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The International Geosphere–Biosphere Programme (IGBP):
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3rd IGBP Congress – Special Edition

In early 2003 IGBP launched a new structure based on research into the Earth's major compartments (atmosphere, ocean, land), the interfaces between them, and their integration in past, present, and future time-frames. IGBP has also joined with the other international global change research programmes (World Climate Research Programme – WCRP, International Human Dimensions Programme on Global Environmental Change – IHDP, and DIVERSITAS - an international programme of biodiversity science) to form the Earth System Science Partnership (ESSP). The new IGBP structure and the ESSP were described in Global Change NewsLetter No. 50, June 2002.

In June 2003 the 3rd IGBP Congress was held in Banff, Canada. The Congress was an exceptionally important event in the process of implementing the new IGBP structure and clarifying the role of IGBP within ESSP.

This edition of the NewsLetter presents an overview and science highlights from the Congress. The Congress was sub-titled "Connectivities in the Earth System" and several articles in this edition focus on connectivities, feedbacks, and non-linear behaviour in the Earth System, based either on plenary presentations (*Disturbances and Earth System Dynamics* and *Earth System Science in the Early Anthropocene*) or working group discussions (*Non-linearities in the Earth System*). From the National Committee Chairs meeting comes an article reporting on *The Changing Role of IGBP National Committees*. In Integration, *The Common Land Model Experience* article (conceived at the Congress) summarises some lessons learnt from a cross-disciplinary model integration project. Finally in the Discussion Forum the question *Why are Global Fish Stocks Declining?* is considered, based on an invited-specialist plenary from the Congress. Together, these articles provide a flavour of the presentations and discussions at Banff, and highlight some key emerging characteristics of IGBP research.

3rd IGBP Congress Overview

G. Brasseur

Every four years, the IGBP Congress, attended by all the members of the different Science Steering Committees of IGBP Projects, offers a unique opportunity to discuss future scientific directions for international Global Change research. The 3rd IGBP Congress that took place in Banff on June 19-24, 2003, was particularly important because it provided an opportunity to review the new directions for the second phase of the Programme, and to discuss how to best implement them. Therefore, the members of the Transition Teams of several developing IGBP projects, as well as the chairs of the 73 IGBP (or Global Change) National Committees were also invited to attend the Congress.

Many questions were discussed during the five days of intensive work, and it was soon apparent that the second phase of IGBP will be very different to the first. Although disciplinary aspects will remain important, new attempts will be made to broaden the scientific approaches, to integrate scientific knowledge, to better relate the natural and social sciences, and to provide answers that are directly useful to decision makers. Congress participants recognised that the Earth is currently operating in a "no-analogue state", and that it is therefore important to assess the potential disturbances in the future functioning of the Earth System. IGBP must identify the vital elements and functions of the Earth System that can be transformed by human activities, and determine the tolerable and the intolerable domains for humans in the Earth System. The development of new methodologies, and their implementation in international research efforts will be a major challenge for the Programme.

We should of course remember that Earth System science has had a long itinerary during the entire 20th century, from when Wladimir Vernadsky first introduced the concept of the *biosphere* and stated that "there are no stronger chemical forces at the Earth surface than living organisms taken in their totality" [1]. A few decades earlier Svannte Arrhenius had calculated that a doubling in the atmospheric level of carbon dioxide would warm the planet by approximately 5 degrees Celsius [2]. Since these pioneering studies the science and engineering communities have made tremendous progress that has led to a better understanding of many physical, chemical, and biological processes, and allows us today to better assess the future behaviour of the planet in response to human activities.

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Among the milestones of the last fifty years are the development of weather prediction models in the 1950's, the implementation of the first comprehensive climate models in the 1960's, the beginning of the space era with the launch of Sputnik in 1957, and the historical first picture of the Earth taken from space in 1969.At the beginning of the 21st century new questions are on the agenda, for example:

- what is the role of biology in the functioning of the Earth System?
- how important are chemical and biological complexity in the functioning of the Earth System?
- how can societies understand, anticipate, and adapt to the cascading impacts of multiple interacting stresses?

Such questions need to be addressed in an "Earth System context". They require the development of an monitoring capability that captures the "heart beat" of the Earth and provides the basis for Earth System stewardship. Data assimilation and inverse methods applied to the entire Earth System will help exploit new observational data. IGOS[1] and related initiatives to observe the functioning of the Earth System will be encouraged by IGBP. The Earth Summit – Washington, DC, USA, July, 2003 – was an important step in this direction.

