxes are higher at high loads and short exchange times.

workshop" that was held in Lawrence, Kansas, in November 2001. Analyses of the geo-spatial global settings, functional processes in the form of land-derived and oceanic loadings that influence the coastal systems, and development of models describing system response relationships provided important milestones and destination points in the longer journey of up-scaling; further analyses are proceeding. A report on these interim findings is in preparation and there will also be a chapter in the LOICZ synthesis book encompassing subsequent global and regional integration. A preliminary draft of that book will be prepared in 2002.

Acknowledgements

There have been literally dozens of contributors to this effort (see the list of contributing authors, on the LOICZ Modelling web page [1]). The core team consists of: S. Smith, F. Wulff, D. Swaney, V. Dupra, V. Camacho, L. David, M. McGlone, H. Waldron. In addition, we have close interaction with the Typology Team (headed by R. Buddemeier) and from the LOICZ International Project Office (C. Crossland et al.). We also acknowledge support from institutions that hosted workshops, the Netherlands government agency WOTRO and the GEF programme of UNEP.

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This article was first published in the LOICZ newsletter (No. 21, Dec 2001).

More information

For more information on LOICZ, see: http://www.nioz.nl/loicz

References

1. Gordon Jr. DC, Boudreau PR, Mann KH, Ong J-E, Silvert WL, Smith SV, Wattayakorn G, Wulff F and Yanagi T. (1996). LOICZ Biogeochemical Modelling Guidelines. LOICZ Reports & Studies No 5, 1-96
2. LOICZ Modelling web page: http://data.ecology.su.se/MNODE
3. Buddemeier RW and Maxwell BA. (2000). Typology: Low-budget Remote Sensing. LOICZ Newsletter No. 15, June 2000

Modelling climate - carbon cycle feedbacks: a cross disciplinary collaboration priority

by P. Cox, P. Friedlingstein and P. Rayner

The carbon cycle and climate are tightly coupled. The most obvious illustration of this is provided by the ice-core records which show atmospheric carbon dioxide and global temperatures varying together over glacial cycles. Climate also affects the Earth's carbon cycle on the shorter timescales associated with seasonal cycles and interannual climate variations such as El Niño. Similarly, the carbon cycle is capable of affecting the climate through changes in the concentration of the greenhouse gases, carbon dioxide and methane. Despite these known links between climate and the carbon cycle, General Circulation Model (GCM) projections of future climate have typically neglected climate-carbon cycle feedbacks. The first attempts to include the carbon cycle as an interactive element of climate models suggest that these longer-timescale interactions could produce significant feedback on climate change over the next century.

Carbon budget studies show that only about a half of the current human emissions of CO_2 remain in the Earth's atmosphere. The remainder is being absorbed by the oceans and by vegetation and soil on the land, but in both cases the processes involved are known to be sensitive to climate. GCM climate change simulations typically use prescribed scenarios of increases in atmospheric CO_2, which are derived 'off-line' neglecting the potential impacts of climate change on the carbon cycle. These simulations have therefore excluded the effects of feedback between climate and the carbon cycle.

Two recent GCM experiments have instead treated atmospheric CO_2 as an internal variable, calculating its evolution based on emissions and modelling uptake by land and ocean as a function of the climate. This advance has been strongly supported by IGBP projects devoted to the development and testing of ocean and land carbon models. Both coupled GCM experiments show accelerated climate change as a result of suppression of the land carbon sink, but the magnitude of the effect differs markedly. The Hadley Centre coupled climate-carbon cycle model produces about 250 ppmv higher CO_2 concentrations by 2100, compared to an experiment with the same GCM in which climate and carbon cycle are decoupled [1]. As a result the climate warming predicted for the 21st century is much more rapid than previously modelled. This positive feedback is associated with the conversion of the global net land carbon sink to a source by the middle of the 21st century. A similar set of numerical experiments carried out at the Pierre Simon Laplace Institute (IPSL), France [2] shows a smaller increase of 75 ppmv in the atmospheric CO_2 projected for 2100 (see Figure 1).

The reasons for these different responses are still under investigation, but it seems that

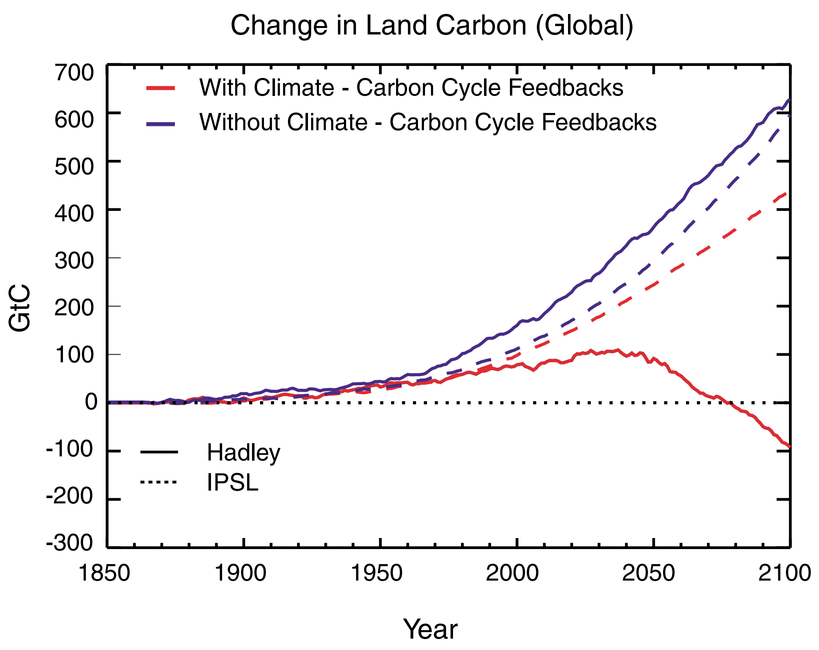

Figure 1. Climate-carbon cycle GCM experiments carried out at the Hadley Centre (continuous lines) and the Pierie Simon Laplace Institute (IPSL) (dashed lines). Results are shown from runs both with and without carbon cycle feedbacks (red and bluelines respectively).

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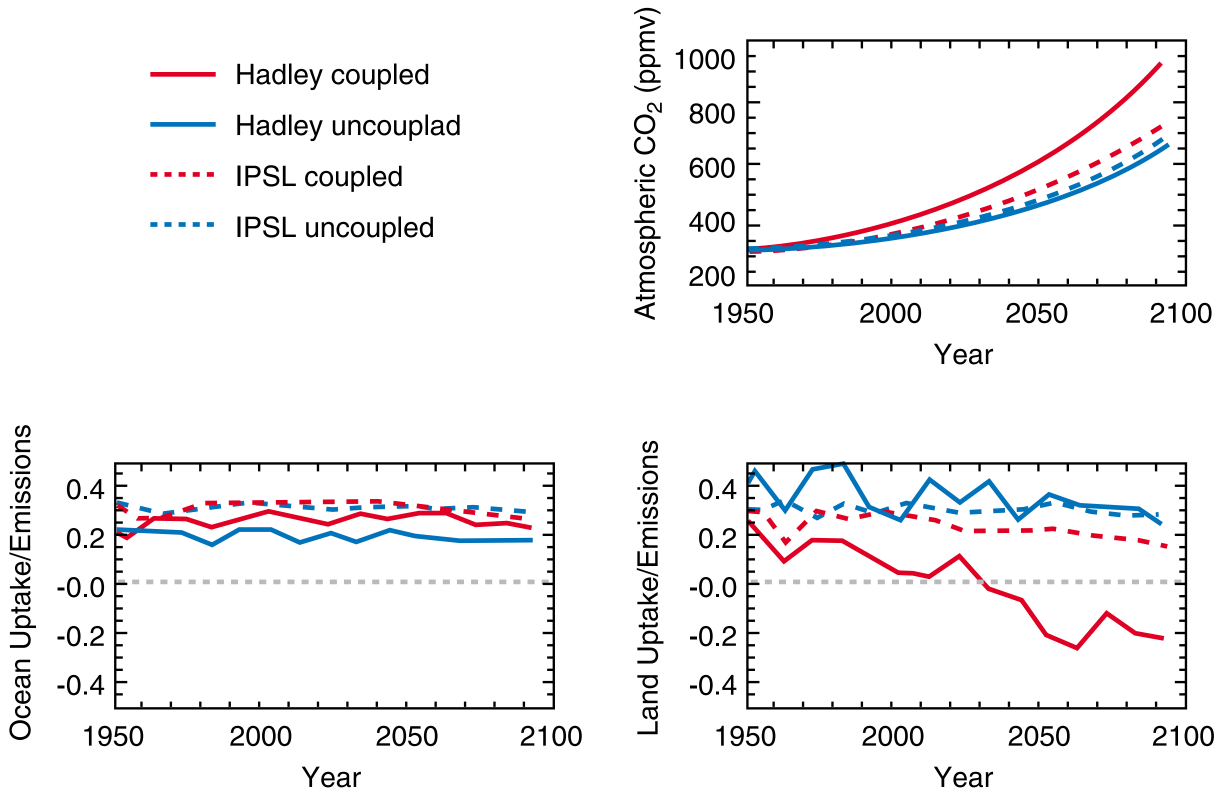

Figure 2. The three panels compare the evolution of atmospheric carbon dioxide (top right), and the ocean and land uptake as a fraction of the emissions (lower 2 panels).

differences in ocean carbon uptake, regional climate change and terrestrial model responses all play a part (Figure 2). For example, the Hadley Centre model produces a relatively weak ocean uptake and a large warming and drying in Amazonia under enhanced CO_2, which leads to dieback of the tropical forest releasing carbon to the atmosphere. A smaller tropical drying is seen in the IPSL model, which also has much stronger ocean uptake. Both models produce reduced soil carbon (relative to experiments without climate-carbon cycle feedback) but this effect is dependent on uncertain factors such as the assumed sensitivity of soil respiration to temperature and the fraction of the total soil carbon which can be readily decomposed by micro-organisms.

The experiments to date suggest in particular that the response of the land biosphere to climate change represents a zeroth-order uncertainty in climate predictions. It is therefore vital that we identify the key uncertainties, and then work with our colleagues from ecological and climate disciplines to reduce these. The coupling of physical climate models with models of the biosphere is clearly a cross-disciplinary activity which requires expertise encompassed by both the World Climate Research Programme (WCRP) and the IGBP. The most fruitful way to bring life to the GCM land surface will be to make use of the findings gained in both communities, to produce models which consistently treat the cycling of energy, water, carbon and nutrients within the Earth System. For the land surface this will entail combining the short-time scale components included in GCM land surface schemes with the longer-timescale components modelled by Dynamic Global Vegetation Models (DGVMs).

A first stage will be to produce a better sample of possible climate carbon cycle feedbacks by encouraging other groups to include interactive carbon cycles within their GCMs. The Coupled Climate Carbon Cycle Model Intercomparison Project (C4MIP) is a joint initiative of IGBP-Global Analysis Integration and Modelling (GAIM) and the WCRP-Working Group on Coupled Models (WGCM). C4MIP will provide a framework for the intercomparison of coupled climate-carbon cycle models and ultimately an assessment of the dominant sources of uncertainty.

Other cross-disciplinary projects are also of vital importance to this endeavour. The Global Land-Atmosphere System Study (GLASS) is utilising the well developed PILPS off-line methodology to compare and assess the latest generation of GCM land-surface schemes which include carbon cycling ("PILPS-C1"). The "Global Carbon Project" (GCP) is a joint IGBP-WCRP-IHDP (International Human-Dimensions Programme) initiative which will provide valuable advances on the coupling between climate and the carbon cycle, as well as extending the study of the carbon cycle to include socioeconomics as an interacting element.

These cross-disciplinary collaborations will be vital in ensuring the global carbon cycle is accurately represented in our models of the greenhouse world.

Websites

C4MIP - http://www.atmos.berkeley.edu/c4mip/

GLASS - http://hydro.iis.u-tokyo.ac.jp/GLASS/

GCP - http://gaim.sr.unh.edu/cjp/GCP_FRAMEWORK.html

References

1. Cox PM, Betts RA, Jones CD, Spall SA, Totterdell IJ. (2000). Acceleration of global warming due to carbon cycle feedbacks in a coupled climate model. Nature 408,184-197.
2. Friedlingstein P, Bopp L, Ciais P, Dufrene J-L, Fairhead L, LeTreut H, Monfray P, Orr J. (2001). Positive feedback between future climate change and the carbon cycle. Geophys. Res. Let., 28, 1543-1546.

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Reprinted with modifications from the joint BAHC/GEWEX newsletter, November 2001.

Interactions between anthropogenic aerosols and the hydrological cycle

by U. Lohmann

The anthropogenic component of sulphate and carbonaceous aerosols has substantially increased the global mean aerosol burden from pre-industrial times to the present day and can influence the climate in different ways. The direct aerosol effect is caused by the absorption and scattering of solar radiation. Additionally, aerosols act as cloud condensation nuclei and thereby determine the initial cloud droplet number concentration, albedo, precipitation formation, and lifetime of warm clouds. For constant liquid water path, an enhancement in the cloud droplet number leads to an increase in cloud albedo (cloud albedo or first indirect aerosol effect). As smaller cloud droplets have a lesser chance to collide and form precipitation size drops, the enhancement in cloud droplet number and decrease in cloud droplet size due to anthropogenic aerosols may cause a reduction in precipitation formation and increase in cloud lifetime (cloud lifetime or second indirect aerosol effect).

The cooling of the cloud albedo effect is estimated to be between 0 and -2 W m^{-2} in the global mean, but is still very uncertain [1]. The cloud lifetime effect is not a forcing because it involves interactions of aerosols with cloud droplets. It is estimated to be of comparable magnitude to the cloud albedo effect. This effect is even more uncertain because changes in the hydrological cycle associated with aerosols presently cannot be deduced from observational studies alone, but depend on a modelling component to fill in the gaps. It is these latter interactions between aerosols and the hydrological cycle that will be discussed below.

Anthropogenic aerosol emissions

Can anthropogenic aerosol

emissions in the Northern Hemisphere influence the precipitation in the tropics and subtropics?

A mechanism by which anthropogenic aerosols could influence the Sahelian rainfall was proposed by Rotstayn and Lohmann [2] and Feichter et al. [3]. They used different atmospheric general circulation models (GCM), the CSIRO and ECHAM4 GCMs respectively, coupled to a mixed layer ocean to conduct equilibrium experiments in response to the anthropogenic aerosol loading. Whereas Rotstayn and Lohmann [2] included only sulphate aerosols, Feichter et al. [3] considered sulphate, dust, sea-salt and carbonaceous aerosols. In both simulations the greenhouse gas concentrations were kept at present day values. In the pre-industrial simulations, the fossil fuel emissions were set to zero and the biomass burning emissions were reduced to 0% or 10% of their present-day values. The CSIRO model only considers the cloud albedo and the cloud lifetime effect by empirically relating the sulphate aerosol mass to the number of cloud droplets. In this approach sulphate aerosols are used as a surrogate for all aerosols.

The ECHAM model considers the direct and the semi-direct aerosol effect in addition to both indirect aerosol effects. The semi-direct effect refers to absorption of solar radiation by black carbon (BC) which can lead to a heating of the air and can result in an evaporation of cloud droplets. Thus, the warming caused by the semi-direct effect can partially offset the cooling due to the indirect aerosol effect, as outlined in Lohmann and Feichter [4]. Here the number of cloud droplets is obtained from a balance equation. Cloud droplet nucleation is parameterised as a function of total aerosol number concentration, updraft velocity, and a shape parameter, which takes the aerosol composition and size distribution into account. The total number of aerosol particles is obtained as the sum of marine sulphate aerosols produced from dimethyl sulphide, hydrophylic organic and black carbon, submicron dust, and sea-salt aerosols. Anthropogenic sulphate aerosols only add mass to the pre-existing aerosols but do not form new particles.

The response due to the anthropogenic aerosol loading in both models was then obtained as the difference between the present-day and the pre-industrial simulations. The surface temperature was reduced everywhere, caused by the different anthropogenic aerosol effects. As this cooling is largest in the Northern Hemisphere, it changes, for instance, the meridional gradient of the sea surface temperature in the Atlantic. In the model simulations, this strengthens the trade winds and reduces the strength of the African monsoon resulting in drought conditions in the Sahelian region.

"...increasing pollution in the Northern Hemisphere can have far reaching effects, such as contributing to droughts in the Sahel region."

The strength of the African monsoon and the observed rainfall amounts in the Sahelian region closely follow the trends in sulphur dioxide emissions.

The Sahelian precipitation decreased continuously from the 1950s through the 1980s but recovered in the 1990s. This coincides with reduced emissions of sulphur dioxide enforced by the Clean Air Act in North America in the 1980s and in Europe in the 1990s.

Rotstayn and Lohmann [2] compared the hemispheric difference in cloud droplet effective radius from the model to satellite estimates. The underlying idea is that the higher aerosol concentrations in the Northern Hemisphere caused by anthropogenic activity would lead to more but smaller cloud droplets so that the cloud droplet size distribution is characterised by a smaller effective radius. Unfortunately, the two available satellite retrievals by Han et al. [5] and Kawamoto et al. [6] substantially differ in their estimates of the hemispheric effective radius difference over the oceans. Whereas Han et al. [5] predict 0.9μm smaller droplets in the North Atlantic, Kawamoto et al. [6] actually predict 0.1μm larger droplets over the North Atlantic as compared to the South Atlantic. The CSIRO models agree exactly with the earlier estimate by Han et al. [5].

The change in zonally averaged rainfall in response to the anthropogenic aerosol loading from the CSIRO model is shown in Figure 1 together with the observed trend in precipitation from 1901 to 1998. Most striking is the southward shift in precipitation with a decrease in precipitation between the equator and 20°N and an increase between 20°S and the equator in both the model and the observations. The increase in precipitation in the Northern Hemisphere mid latitudes probably results from the increase in greenhouse gases and, therefore, cannot be captured in this simulation where greenhouse gas concentrations were kept constant. The ECHAM model gives similar results (not shown). Here the shift in precipitation is less pronounced because of the effect of including biomass burning aerosols that cool the tropical southern hemisphere and therefore reduce the meridional temperature gradient in the Atlantic if compared to including only the effect of sulphate aerosols.

Analyses in more detail, in agreement with observations, show that both models simulate less precipitation over the Sahel zone in response to a weaker summer monsoon. In other words, the authors suggest that the simultaneous increase in the abundance of atmospheric greenhouse gases and aerosol particles since World War II may have contributed to the observed drought in Western Africa via a change in the meridional temperature gradient. The increase in sulphate aerosols over the North Atlantic results primarily from fossil fuel use in North America and Europe. Control of sulphur emissions in the industrialised countries of the northern hemisphere might have been a significant factor in the recovery from the drought during the 1990s. If confirmed, this hypothesis would provide a striking example of a teleconnection between anthropogenic perturbations in the industrialised regions of the northern mid-latitudes and climate change in the subtropics.

"Control of sulphur emissions in the industrialised countries of the northern hemisphere might have been a significant factor in the recovery from the drought during the 1990s"

Can anthropogenic aerosols influence mid-latitude precipitation?

Since natural ice nuclei are scarce, especially at small supercoolings, on the order of 1 ice nucleus in 1 million aerosol particles, anthropogenic ice nuclei can potentially be a very important contributor to glaciation of supercooled clouds. However, the connection between aerosols and ice clouds is presently considered to be too uncertain to even speculate on whether it would be a positive or negative radiative climate forcing [1].

Evidence for ice-forming activity of soot particles of various sizes as contact nuclei has recently been studied in a cloud chamber for temperatures ranging from -5°C to -20°C [7]. This study found that the fraction of soot particles forming ice crystals increased with decreasing temperature, increasing size of the aerosol particles and with the degree of oxidation of the soot particle surface. If soot was oxidised, the surface chemical groups could form hydrogen bonds with water molecules.

These findings motivated Lohmann [8] to propose the hypothesis that anthropogenic

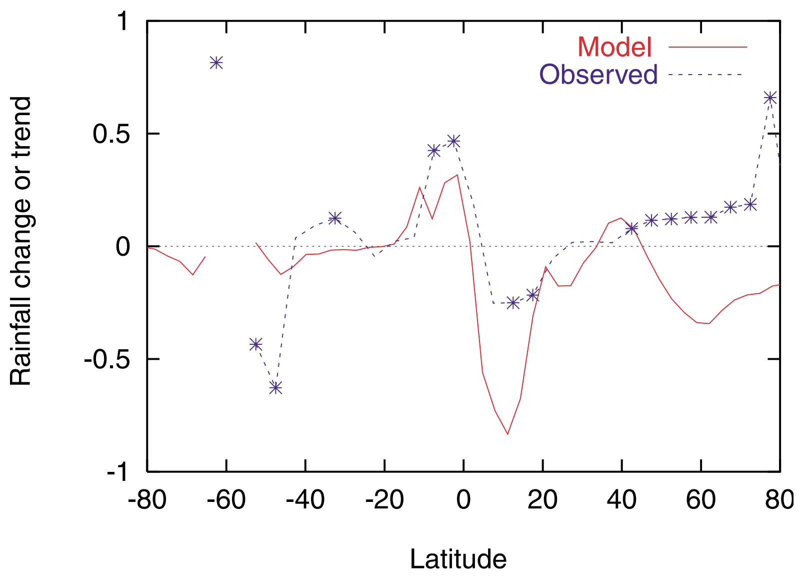

Figure 1 Zonally averaged trend in observed annual-mean precipitation over the period 1901-1998 [mm day^{-1} century^{-1}] (dotted line) and zonally average difference in annual-mean precipitation between present-day and pre-industrial simulations with the CSIRO [mm day^{-1}] (solid line) GCM. Points at which the observed trend is significant at the 5% level are shown as asterisks.}

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soot aerosols can influence the glaciation of clouds and with that modulate the indirect aerosol effect as shown in Figure 2. If no ice nuclei are present, more aerosols lead to more cloud condensation nuclei (CCN), a higher cloud droplet number concentration (CDNC) and less precipitation. For a constant liquid water content, this will increase cloud albedo. In addition, the reduction in precipitation prolongs the lifetime of clouds and the cloud fraction, which also increases the cloud albedo.