The 3rd IGBP Congress recognised that fundamental research remains vital to address societal concerns. By promoting international research devoted to global change, IGBP will maintain a balance between process studies and integrative initiatives, and recognise that the foundation of interdisciplinary research remains the information provided by disciplines. IGBP will thus continue to host a wide spectrum of approaches and studies. At the same time, the Programme must acquire a more exploratory character, and test imaginative hypotheses involving complex potential mechanisms. For example, what are the possibilities that we trigger extreme and abrupt changes? What are the limits of our adaptability? Addressing such ques-

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tions will require a hierarchy of models, ranging from simple conceptual models for exploring ideas to highly detailed models to check process simulations against observational data. Models will become increasingly important tools to help decision-makers in Earth System stewardship.

The Earth System should be viewed as a single system with interactions between natural and social systems. The introduction of the human dimension is a challenge for IGBP, because it involves scientific communities that have not yet interacted extensively and need to find a common language. The task is also complicated because Earth System processes involve global interactions and their impacts, the prospect of irreversible changes, and the long time horizon for the consequences. Methodologies must go beyond equilibrium models and consider non-linear dynamic processes with cascades, phase changes, bifurcations, and abrupt transitions. In any case, we must recognise that human-driven changes are pushing the Earth System into planetary *terra incognita,* and that management options range from merry ignorance to maximum precaution, and from judicious avoidance to systemic regularisation. Earth System models will help us choose between these options.

The new IGBP structure has been developed to facilitate the research objectives of the international community. IGBP will continue to support projects focusing on model components (IGAC[2] for the atmosphere, the GLOBEC[3]-IMBER[4] partnership-for the ocean, and the new land project in development), but at the same time, it will develop projects at the interface of Earth System components (iLEAPS[5] for the land-atmosphere interface, SOLAS[6] for the ocean-atmosphere interface and LOICZ[7] for the land-ocean interface). In addition, several integrative projects or integration mechanisms will be instituted; one of them remains the PAGES[8] project focusing on long-term changes in the Earth System. Exploratory elements of the GAIM[9] task force will be elevated to an integrative activity within the Earth System Science Partnership (ESSP) which, in addition to IGBP, includes WCRP, IHDP, and DIVERSITAS.

New Integrated Regional Studies (IRS) will be developed in different parts of the world. They will provide a conceptual framework for drawing regional information into a coherent global picture. The first IRS will focus on the Asian monsoon region. Fast-Track Initiatives (FTI) will also be initiated, to address specific scientific questions in a more integrated fashion than at the core project level. FTI will be established for well defined periods – most likely two to three years – and will produce seminal papers or 'milestone' books that significantly advance the field. The first five FTIs established by the IGBP-SC focus on the global nitrogen cycle, the role of fires in the global environment, iron fertilisation of the ocean, the establishment of global emission inventories, and the development of an electronic Global Change atlas.

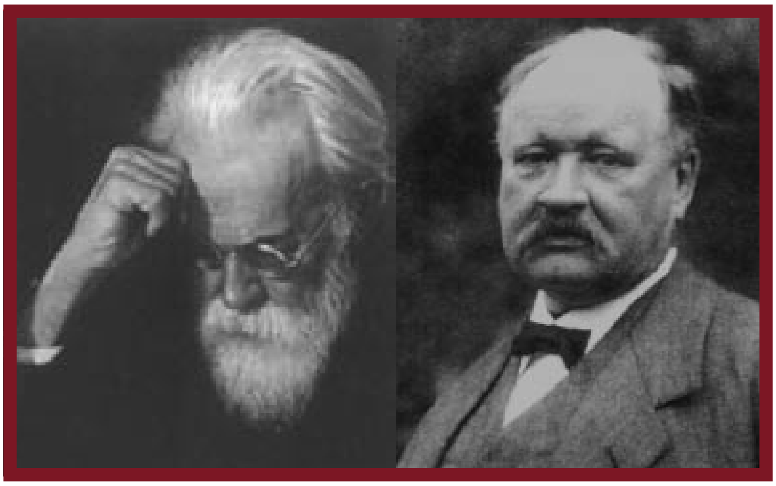

Figure 1: Two pioneers of Earth System science – Wladimir Vernadsky (left) and Svante Arrhenius (right).