If, on the other hand, sufficient contact ice nuclei (IN) are present, more ice particles (IP) can be formed. This would lead to more frequent glaciation of supercooled clouds as the ice crystals grow rapidly at the expense of the droplets in a high ice supersaturated environment so that more precipitation is formed. As a consequence, the cloud fraction would decrease thus allowing more shortwave radiation to be absorbed in the Earth-atmosphere system.

Sensitivity studies with varying amounts of soot acting as ice nuclei showed that if 1% to 10% of the hydrophilic black carbon acted as ice nuclei in addition to dust as a natural ice nuclei, then the precipitation is increased and cloud cover and liquid water path (LWP, the vertically integrated cloud liquid water amount) are decreased in mid-latitudes via the above mentioned mechanism, see Figure 3. Thus, more solar radiation can penetrate to the surface. This means, if a non-negligible fraction of soot aerosols acts as ice nuclei, the glaciation indirect aerosol effect could reverse or at least reduce the effect that anthropogenic aerosols have on the shortwave radiation at the top of the atmosphere.

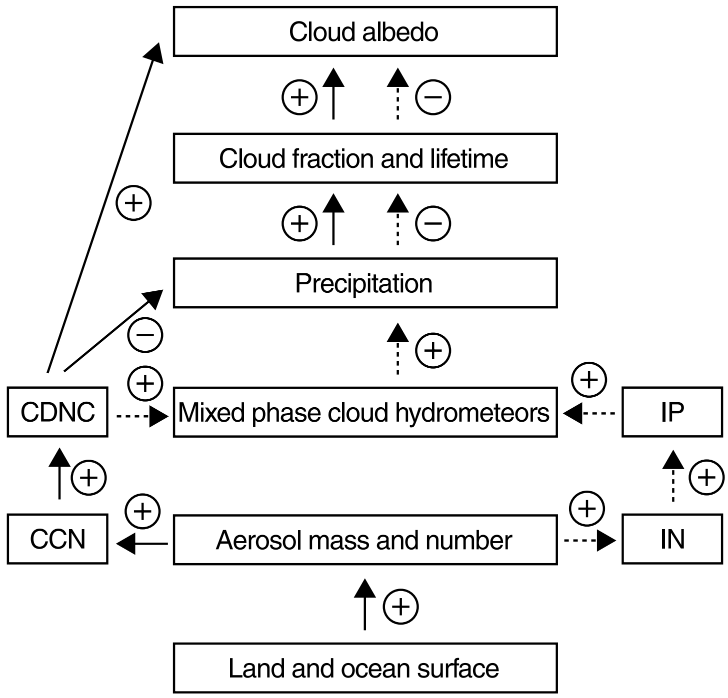

Figure 2. Schematic diagram of the warm indirect aerosol effect (solid arrows) and glaciation indirect aerosol effect (dotted arrows).

CDNC = cloud droplet number concentration
CCN = cloud condensation nuclei
IP = ice particles
IN = ice nuclei

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Could anthropogenic aerosols change the global hydrological cycle?

Whether aerosols scatter or absorb solar radiation, the dominant effects of aerosols on the radiation balance at the surface is a reduction in shortwave radiation. This cooling of the surface temperature leads to smaller evaporation rates which, in equilibrium, are then balanced by lower precipitation rates. This can result in a weaker monsoon due to the cooler land surface temperatures as outlined above. This will reduce the latent and sensible heat transfer from the surface to the atmosphere. To investigate the importance of this effect in a future climate Roeckner et al. [9] conducted a set of transient experiment from 1860 to 2100 in which the ECHAM4 GCM was coupled to an oceanic general circulation model and included an interactive sulphur cycle. The first experiment only included carbon dioxide and other well mixed greenhouse gases (GHG), the second included GHG and the direct effect of sulphate aerosols, and the third included GHG plus tropospheric ozone and the direct and first indirect aerosol effect, the effect of aerosols on cloud albedo, empirically estimated from the sulphate aerosol mass.

Roeckner et al. [9] concluded that the hydrological cycle will be weaker in the period 2030-50 as compared to the present-day climate when the direct and indirect effect of sulphate aerosols and tropospheric ozone are included. In this scenario, precipitation decreased by 0.4%

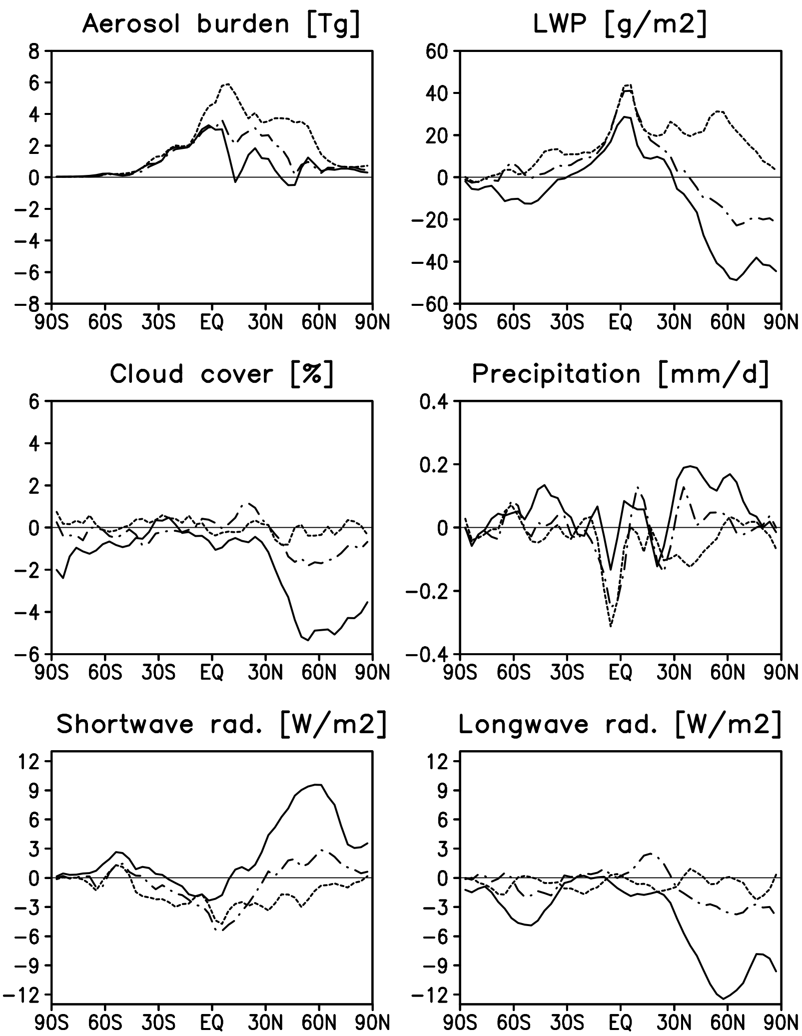

Figure 3. Zonal annual mean changes between present-day and pre-industrial times for experiments with varying amounts of black carbon (BC) acting as ice nuclei: BC10% (solid line) BC1% (dot-dashed line) and BC0% (dotted line)

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per degree increase in temperature. In contrast, if only greenhouse gases are considered, then the precipitation increases by 0.7%K. The weaker hydrological cycle in the aerosol experiment is caused by the anomalous net radiative cooling at the Earth's surface through aerosols. It is balanced by reduced turbulent transfer of both sensible and latent heat. It is interesting to note that the direct effect of sulphate aerosols alone is not able to decrease precipitation in the warmer climate but only reduces the increase of precipitation in the warmer climate to 0.3%K.

Conclusions

We are entering a new area of aerosol research by investigating the interactions between aerosols and the hydrological cycle. Research in this area started with cloud seeding research, as summarised in the overview article by Bruintjes et al. [10]. Investigations in cloud seeding research are interested in satellite-based microphysical retrievals that can be combined with *in situ* cloud sampling to monitor the effects of natural and anthropogenic aerosol or hygroscopic seeding material on cloud droplet size evolution, and the effects of ice-forming nuclei on ice-particle concentrations, both of which determine the efficiency of precipitation production. The cloud seeding community, however, is not interested in the climate impact of anthropogenic aerosols or their effect on the global hydrological cycle, but only the influence of aerosols on precipitation on a local to regional scale. Still a knowledge exchange between the two research communities would be beneficial.

As presented above, increasing pollution in the Northern Hemisphere can have far reaching effects, such as contributing to droughts in the Sahel region. Such an effect could lead to positive feedbacks as a decrease in precipitation could increase dust storms and biomass burning which in turn could decrease the precipitation even more via the cloud lifetime effect. Changes in meridional sea surface temperature gradient may have further teleconnection effects that we are currently not aware of. Longitudinal changes in temperature could result from strong biomass burning and could, for instance, influence the Walker circulation. This is an area that requires further research as only recently scientists started to investigate these effects.

In general, our knowledge about aerosol effects on clouds and the hydrological cycle is still very rudimentary. Therefore, clearly more research in terms of field experiments, laboratory studies and modelling efforts is needed in order to understand and quantify the effect of anthropogenic aerosols on clouds and the hydrological cycle. This is especially impor-

References

1. Ramaswamy V et al. (2001). In 'Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Chapter 6: Radiative Forcing of Climate Change, pp 349-416, Cambridge Univ. Press, New York
2. Rotstayn LD and Lohmann U. (2002). Tropical rainfall trends and the indirect aerosol effect. J. Climate, in press
3. Feichter JE, Lohmann U, Roeckner E and Brasseur GP. Did anthropogenic aerosols contribute to the 1970-1990 Sahelian drought? Submitted to Nature, 2002
4. Lohmann U and Feichter J. (2001). Can the direct and semi-direct aerosol effect compete with the indirect effect on a global scale? Geophys. Res. Lett. 28: 159-161
5. Han Q, Rossow WB and Lacis AA. (1994). Near-global survey of effective droplet radii in liquid water clouds using {ISCCP} data. J. Climate 7: 465-497
6. Kawamoto K, Nakajima T and Nakajima TY. (2001). A global determination of cloud microphysics with {AVHRR} remote sensing. J. Climate 14: 2054-2068
7. Gorbunov B, Baklanov A, Kakutkina N, Windsor HL, and Toumi R. (2001). Ice nucleation on soot particles. J. Aerosol Science 32: 199-215
8. Lohmann U. (2002). A glaciation indirect aerosol effect caused by soot aerosols. Geophys. Res. Lett. 29, in press.
9. Roeckner E, Bengtsson L, Feichter J, Lelieveld J and Rodhe H. (1999). Transient climate change simulations with a coupled atmosphere-ocean GCM including the tropospheric sulphur cycle. J. Climate 12: 3004-3032
10. Bruintjes RT. (1999). A review of cloud seeding experiments to enhance precipitation and some new prospects. Bulletin of the American Meteorological Society 80: 805-820
11. Stocker TF et al. (2001). In 'Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Chapter 7: Physical climate processes and feedbacks, pp 417-470, Cambridge Univ. Press, New York

tant because cloud feedbacks in climate models still present one of the largest uncertainties. As shown in Stocker et al. [11] there is still no consensus on whether clouds provide a negative or positive climate feedback in response to a doubling of carbon dioxide. It is largely because of these uncertainties in cloud feedback that the uncertainty range of the increase in the global mean surface temperature in response to a doubling of carbon dioxide varies between 1.5 and 4.5 K.

Acknowledgements: Thanks to Hans Feichter for comments and suggestions, to Stockholm University for support and to IGAC for providing travel support to the IGAC Planning Meeting in Stockholm (27-30 January 2001).

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Reprinted with modifications from the IGAC newsletter No 26 (April 2002)

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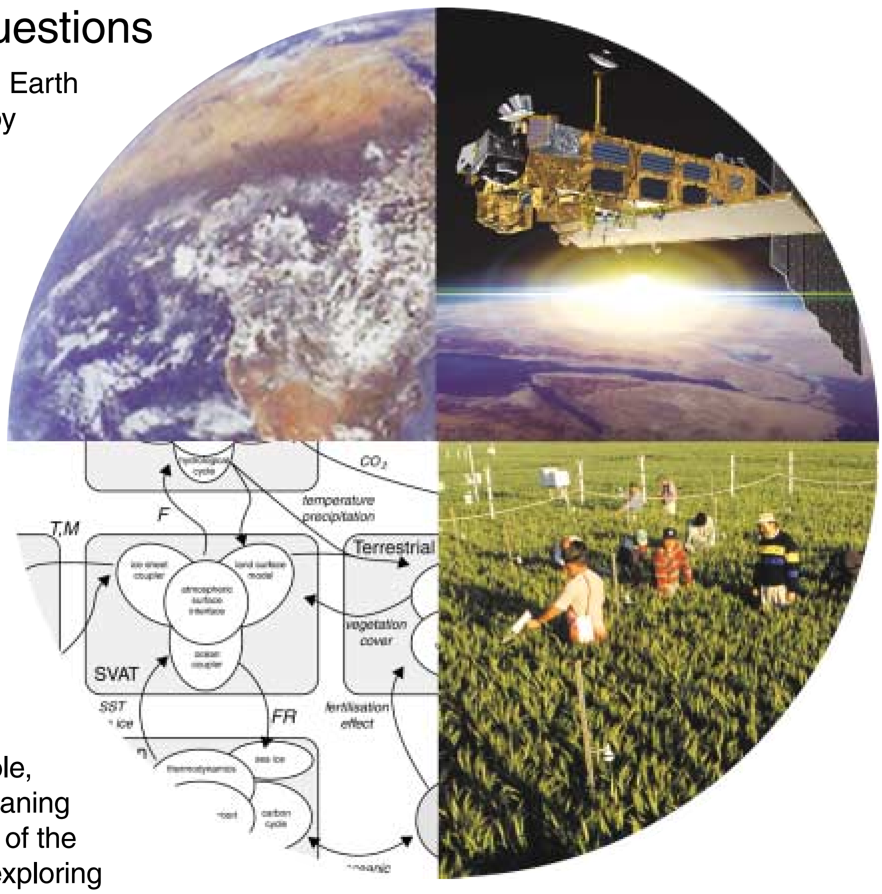
Integration

This article is the first in our new regular feature on integration. One of the most prominent characteristics of IGBP II is the increasing emphasis on the integration of the subcomponents of the Earth System to build a more complete picture of the functioning of the global environment. Such integration can occur in various ways - through inter-core project collaboration, through regional studies, through the activities of GAIM, and by the joint research of IGBP and its partner global change programmes in the 'Earth System Science Partnership'.

In this issue we feature the 23 GAIM questions, a set of overarching questions designed to challenge the entire global change research community, and society more generally, for decades into the future. Following a general introduction to the whole set of questions, we focus more strongly on of them – no. 14: "What are the most appropriate methodologies for integrating natural-science and social-science knowledge?" We hope to focus on other questions in future editions of the newsletter.

The Twenty-Three GAIM Questions



The course of global change research, and Earth System science in general, is determined by the scientific questions that challenge the scientific community. In 2001, in response to the evolving science, structure and results of IGBP, GAIM developed a set of such questions (see box). As well as challenging the community, they put the present body of IGBP research into context, and also highlight any gaps in our conceptual approach or research strategy.

These questions are not limited in scope to those that can be answered by individual research projects, programs, or even communities. Rather, they help to define the overall context of global change science regardless of present ability to address the issues articulated therein. As part of its analysis role, GAIM is developing explanations of the meaning and implications of the questions, the state of the art as pertains to each, and a strategy for exploring each one. The latter is a critical aspect, and due to the breadth of the questions, will range from specific scientific activities, to the exploration of dialogue with communities

Box: The GAIM Questions

Analytic Questions:

1. What are the vital organs of the ecosphere in view of operation and evolution?
2. What are the major dynamical patterns, teleconnections and feedback loops in the planetary machinery?
3. What are the critical elements (thresholds, bottlenecks, switches) in the Earth System?
4. What are the characteristic regimes and time-scales of natural planetary variability?
5. What are the anthropogenic disturbance regimes and teleperturbations that matter at the Earth-System level?
6. Which are the vital ecosphere organs and critical planetary elements that can actually be transformed by human action?
7. Which are the most vulnerable regions under global change?
8. How are abrupt and extreme events processed through nature-society interactions?

Operational Questions:

9. What are the principles for constructing "macroscopes", i.e., representations of the Earth System that aggregate away the details while retaining all systems-order items?
10. What levels of complexity and resolution have to be achieved in Earth System modelling?
11. Is it possible to describe the Earth System as a composition of weakly coupled organs and regions, and to reconstruct the planetary machinery from these parts?
12. Is there a consistent global strategy for generating, processing and integrating relevant Earth System data sets?
13. What are the best techniques for analysing and possibly predicting irregular events?
14. What are the most appropriate methodologies for integrating natural-science and social-science knowledge?

Normative Questions:

15. What are the general criteria and principles for distinguishing non-sustainable and sustainable futures?
16. What is the carrying capacity of the Earth as determined by humanitarian standards?
17. What are the accessible but intolerable domains in the co-evolution space of nature and humanity?
18. What kind of nature do modern societies want?
19. What are the equity principles that should govern global environmental management?

Strategic Questions:

20. What is the optimal mix of adaptation and mitigation measures to respond to global change?
21. What is the optimal decomposition of the planetary surface into nature reserves and managed areas?
22. What are the options and caveats for technological fixes like geoengineering and genetic modification?
23. What is the structure of an effective and efficient system of global environment and development institutions?

far beyond IGBP and the 'Earth System Science Partnership'.

The GAIM questions should, in fact, anticipate the advent of a unified Earth System Science and therefore encompass the natural and socioeconomic dimensions in a balanced way. This accounts for "horizontal integration" across the disciplines, but "vertical integration" across the layers of the problem-solving process is no less important.

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Some of the 23 questions are quite specific and apply only to certain fields within Earth System Science. Others are very broad, and can be seen either as overarching questions or interpreted with different angles by different fields. There will many ways to tackle these questions. At the recent IGBP SC meeting in Stockholm (19-22 February 2002), two main approaches were proposed. Firstly, each core project should adopt the relevant questions into more focused questions appropriate for their science. Secondly, each year a few of the GAIM questions will be addressed by small task teams, who will meet and possibly produce a paper with a state-of-the-art review of the knowledge existing to begin answering the question. A newly formed task-team, the Oslo Group, has already begun this process by taking on question 14. The following section describes their approach.

Human-Environment Interactions: Methods and Theory

The new IGBP embraces the challenge of a more integrated approach to analysis and synthesis of knowledge about the Earth System. This System is a close set of interrelationships between people and nature, and the greatest intellectual challenge is to make the 'Earth System Science Partnership' (ESSP) work so that these interrelationships can be better understood. We will need workable analytical and synthetic methods, and theories of the interrelationships, that will help policy and decision makers better understand the world in which they are operating.

The integrative research required by the ESSP is being pursued in many parts of the Global Change Programmes, and the challenge of integration within the natural sciences is gradually being met. But by far the greatest challenge is bridging the disciplinary divide between natural science, social science, and the humanities to develop generalisations (theory) about human environment interactions.

A small group spanning the interests of IGBP and IHDP has formed to tackle some of the methodological and theoretical issues that all partners in the ESSP will face. Our role is not to displace work already going on in parts of the Partnership, but to pool experience and knowledge, reflect on successes and failures, and by publishing our ideas and conclusions, aid the development of this crucially important field of research.

The small group met in Oslo in 2001, and so is called The Oslo Group (TOG). The acronym is also the Norwegian word for train, and the group sees itself as setting out on an important and difficult journey.

Sustainability problems demand integrated knowledge about natural systems, history, human society, and human behaviour. The human-environment system involves large numbers of interacting agents and components (both human and non-human), is adaptive and self-organising, and is dynamic in rich and often surprising ways. This system is therefore an iconic complex system.

There are already in existence methods for studying this system, including system dynamics, the narrative methods of environmental historians, environmental and ecological economics, human ecology, policy and institutional analysis. These are also generic concepts such as risk and resilience that pervade both the human and non-human worlds. These methods need further development, and TOG intends to undertake some of this development. TOG will be most effective if it takes a global change view, and seeks to complement other relevant activities (e.g. IGBP's Non-linear Group, the Resilience Alliance, and various national efforts).