> .....we must recognise that human-driven changes are pushing the Earth System into planetary *terra incognita......*

Capacity building is inextricably linked to achieving success in any Earth System Science endeavour. IGBP has a difficult, but important challenge in this regard. The Programme, with the aid of START[10] and the IGBP projects, will enhance scientist-to-scientist, group-to-group, and institution-to-institution collaborations, as well as the participation of developing country scientists in international programmes. Considering new sources of funding including those provided by development agencies will be required.

Finally, as the new IGBP activities progress, we will have to constantly evaluate achievements and ask ourselves: how much ignorance has turned into knowledge as a result of IGBP activities?

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[1] Integrated Global Observing Strategy
[2] International Global Atmospheric Chemistry Project
[3] Global Ocean Ecosystem Dynamics
[4] Integrated Marine Biogeochemistry and Ecosystem Research Project
[5] Integrated Land Ecosystem-Atmosphere Processes Study
[6] Surface Ocean-Lower Atmosphere Study
[7] Land-Ocean Interactions in the Coastal Zone
[8] Past Global Changes
[9] Global Analysis, Integration and Modelling
[10] Global Change System for Analysis, Research and Training

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Science Features

Disturbances and Earth System Dynamics

M. Apps

Disturbances are system phenomena that occur due to the exchange of energy, matter, and/or information amongst system components. Disturbances occur in all parts of the Earth System (terrestrial, atmospheric, and aquatic) at any spatial or temporal scale, as well as in other natural systems (e.g. cosmic supernovae), socio-economic systems (e.g. stock market crashes), and other systems (e.g. crystal formation). Disturbances are most commonly observed at the local- or ecosystem-scale, but disturbances observed at one space or time scale are often linked to perturbations at larger or smaller scales. Improved understanding of disturbance regimes may therefore help us to understand not just the internal dynamics of terrestrial, ocean, atmospheric, and social systems but also the coupling between these Earth System components.

The role of disturbance in ecosystems has been acknowledged for many years, arising in systems as diverse as tropical rainforests and coral reefs [1]. In terrestrial ecosystems disturbances such as fire, insect outbreaks, and storm damage have been observed to play pivotal roles in system dynamics, facilitating the adaptation of forest biomes to changing climatic conditions [2]. At the landscape scale, changing disturbance regimes associated with global change can result in forests switching from atmospheric CO_2 sinks to atmospheric CO_2 sources [3] – or *vice versa* [4], depending on the nature of the disturbance regime change. Recently, there has been increasing interest in incorporating disturbances in Dynamic Global Vegetation Models that seek to simulate biome-scale responses to global change pressures [5,6]. Disturbances have even influenced Kyoto Protocol negotiations, where interest in the pre-1990 conditions and age-class structures of forests explicitly focused attention on both natural and human-induced disturbances. Within the Earth System, local natural or human-induced disturbances may have wide ranging impacts, or conversely, global change processes may induce local disturbances. Gaining improved data for, and predictive understanding of the role disturbances play in Earth System dynamics is therefore an important goal for Earth System research.

Disturbances that occur at discrete points in time and space – abrupt, locally catastrophic events – are especially interesting. Such disturbances evoke immediate responses and rearrangement of resource connections between components of the disturbed system, but also trigger long-term responses and rearrangements. These impacts are highly non-linear and not easily approximated by low-order power series. An example of such response is the stock of organic carbon in a forest ecosystem subjected to a stand-replacing fire, harvest, or insect event (Box 1). The notion of disturbance as a discrete event is of course inherently scale-dependent. What is an event-specific disturbance at one temporal or spatial scale may blur into statistical noise at a much broader scale, or be represented by a smoothly changing state variable at a finer scale. For example, a small mudslide may be locally catastrophic with

BOX 1: Forest stand dynamics illustrating how disturbances can facilitate the adaptation of the system to changing conditions.