TOG has undertaken to answer one of the GAIM questions:

What are the most appropriate methods for integrating natural science, social science, and humanities knowledge? (No. 14)

This question has been modified from the original to include the humanities, because most decisions about the environment include human values and beliefs, and we also wish to highlight the importance of environmental history.

To this question we have added:

What are the current theories of human-environment interactions that help identify sustainable futures?

Our initial discussions in Oslo identified two broad themes within the second question that we wish to tackle, namely the identification of the characteristics of resilient (durable) systems, and the dynamical relationships between knowledge production, policy formulation, and decision making.

TOG currently consists of Carol Crumley, Eric Lambin, Nordin Hassan, Claudia Pahl-Wostl, Barry Newell, Arild Underdal and Bob Wasson. We have begun to write an overview paper for wide distribution within the ESSP and also plan to work our way through many of the issues identified in Oslo over the next few years. We would welcome ideas, material and critical comments so that our work is connected to the rest of the ESSP. TOG will operate as a complex, adaptive system!

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Atmospheric Chemistry within the Earth System: From regional pollution to global change

10th Scientific Conference of the CACGP and 7th Scientific Conference of the IGAC

18-25 September 2002

CACGP

Creta Maris, Hersonissos, Heraklion, Crete, GREECE

Observing our changing atmosphere

Distributions and trends of radiatively and chemically active substances, The view from space (gases, aerosols, clouds, radiation) - A. Thompson, F. Raes, D. Rosenfeld, J. Burrows, J. Fishman

Atmospheric composition change: Processes and mechanisms

New radical chemistry, Multiphase chemistry, Upper troposphere - lower stratosphere interactions, Aerosol/cloud/radiative processes and interactions, Atmosphere-surface exchanges - U. Platt, M.C. Facchini, A. Cox, P. Quinn.

Major campaigns with regional focus

Mediterranean area, India, Asia, Pacific, Amazon, Africa, Others - J. Lelieveld, V. Ramanathan, B. Huebert, D. Jacob, P. Artaxo, H. Annegarn

Impacts

Radiative forcing/Chemistry-Climate Interactions, Element Cycle interactions, Nutrient mobilisation, redistribution, fertilisation, other impacts. - J. H. Seinfeld, R. Duce, J. Galloway

'Hot' Topic short sessions

- Stability of global OH and detection of OH trends - R. Prinn, P. J. Crutzen
- New particle formation: where does it happen and how? - Th. Hoffmann, M. Kulmala
- Model results and satellite observations: How can we optimally confront them?
- O. Boucher, C. Granier
- Large scale/Hemispheric scale air pollution - S. Penkett
- How important are controls of short lived greenhouse gases/aerosols for alleviating global warming as compared to CO_2 control? -V. Ramanathan, M. Heimann
- The role of the biosphere in climate change - P. Matson

Open meetings:

18th of Sept: 'IGAC in its second decade: plans for a follow up program'

23rd of Sept: 'CACGP activities'

Registration fees:

Payment before June 30, 2002: 350 Euro (students: 250 Euro)

Payment after June 30, 2002: 400 Euro (students: 300 Euro)

Hotel reservation deadline: June 30, 2002
e-mail to info@grecomar.gr

Contact us by E-mail: igac2002@chemistry.uoc.gr
Symposium website: http://atlas.chemistry.uoc.gr/IGAC2002

Discussion Forum

Interdisciplinary research is central to the rapidly developing agenda of Phase II of IGBP, and collaboration with the International Human Dimensions Programme is essential. But interdisciplinary is not the same as multidisciplinary – integration is not the same as summation! To achieve this integration will require a flexible, open-minded approach by both the natural and social scientists, and their funding agencies.

Natural Sciences, Social Sciences: Integration or Summation?

Collaboration between natural and social scientists will only be successful if programmes and projects are initiated and planned by integrated teams from both disciplines, and supported by funding agencies who have a high-level commitment to interdisciplinary research. This was one of the conclusions drawn by a European Science Foundation (ESF) Forward Look meeting, held in Stockholm between 30th January and 1st February 2002. The meeting looked at the management and funding of global change research in Europe. This brief article is a personal report on some of the conclusions.

As the policy and societal relevance of the IGBP research agenda increases, so does the need to collaborate with social scientists, such as those of the International Human Dimensions Programme (IHDP). People, of course, live on the land surface, so it is in land surface science where this need to collaborate is most urgent. Ten years ago social science was totally absent from IGBP land surface research, such as the HAPEX-Sahel experiment held in 1992. Yet, recent use of the HAPEX-Sahel data to model the climatic effects of land cover change in the Sahel revealed the need for factual, historical land cover change data, and estimates of future land cover based on predicted demographic and other social changes. A resulting collaboration between BAHC and LUCC scientists has now produced the first realistic estimate of the climatic effects of actual land cover change in the region [1].

Similarly in South America the current Large-Scale Biosphere-Atmosphere Experiment in Amazonia (LBA) was designed with no socioeconomic component. This is now being added and studies such as those on the causes of deforestation and the sustainability of deforested land are being added to the studies of the physical and biological functioning of the Amazon basin. However, making these additions at this late stage is difficult - it would have been

Box. Natural and Social Science Collaborations

Failed collaborations are likely to have:

- No shared concepts
- Questions formulated by one side
- Problems with semantics
- Lack of commitment
- Misconception of roles and place
- Difficulty in attracting scientists
- Poor communication and physical separation

Successful collaborations are likely to have:

- Shared concepts & language
- Excellency in own field
- Joint proposal development
- Sub-projects to allow individuals to succeed in their own field
- Intellectual respectability
- Long term commitment
- Good communication and personal contact

(photos by C Batchelor)

Food provision was identified as one area where good collaboration between natural and social scientists is essential. Hydrologists and economists working in Zimbabwe found that when community gardens are organised around productive wells that provide more water than is needed for basic sanitation and subsistence, surplus vegetables are sold. This provides cash for pump maintenance and produces a positive spiral of economic growth which is sustainable. Good siting and design of wells combined with community ownership and management is the key to success [3].

much more easily done as part of the initial design process five years ago. If it had been, a very different experimental design might well have emerged.

Management

The social and natural sciences have different cultures and to be successful collaboration requires each to be aware of these differences. A working group at the ESF Forward Look meeting discussed these differences starting with the lists in the Box, which were drawn up by Professor Leen Hordijk of Wageningen University. Clearly, without an open-minded attitude and a willingness to learn on both sides it will be easier to fail than to succeed.

The reasons for success in the Box are really no more than the basic rules of team management: shared project design and shared decision making leads to shared project ownership, motivation and commitment. The meeting recognised that the key to success is to build an integrated team from the start. This is the approach advocated by the new UNESCO/WMO HELP (Hydrology for the Environment, Life and Policy) initiative. This programme plans to establish a global network of catchments as a framework for natural and social scientists to work together with environmental managers to research locally defined issues [2].

Lastly, building on already established strong areas of collaboration to create a "flagship" projects was identified as a sensible starting point. Land use and land cover change, vulnerability and food provision were seen as good examples where existing collaboration could be expanded.

Institutional obstacles

Research funding agencies are generally not well structured for dealing with interdisciplinary projects. In most cases national funding is channelled through different agencies for the natural and social sciences. Even where it is not, there will almost certainly be different committees responsible for funding the research from the various disciplines. These committees may well have terms of reference which effectively prevent them from funding interdisciplinary proposals.

Rather than fight this system from below, what is needed is a high-level commitment to interdisciplinary research. When this exists the situation can be radically transformed. A good example is the United Kingdom's Tyndall Centre. This centre is funded by a large grant jointly provided by the three UK research councils responsible for funding the environmental, physical and social sciences (NERC, EPSRC and ESRC). The Tyndall Centre is researching the impacts of climate change – working at the interface between climate research and research on policy.

In the longer term there is a need to expose young scientists to the whole spectrum of the natural and social science aspects of global change research. Both generalists and specialists are needed, but whatever the subject of their thesis, newly qualified PhDs should be comfortable working in an interdisciplinary environment. Graduate summer schools on global change research are one way of starting this process.

Summing up

Summing up at the end of the meeting Dr John Marks, Director for Earth and Life Sciences at The Netherlands' funding agency NWO, said "Breaking down the intellectual barriers to collaboration is ultimately up to the scientists themselves, but there is a clear role for the ESF to mobilise the commitment of the European funding agencies to the new global change agenda, and to ensure that artifical administrative barriers do not prevent the necessary interdisciplinary research from being funded".

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References

1. Taylor CM, Lambin EF, Stephenne N, Harding RJ and Essery R. (2002). The influence of land use change on climate in the Sahel. Submitted to J. Climate
2. UNESCO. (2001). The design and implementation strategy of the HELP initiative. IHP-V, Technical Document in Hydrology, 44, UNESCO, Paris
3. Lovell C. (2000). Productive Water Points in Dryland Areas: Guidelines on integrated planning for rural water supply. ITDG Publishing, London.

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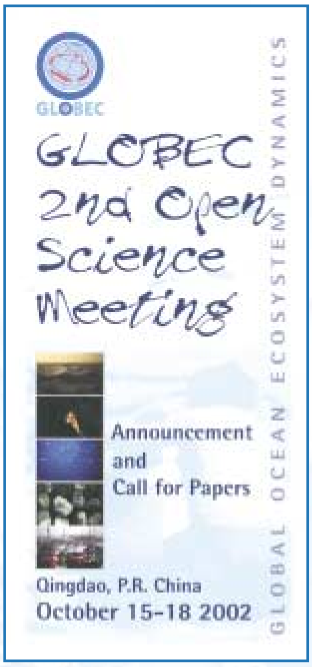

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People and events

IGBP is in a transition phase. New projects are under development, both within IGBP and as joint projects with our three partner programmes (IHDP, WCRP and DIVERSITAS). Changes are also occurring this year in the composition of the IGBP Scientific Committee, and this extends right through to the Chair of the organisation.

Musical Chairs

On 1 January 2002 Professor **Guy Brasseur** became the Chair of the SC-IGBP, succeeding Professor **Berrien Moore**. Guy has a long history with IGBP, starting with membership on the IGAC Scientific Steering Committee in the early 1990s, followed by his chairmanship of IGAC from the mid-90s. He has played an especially strong role in the IGAC Integration & Synthesis project, which has produced a landmark state-of-the science report in atmospheric chemistry. In addition to his IGAC duties, he has also been a member of the GAIM Task Force for the past three years.

One of Guy's unique strengths is his in-depth knowledge of global change science on both sides of the Atlantic, and in many other parts of the world. For many years he worked at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, USA, where he was head of the Atmospheric Chemistry Division. Two years ago he returned to Europe, becoming Director of the Max Planck Institute for Meteorology in Hamburg, Germany. In addition, he also has a background in politics, having interrupted his scientific career earlier to become a member of the Belgian Parliament. This experience will no doubt serve Guy well as the whole field of global change science becomes increasing important in the political sphere of life.

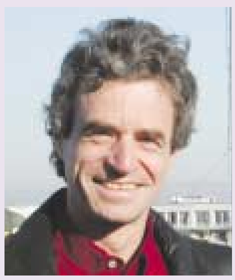
While welcoming Guy to the Chairmanship, the IGBP community also sincerely thanks Berrien for his outstanding leadership during this challenging period for the programme, and for his tireless efforts in promoting global change science around the world. Although Berrien has officially stepped down as Chair, he will continue on the SC-IGBP through 2002 and will continue to play an active part in the programme's future for many years to come.

Almut Arneth will be assisting Guy Brasseur with the daily tasks of chairing IGBP. Her research at Landcare Research in Lincoln (New Zealand) and the Max Planck Institutes for Biogeochemistry and Meteorology (Germany) has focused on terrestrial ecosystem carbon and water fluxes (i.e., long-term responses to climate change, and atmospheric CO_2 concentration, impacts

Scientific Committee

At the end of 2001, Isao Koike (Treasurer), Bert Bolin, Wolfgang Cramer and Peter Tyson all rotated off; we thank them all for their invaluable contribution to IGBP during their terms of office. This of course means some new faces on the SC:

Takashi Kohyama is a professor at Hokkaido University, Japan. His interest is the architectural dynamics of forest ecosystems and tree species coexistence. Focal sites have been subalpine coniferous forests in central Japan, warm-temperate rain forests in southern Japan, and tropical rain forests in Sumatra and Kalimantan. He has been carrying out fieldwork such as permanent plot monitoring, tree dimension analysis and theoretical modelling of forest dynamics at various levels, from tree architecture to forest landscape. He is Chairman of the Steering Committee of the GCTE project "Global Change Impacts on Terrestrial Ecosystems in Monsoon Asia" (TEMA).



Michel Loreau is a professor at Pierre and Marie Curie University in Paris. He joins the IGBP SC by virtue of being the chairman of the Scientific Committee of DIVERSITAS, but is already familiar to the IGBP community through his work with GCTE. He is currently an editor of four of the top ecological journals, the winner of several scientific prizes, and the author of over 150 scientific publications in the fields of theoretical ecology, community ecology, ecosystem ecology, population ecology and evolutionary ecology. His current research aims to make a synthesis between the widely separated fields of ecosystem functioning and community organisation and diversity.

Prof **Mary Scholes** is currently an associate professor in the Department of Animal, Plant and Environmental Sciences at the University of the Witwatersrand, South Africa. She has spent time at North Carolina State University working on the sustainability of low-input agriculture in the Peruvian Amazon, and also at the National Center for Atmospheric Research and Colorado State University, USA. Her research activities focus on soil fertility and biogeochemistry in savannas, forests and croplands. She is active in a number of regional and international advisory committees to do with soil fertility and tropical agriculture. Her interests in nitrogen cycling have resulted in her being elected to two international science steering committees focusing on trace gas emissions; this involves collaborative research with a number of overseas institutes.

Peter Liss was featured in NL 48 (Dec 2001) as the new chair of SOLAS: he also joins the IGBP SC.

Seth Krishnaswami is already known to us as an SC member, but has a new role as Treasurer.

Two other people join SC members due to their new positions as co-Chairs of START:

Sulochana Gadgil is a professor at the Centre for Atmospheric and Oceanic Sciences, Indian Institute of Science, Bangalore. She actively participated in the Joint Scientific Committee of the WCRP and the START SSC, and has played a major role in the preparation and execution of the science plan of the Indian Climate Research Programme. She has worked on monsoon dynamics and variability and its links with agriculture and has been involved in CLIMAG since its inception.

Graeme Pearman is Chief of CSIRO Atmospheric Research, Australia and is also Chair of the Scientific Planning Group of the Asia-Pacific Network. He was a participant in the 1990 IGBP Bellagio workshop that led to the creation of START and is a past chair of the START committee for SE Asia (SARCS). His research interests focus on the field of atmospheric composition and, in particular, the global carbon cycle.

Joint Project Chairs

Global Carbon Project Co-Chairs

Robert Dickinson is an atmospheric scientist with the School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, Georgia, having been educated at Harvard and MIT. He will soon serve as President of the American Geophysical Union until 2004, and is already Chair of the Atmospheric and Hydrospheric Sciences Section of the American Association for the Advancement of Science (2001-2002), a member of the American Meteorological Society and the Climate System Modeling NCAR Scientific Steering Committee (1995-2002); and a Co-Chair for CLIVAR (2001-2002). In 2001, he served on the National Research Council Committee on the Science of Climate Change.

Michael Raupach is presently a Chief Research Scientist in CSIRO Land and Water, Canberra, Australia His major research interests are:

- Biosphere-atmosphere interactions: the flows and stores of energy, water and carbon in landscapes, at local, continental and global scales
- Wind flows and the spread of windborne materials in the lower atmosphere, especially over the Earth's surface
- Soil erosion by wind, including studies of the windborne transport of solid particles, erosion control by vegetation, and wind erosion and long-term agricultural sustainability.

Oran R. Young is Professor of Environmental Studies and Director of both the Institute of Arctic Studies and the Institute on International Environmental Governance at Dartmouth College in the United States. He is also Professor II of Political Science at the University of Tromsø in Norway. He chairs the Scientific Steering Committee of the international project on the Institutional Dimensions of Global Environmental Change (IDGEC) and is chairman of the Board of Governors of the University of the Arctic. The most recent of his many books is 'The Institutional Dimensions of Environmental Change' (2002).

GECAFS (Global Environmental Change and Food Systems)

Peter Gregory (GECAFS Chair) is Professor of Soil Science at the University of Reading, UK, where he has also held a number of senior positions. Over the last 20 years he been working in the UK and Australia on the microclimatology of tropical crops, plant/soil interactions, root growth and the uptake of water and nutrients by crops, and the chemical and physical limitations imposed by soils on crop production. His current research interests include the development of non-invasive techniques for imaging roots growing in soil, the chemical and physical properties of the mucilage produced by roots, modelling water and nutrient uptake by plant root systems, and developing sustainable systems of crop production.

Michael Brklacich (GECAFS Vice Chair) is an Associate Professor in the Department of Geography and Environmental Studies at Carleton University, Canada. His interests lie in interdisciplinary approaches for assessing relationships between human use and impacts on environmental and natural resources, and in the application of science to public policy. Over the past few years, he has focused on issues relating to agricultural adaptation to global change and food security. This newer work relies heavily on participatory research methods and on the integration of quantitative and qualitative research methods. He has been actively involved in the development of the Global Environmental Change and Human Security project, a core project within the International Human Dimensions Program on Global Environmental Change.

Transition Team Leaders for IGBP Phase II

Atmosphere

Timothy Bates is currently a Supervisory Research Chemist at NOAA's Pacific Marine Environmental Laboratory in Seattle, Washington, but also holds posts at the Department of Atmospheric Sciences and the Joint Institute for the Study of the Atmosphere and Ocean (JISAO), both at the University of Washington. His research has focused on marine atmospheric chemistry including the air-sea exchange of trace gases, the biogeochemical sulphur cycle, and the chemical, physical and radiative properties of atmospheric aerosols. During the past eight years, he has been a coordinator of IGAC's three Aerosol Characterization Experiments (ACE). He is currently a member of the Commission on Atmospheric Chemistry and Global Pollution (CACGP), and a member of the US interagency steering committee developing a National Aerosol-Climate Interactions Program.

Mary Scholes (see SC section on page 28)

Land

Lisa Graumlich is a professor at Montana State University (Department of Land Resources & Environmental Sciences), where she is also the Director of the Mountain Research Center. Her interests are the interaction of climatic variation at multiple scales, ecological processes, and land-use and social factors in governing change in mountain regions.

Sandra Lavorel's research interests focus on the dynamics of plant diversity in landscapes, especially in relation to natural and land use disturbances. She has been involved with several international comparative studies, and has coordinated research on global change effects on landscape structure and function. Since 1994 she has been a Research Scientist with CNRS in France, but has close connections with the Research School of Biological Sciences, Australian National University in Australia, where she worked from 1991-94. In 1997 she joined GCTE's SSC, and has since become interested in integrating approaches to land use change research.

Emilio Moran is an expert in the field of environmental anthropology, tropical ecology, and the human dimensions of global environmental change. He has contributed to the development of theory in cultural ecology and ecosystem ecology and has served as Leader of Focus 1 of LUCC since 1999. His major field research has focused on land use change in the Amazon Basin, a topic he has fol-lowed for more than 30 years. He has been Director of the Anthropological Center for Training and Research on Global Environmental Change since 1992 and Co-Director of the Center for the Study of Institutions, Population and Environmental Change since 1996. He is a member of the National Academy of Sciences' Committee on the Human Dimensions of Global Change, the Board of the National Museum of Natural History at the Smithsonian, and of the Scientific Steering Committee of the US Carbon Cycle Science Program.

Dennis Ojima is a senior research scientist at the Natural Resource Ecology Laboratory and an Assistant Professor at Colorado State University. He has served on a number of international and national committees dealing with ecosystem science, and was contributing author to several chapters of the 1995 Intergovernmental Panel on Climate Change. From 1988 to 1990, he was a Programme Officer with IGBP and was subsequently involved with LUCC. Dr. Ojima's research activities address ecological issues related to global and regional land use and climate changes on ecosystem dynamics; studies of the interaction between terrestrial ecosystems and the atmosphere; the impact of changes in land management on trace gas exchange; and the development of a global ecosystem model. Specifically his research is aimed at developing a better understanding of factors affecting ecological integrity and sustainable resource use.

Land-Atmosphere

Pavel Kabat is already well known to the IGBP community through his work with BAHC, and as a member of the SC. His co-leader for Land-Atmosphere project is still to be decided.

Ocean Biogeochemistry and Ecosystem Activity

Julie Hall is a biological oceanographer from the National Institute of Water and Atmosphere in New Zealand. Her research is focused on the structure and dynamics of the microbial food web in both coastal and open ocean systems. Julie has been involved in the JGOFS programme both in New Zealand and internationally and was one of the team of scientists who conducted the first iron addition experiment in the Southern Ocean. She has been a member of the JGOFS SSC and has also Co-Chaired the JGOFS/LOICZ Continental Margins task team. Julie is also involved in the development of the Global Ocean Observing System (GOOS) as Vice Chair of the GOOS SC and is also a member of the team developing the strategic and implementation plan for Coastal GOOS.