In forest stands subject to repeated disturbances, the passage of time may be indexed to stand age (Figure A), and each point on the closed curves of Figure 2 corresponding to a given stand age and stage of stand development. Starting with stand initiation (age zero), young seedlings aggressively compete for establishment and access to life-sustaining resources such as nutrients, light, and water. The successful individuals become increasingly dominant, tending to lock-up and control the site resources as they age, suppressing further competitors, and adaptively modifying their own micro-environment. As these survivors reach maturity, their development typically slows as they shift from aggressive growth to conservation and maintenance of existing structure and resource use. The cycle is typically restarted by a disturbance event that kills off the dominant individuals, releases and redistributes their resources, and provides the opportunity for a new cohort of individual seedlings to exploit the site.

Obviously the new cohort of individuals will not be identical to the original cohort, but may be of the same species and genotypes, and if the external environment has not changed appreciably, the resulting new stand will be very similar. In phase space (see [14] for details), this cyclic behaviour appears as a closed curve (Figure 2A). In detail, successive cycles follow trajectories that always differ to a lesser or greater degree due to fluctuations in both initial and time-dependent conditions. This is shown as the family of green curves in Figure 2B. If however, conditions have changed significantly (for example, climate change), or under different disturbance types that remove or replace the seed stock (for example, silviculture), the re-established stand may be very different (brown curves in Figure 2B), and may even involve a change to a different vegetation type (for example, grass) that is better adapted to the new conditions.

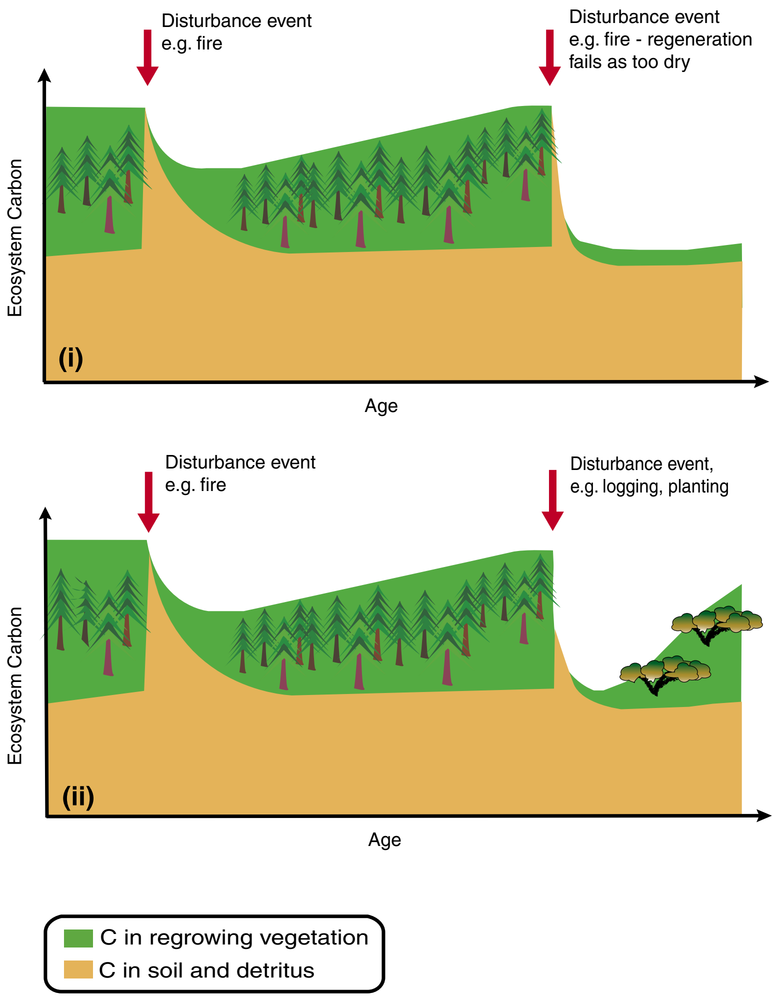

Figure A: Forest ecosystem responses to repeated disturbance. **(i):** Different responses to a similar disturbance due to differences in system condition – for example moisture availability. **(ii):** Different responses to dissimilar disturbances. Disturbance may push system into an entirely new mode – for example with a different vegetation type dominating.

both immediate and long-term consequences for the organisms directly affected, but the impact on the population across the wider landscape is less obvious and contingent on other factors. At these larger scales, statistical indices of the disturbance *regime*, such as the probability distributions of event frequency and severity, are often more useful than the characteristics of individual events.