New faces at the IGBP Secretariat

Last but not least, we have two new people at the Secretariat. **Angelina Sanderson** will be working on the IGBP Synthesis volume 'Earth System Overview' until the end of 2002. She has an Honours degree in Human Biology from Stanford University, and her interests are in small-scale agricultural development.

Petra Nilsson will be helping John Bellamy with IGBP graphic design duties until the end of May.

A warm welcome to everyone in their new roles within IGBP!

IGBP and Related Global Change Meetings

For a more extensive meetings list please see our web site at www.igbp.kva.se

GCTE: From Transient to Steady State Response of Ecosystems to CO_2-Enrichment and Global Warming

28 April-1 May, Durham, New Hampshire, USA

Contact: Diane Pataki, pataki@biology.utah.edu

Workshop on Building Adaptive Capacity to Environmental Change in Southeast Asia

TBA, April, Chiang Mai, Thailand (tentative)

Contact: Louis Lebel, llebel@loxinfo.co.th

IGBP/SCOR: Ocean Biogeochemistry and Ecosystems Transition Team Planning Meeting

23-26 April, Potomac, Maryland, USA

Contact: Ed Urban, scor@jhu.edu

IGBP: Water Joint Project Meeting with Core Project Representatives

8-10 May, Paris, France

Contact: Holger Hoff, hhoff@pik-potsdam.de

GLOBEC: SPACC Executive Committee Meeting

11-12 May, Dartington, UK

Contact: GLOBEC IPO, globec@pml.ac.uk

Obituary

James Ellis, an ecosystem scientist at the Natural Resource Ecology Laboratory of Colorado State University, died in an avalanche in western Colorado on March 14, 2002. The world is diminished by his loss.

Dr. Ellis' preeminent work on understanding the interplay between people and natural processes in arid ecosystems set a global standard for novel research spanning scientific disciplines. Jim focused much of his research on the role of climate variability in affecting ecosystem dynamics and human response to these dynamics in semi-arid ecosystems. He applied integrated, interdisciplinary approaches to understanding pastoral ecosystem ecology throughout the world - in Africa, the Middle East, Asia, and North America. His work exerted broad impacts on contemporary science, but more, played a fundamental role in supporting wise management and policy in the developing world. Particularly notable was his extensive research on the ecology of pastoralism in the Turkana District of Kenya during the 1980s, studies supported by three major grants from the Ecosystem Studies Program and the Anthropology Program of the National Science Foundation. This project produced over 200 scientific publications. It was the first example of a major research project integrating social and ecosystem science, an example that has been frequently imitated.

Dr. Ellis was a systems ecologist in the classical sense - his greatest strength was his ability to conceptualise large, complex scientific problems as whole systems, to sketch the interactions among their significant components, and to develop ways to understand their dynamics. In this way, he contributed much to global change science and was a key player in many research activities that became components of IGBP core projects. Dr Ellis was an outstanding example of the world-class scientists who so willingly contribute their time and expertise to international, collaborative research, and who form the backbone of IGBP's networks around the world. His passing is a loss to all of us who value the sharing of scientific excellence across national and cultural boundaries towards a common vision of a better world.

He is survived by his wife and longstanding scientific colleague, Dr. Kathleen Galvin, and four sons, Gregory, Eric, Ian, and Stefan. The IGBP community sends its condolences to them.

GCTE: GCTE Focus 1 Workshop: Biological controls on the stable isotope composition of atmospheric carbon dioxide, methane and nitrous oxide: processes and applications

12-14 May, Banff, Canada

Contact: Diane Pataki, pataki@biology.utah.edu

GLOBEC: GLOBEC Executive Committee Meeting

13-14 May, Dartington, UK

Contact: GLOBEC IPO, globec@pml.ac.uk

State of the Planet 2002: A Conference Exploring Science and Sustainability

13-14 May, New York, USA

Contact: http://www.earth.columbia.edu/sop2002/aboutsop.html

16th Global Precipitation Climatology Project - Working Group on Data Management meeting

13-17 May, Tokyo, Japan

Contact: GEWEX Project Office, gewex@cais.com

PAGES: PAGES Scientific Steering Committee

14-15 May, Moscow, Russia

Contact: PAGES IPO, pages@pages.unibe.ch

PAGES: High Latitude Paleoenvironments

16-17 May, Moscow, Russia

Contact: Olga Solomina: solomina@gol.ru
Isabelle Larocque: larocque@pages.unibe.ch
http://www.pages.unibe.ch/

Future of Glaciosphere in Changing Climate

18-20 May, Pushchino, Russia

Contact: igras@igras.geonet.ru or geograph@online.ru

GCSS-ARM Workshop on the Representation of Cloud Systems in Large-Scale Models

20-24 May, Alberta, Canada

Contact: GEWEX Project Office, gewex@cais.com

GCTE: GEGC-II/GCTE Soil Erosion Network co-sponsored Meeting

22-25 May, Chengdu, China

Contact: Dr Yong Li, yongli32@hotmail

PAGES: The Northern Environment, 36th Congress Canadian Meteorological and Oceanographic Society

22-25 May, Rimouski, Quebec, Canada

Contact: larocque@pages.unibe.ch

GCTE: GCTE-SEN co-sponsored meeting. "Soil Erosion and Land Use Change"

26-31 May, Chengdu, China

Contact: http://www.wscc.org.cn/isco2002/index.htm

Holocene Environmental Change in the Great Lakes Region

28 May-1 June, Toronto, Canada

Contact: Matthew Peros: matthew.peros@utoronto.ca
Sarah Finkelstein: sarah.finkelstein@utoronto.ca

LOICZ: Synthesis and Futures Meeting and Scientific Steering Committee Meeting

27 May-2 June, Miami, Florida

Contact: loicz@nioz.nl

Global Change Programmes. Chairs and Directors Meeting

31 May-2 June, Bonn, Germany

Contact: IHDP Secretariat, ihdp@uni-bonn.de

IHDP, START: 3rd IHDP/START bi-annual Workshop on Human Dimensions of Urbanisation and the Transition to Sustainability

3-14 June, Bonn, Germany

Contact: Maarit Thiem, thiem.ihdp@uni-bonn.de
http://www.ihdp.org

START: AIACC Vulnerability and Adaptation Assessment Methods Training Course

3-14 June, Treiste, Italy

Contact: Sara Beresford, sberesford@agu.org

SOLAS: SOLAS Implementation Strategy Meeting

10-14 June, Amsterdam, The Netherlands

Contact: Peter Liss, p.liss@uea.ac.uk

GLOBEC: ICES Symposium on 'Acoustics in Fisheries and Aquatic Ecology'

10-14 June, Montpellier, France

Contact: François Gerlotto, gerlotto@orstom.fr or Jacques Massé, jacques.masse@ifremer.fr

GCTE: GCTE Focus 1/NCEAS 2nd working group meeting: Progressive nitrogen limitation of plant and ecosystem responses to elevated CO2

18-21 June, Santa Barbara, CA, USA

Contact: Diane Pataki, pataki@biology.utah.edu

5th International Integration of Icecore, Marine + Terrestrial Records (INTIMATE) workshop

22-28 June, Tromso, Norway

Contact: Wim Hoek: w.hoek@geog.uu.nl
http://www.geog.uu.nl/fg/INTIMATE

Global Ocean Productivity and the Fluxes of Carbon and Nutrients: Combining Observations and Models

24-27 June, Ispra, Italy

Contact: Reiner Schlitzer, rschlitzer@awi-bremerhaven.de
Patrick Monfray, monfray@cea.fr

GLOBEC: Focus 4 WG Meeting: 'Global Changes in Marine Ecosystems and Coastal Communities: Who done it?'

26-28 June, Sidney, Canada

Contact: Ian Perry, perryi@pac.dfo-mpo.gc.ca or GLOBEC IPO, globec@pml.ac.uk

START: START Pan-Africa Regional Committee meeting in conjunction with the meeting of the African Ministers of the Environment (AMCEN)

29-30 June, Kampala, Uganda

Contact: Eric Odada, eodada@uonbi.ac.ke

2nd LBA Science Conference

7-10 July, Manaus, Brazil

Contact: LBA Central Office, yara@cptec.inpe.br

START: START/IRI/Packard Advanced Training Institute on Climatic Variability and Food Security

8-26 July, Palisades, NY, USA

Contact: James Hansen, jhansen@iri.columbia.edu

Quaternary Climatic Changes and Environmental Crises in the Mediterranean region

15-18 July, Madrid, Spain

Contact: Ana Vadeolmillos Rodriguez, climatic.changes@uah.es
http://www2.uah.es/qchange2002

GCTE: ICAR5/GCTE-SEN Wind Erosion and Aeolin Processes Conference

22-25 July, Texas, USA

Contact: John Ingram, jsii@ceh.ac.uk

Symposium on Biosphere-Atmosphere Interactions at the VIII International Congress of Ecology (INTECOL)

11-19 August, Seoul, Korea

Contact: Wonsik Kim, wonsik-kim@yonsei.ac.kr
http://www.seoulintecol.org/

Hydrology for the Environment, Life + Policy Symposium

19-22 August,Stockholm, Sweden

Contact: Jim Wallace

World Summit on Sustainable Development

26 August-4 September, Johannesburg, South Africa

Contact: http://www.johannesburgsummit.org

Enviromental Catastrophes and Recoveries in the Holocene

29 August-2 September, West London, UK

Contact: http://www.brunel.ac.uk/depts/geo/CatastrophesUnited

Climate Variability, Predictability and Climate Risks

7-14 September, Bernese Oberland, Switzerland

Contact: nccr-climate@giub.unibe.ch or
http://www.ncccr-climate.unibe.ch

IGAC: "Atmospheric Chemistry in the Earth System: From Regional Pollution to Global Climate Change"

18-25 September, Crete, Greece

Contact: http://atlas.chemistry.uch.gr/IGAC2002/

JGOFS: 17th JGOFS Scientific Steering Committee Meeting and capacity building/training course on ocean biogeochemistry

23-25 September, Concepción, Chile

Contact: Roger Hanson, Roger.Hanson@jgofs.uib.no

Cave Climate and Paleoclimate- Best Record of the Global Change

24-27 September, Stara Zagora, Bulgaria

Contact: P.Delchev@Museum.web.bg

START: START SARCS meeting to be held in conjunction with START/WOTRO/APN

26-28 September, Hanoi, Vietnam (tentative)

Contact: C.H. Liu, chliu@cc.ncu.edu.tw

START: START/WOTRO/APN Southeast Asian Regional Seminar on Building Adaptive Capacity to Global Environmental Change: making better use of research-based knowledge to improve decision making

26-28 September, Hanoi, Vietnam (tentative)

Contact: Nguyen Hoang Tri, nguyenhoangtri@hn.vnn.vn

International Symposium on "Land Use, Nature Conservation, and the Stability of Rainforest Margins in Southeast Asia's

29 September-3 October, Bogor, Indonesia

Contact: symp2002@gwdg.de

26th SCOR General Meeting

1-5 October, Sapporo, Japan

Contact: SCOR Secretariat, scor@jhu.edu

GLOBEC: ICES ASC (ICES Centenary)

1-5 October, Copenhagen, Denmark

Contact: ICES Secretariat, ices.info@ices.dk

START: APN/TEA Workshop on Global Change and Sustainable Development in the Coastal Northeast Asia

2-4 October, Vladivostok, Russia (tentative)

Contact: Vladimir Kasyanov, inmarbio@mail.primorye.ru

START: START TEACOM meeting

2-4 October, Vladivostok, Russia (tentative)

Contact: Congbin Fu, sec@tea.ac.cn

International Workshop on Reducing Vulnerability of Agriculture and Forestry, Climate Variability and Climate Change

6-9 October, Ljubliana, Slovenia

Contact: Dr. Sivakumar, Sivakumar_M@gateway.wmo.ch

IGBP: 15th IGBP Officers Meeting

7-10 October, Casablanca, Morocco

Contact: Clemencia Widlund, clemencia@igbp.kva.se

GLOBEC: GLOBEC WG Meetings

13-14 October, Qingdao, P.R. China

Contact: GLOBEC IPO, globec@pml.ac.uk

START: 16th START Scientific Steering Committee Meeting

14-16 October, TBA

Contact: Ching Wang, xwang@agu.org

GLOBEC: GLOBEC SSC Meeting

14 October (pm). and 19-20 October, Qingdao, P.R. China

Contact: GLOBEC IPO, globec@pml.ac.uk

GLOBEC: OSM2 - 2nd GLOBEC Open Science Meeting

15-18 October, Qingdao, P.R. China

Contact: http://www.pml.ac.uk/globec/

IGBP: Scoping Meeting for the Land-Atmosphere Project

16-18 October, TBA

Contact: Almut Arneth, arneth@dkrz.de

GLOBEC: Joint GLOBEC Foci WG/PICES Task Team Meetings

19 October (am), Qingdao, P.R. China

Contact: GLOBEC IPO, globec@pml.ac.uk
PICES Secretariat, secretariat@pices.int

GLOBEC: PICES XI

21-26 October, Qingdao, P.R. China

Contact: PICES Secretariat, secretariat@pices.int

IGFA (International Group of Funding Agencies) Plenary Meeting

23-25 October, Norwich, UK

Contact: Carola, Roeser, carola.roeser@dlr.de

GLOBEC: **IOC/SPACC Study Group Workshop on the Use of Environmental Indices in the management of pelagic fish**

December, TBA

Contact: Manuel Barange, m.barange@pml.ac.uk

JGOFS: **Continental Margin Task Team Workshop for the Global Synthesis of the 5 Regional Syntheses**

4-6 December, Washington DC, USA

Contact: Larry Atkinson, atkinson@ccpo.odu.edu, Renato Quiñones, rquinone@udec.cl; Richard Jahnke, rick@skio.peachnet.edu

SOLAS: **2nd SOLAS SSC Meeting**

11-13 December, San Francisco, USA

Contact: Peter Liss

2003

IGBP: **18th SC Meeting**

20-24 January, Punta Arenas, Chile

Contact: Clemencia Widlund, clemencia@igbp.kva.se

International symposium "Environmental Change in Central Asia: Climate, Geodynamics, Evolution, Human Impact"

10-15 March, Berlin, Germany

Contact: Bernd Wünnemann, wuenne@zedat.fu-berlin.de

JGOFS: **18th JGOFS Scientific Steering Committee Meeting**

5-8 May, Washington DC, USA

Contact: Roger Hanson, Roger.Hanson@jgofs.uib.no

JGOFS: **3rd JGOFS Open Science Conference**

5-8 May, Washington DC, USA

Contact: Roger Hanson, Roger.Hanson@jgofs.uib.no
Ken Buesseler, kbuesseler@whoi.edu

IGBP: **3rd IGBP Congress**

19-25 June, Banff, Canada

Contact: Clemencia Widlund, clemencia@igbp.kva.se
Charlotte Wilson, charlottew@igbp.kva.se

Land–Ocean Interactions in the Coastal Zone

www.nioz.nl/loicz/

International Geosphere-Biosphere Programme
Scientific Committee on Oceanic Research

First Announcement of

International Open Science Meeting

on Ocean Biogeochemistry and Ecosystems

January 2003

Paris, France

The International Geosphere-Biosphere Programme (IGBP) and the Scientific Committee on Oceanic Research (SCOR) announce an open science meeting on Ocean Biogeochemistry and Ecosystems.

The meeting will be held in Paris in Januari 2003. The purpose of the meeting is to define the next phase of international global change research on marine biogeochemistry and interactions with ecosystems.

More detailed information about the meeting can be found on:

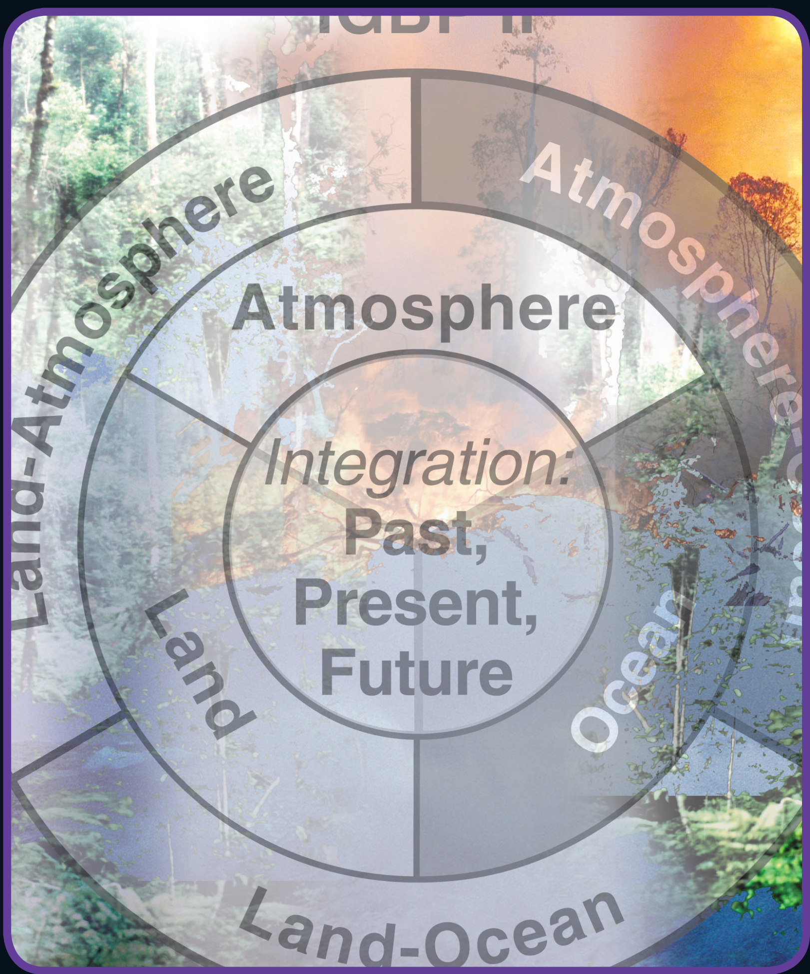
www.igbp.kva.se/obe/

Next issue

"We are entering a new and exciting period for IGBP. After a short transition period, we should soon develop new research foci and methodologies.... Although disciplinary aspects (including process studies) will remain an important part of the scientific agenda, attempts will be made to address scientific questions through a more integrated approach, recognizing that the Earth is a nonlinear system with chaotic behavior, feedback mechanisms, bifurcation points, etc., and that the prediction of its future evolution is not always deterministic."

Guy Brasseur, Chair, IGBP

The next issue of the Global Change NewsLetter will focus on the transition of IGBP towards its new set of questions, new structure, and innovative research approaches. Articles will report on the latest developments in the scientific planning for the next decade of IGBP work, and will provide a useful roadmap for both the science and the programmatics for IGBP II.



Note to contributors

Articles for "Science Features" should achieve a balance of (i) solid scientific content, and (ii) appeal for the broad global change research and policy communities rather than to a narrow discipline. Articles should be between 800 and 1500 words in length, and be accompanied by one to three key graphics or figures (colour or black and white).

Contributions for "Discussion Forum" should be between 500 and 1000 words in length and address a broad issue in global change science. A "Discussion Forum" article can include up to 2 figures.

Contributions for 'Integration' should be between 800-1200 words in length and highlight how IGBP or its core projects are integrating with other areas of Earth System Science. The article can include up to two figures.

"Correspondence" should be no more than 200 words and be in the form of a Letter to the Editor in response to an article in a previous edition of the Newsletter or relating to a specific global change issue. Please include author and contact details.

Required Image Quality for IGBP Publications

Photographic images should be saved in TIFF format. All other images including charts, graphs, illustrations, maps and logos should be saved in EPS format. All pixel images need to be high resolution (at least 300 pixels per inch).

Some charts graphs and illustrations can be reconstructed at the IGBP Secretariat, however, poor quality photographic images, maps and logos cannot be improved. Material "borrowed" from the Internet cannot be used for publication, as it does not fit the requirements listed above.

If you have queries regarding image quality for the Global Change NewsLetter please contact John Bellamy
E-mail: john@igbp.kva.se

Please note: figures of any kind must either be original and unpublished, or (if previously published) the author(s) must have obtained permission to re-use the figure from the original publishers. In the latter case, an appropriate credit must be included in the figure caption when the article is submitted.

Deadlines for 2002:

June issue (special edition on IGBP Phase II)	Deadline for material:	May 10
September issue	Deadline for material:	August 9
December issue	Deadline for material:	November 1

Send contributions by email to the Editor, Clare Bradshaw
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Next edition of the IGBP Newsletter…

- Special edition on IGBP Phase II

ISSN 0284-5865

GLOBAL CHANGE NEWSLETTER

Edited by Clare Bradshaw

Technical Editing by John Bellamy

Layout by Petra Nilsson

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The IGBP Report Series is published in annex to the Global Change NewsLetter