The Burgess Shales in Field, British Columbia, Canada (less than 100 km from the venue of the 3rd IGBP Congress), contain fossils of life forms that are no longer found on Earth [7,8]. These fossils bear stark testimony to the impact of local catastrophes that occurred some 530 million years ago. The mudslides that preserved these fossils were probably not associated with the global extinctions that occurred around the same time (geologically speaking), but they certainly extinguished the local population. Mudslides were probably not unusual for the topographical and climatic conditions that prevailed here at the time, rather, they were probably a result of randomly fluctuating environmental conditions. In nearby locations however, there is evidence of global extinctions that can be tied to specific disturbance events. For example, less than a few hundred kilometres away in Alberta, the sediments of the Drumheller and Pincher Creek badlands contain the bones of dinosaurs believed to have been extinguished by a catastrophic event 65 million years ago. These sediments also contain a thin layer of iridium-rich dust symptomatic of material of extraterrestrial origin, that links the catastrophe to a meteor impact probably located on the Yucatan peninsula [9]. Whether or not

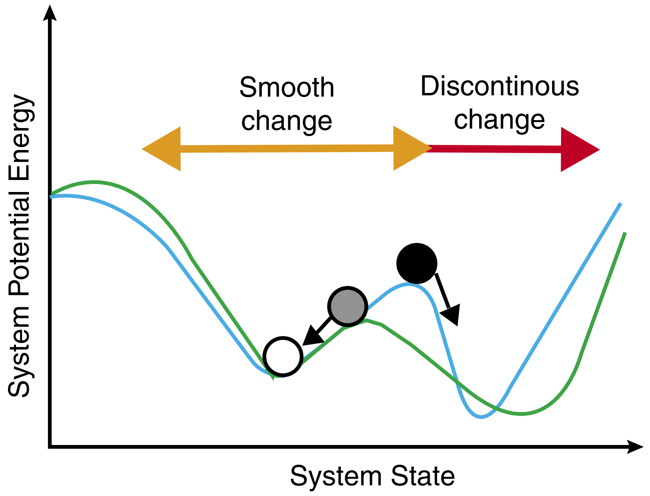

Figure 1: System potential energy surface under prevailing (blue line) and altered conditions (green line). System response when perturbed from initial equilibrium (open circle) is different for small perturbations (grey circle) or larger ones (black circle) relative to the energy surface topography.

the demise of the dinosaurs – as well as that of a large percentage of the planet's mega-fauna – was directly caused by rapid climatic change, a global fireball, or some other combination of phenomena that were triggered by the event [10,11], there is little doubt that the meteor impact was the initiator of these changes.

These examples illustrate the significance of historical contingency: at the scale at which disturbances appear as discrete events, they tend to be relatively infrequent and stochastic in character, but when they act as synchronising agents of large-scale processes their impact can be significant. At these larger scales, the impacts cannot be simply understood in terms of linear, smoothly varying processes. Life on planet Earth today would be very different had the meteorite impact 65 million years ago not occurred. The age of mammals that consequently emerged was probably due to 'contingent fortune' not 'predictable necessity' [7]. We would be unable to predict the present distribution of life without invoking some understanding of the stochastic role of such large-scale disturbances.

Disturbances are intrinsically non-linear processes associated with complex systems that are neither in equilibrium nor at steady state, but rather whose sub-system parts are driven away from such conditions by externally induced changes, giving rise to rich patterns of variation in space and time. The system response to small perturbations may be to return towards an equilibrium state, typically involving a series of oscillations about the lowest accessible energy state (Figure 1). Larger perturbations may however, kick the system into an entirely new mode of operation that better suits the prevailing environmental conditions (Figure 1). Changes in environmental conditions may alter the state-energy response profile (from blue to green line, Figure 1), and thereby also exacerbate or mitigate the effect of the disturbance event. Disturbances and system responses are therefore intrinsically linked to stability and resilience [12], and thus disturbances have been described as agents of 'creative destruction' [13].

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Cyclic behaviour, although not necessarily periodic, is typically associated with repeated perturbations. This is particularly important in biological systems and shows up in evolutionary changes, death-birth-regrowth cycles, and demographic cycles [see Box 1]. Importantly, such cycles need not be, and rarely are, periodic in time. Mortality, mutation rates, and external perturbations follow distribution functions that vary widely with the perturbation processes, and the trajectories in state-space are different after disturbance. However, if the perturbation does induce a large change of state, the new pattern of development may be very similar to the previous one. This 'repetition with a difference' is the result of the reorganisation and redistribution of resources (such as nutrients, energy, and living space), and the restructuring of system components. Where environmental conditions have changed, this reorganisation and restructuring can facilitate adaptation by the redeveloping system. The term 'adaptive cycles' has been coined to describe this property of complex systems [14], leading to a comprehensive theory of stability and resilience in complex systems where repetitive phenomena occur. The trajectory through phase-space for a single cycle of such a system (Figure 2A) may be followed by either subtle changes in trajectory or

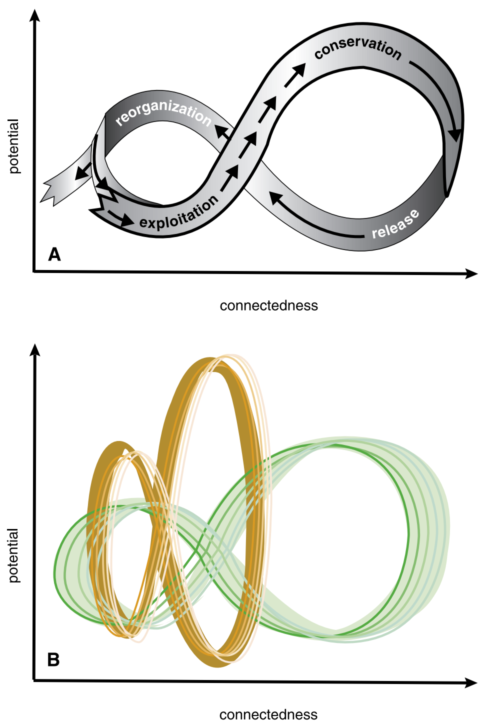

Figure 2: Stylised representation of the adaptive cycle in system potential energy vs connectedness space. **A**: different phases of the adaptive cycle (Redrawn from [14]), **B**: multiple trajectories within the adaptive cycle under small perturbations (same colour lines). Larger perturbations may push system into new mode of operation (different colour lines), with new oscillations within this mode due to small perturbations.

by larger changes (Figure 2B, see example in Box 1).

Disturbances can transmit the effects of small-scale processes to larger ones, and *vice versa*. As a system recovers from a disturbance, it undergoes changes that affect both its structure (for example, population age-structure [3]), and its function within the wider system (for example, nutrient and carbon cycles [15]). As its interactions with its surroundings change, the disturbed system thereby influences the development of its surroundings to a lesser or greater degree. Changes in these influences are greatest when the system is changing most rapidly, focusing attention on the disturbance event and times shortly after it. It is during this re-establishment period of intense competition that the effects of the surroundings (i.e. the environmental conditions) are likely to have their greatest influence on the future dynamics by establishing the winners of this competition. The environmental conditions are, in turn, influenced by the integrated effect of past processes and are reflected in resource availability – for example, soil organic nutrient reservoirs. In this way, the legacy of past events provides constraints for contemporary responses, with the legacy effects that are associated with slowly changing variables tending to constrain the faster processes. At the same time, the small-scale and fast processes provide opportunities for contagious spread of the disturbance to larger spatial scales (e.g. wild fires, insect outbreaks, or the propagation of a crystal from a nucleation point in a super-cooled liquid), the importance of which depends both on the system state and the disturbance itself. In spatial terms, the edge effects associated with the boundaries between recently disturbed and older systems provide discontinuities that may accelerate or retard exchange of information, energy, or mass. Such edge effects are well known to glider pilots who exploit the convection currents set up by differences in albedo (heating) at the edges of cropped fields. This notion has been taken to much larger spatial scales in the study of teleconnection processes that couple state dynamics at spatially separated locations [16]. Because of the role disturbances play in linking processes at different temporal and spatial scales, disturbances must be incorporated in models that attempt to upscale, or downscale, the impacts of global change forces.

Seeking to understand, and predict, the changes in the Earth System under the influence of global change forces, we are increasingly forced away from partial equilibrium and quasi-linear approaches. The complex web of interacting sub-systems, and the non-linearities of these interactions requires us to adopt new systems approaches in which emergent properties and new system states are created. Self-organised criticality is the new way of viewing nature – "perpetually out of balance, but organised in a poised state" [17]. In this view, disturbances play a strong role in the coupling of sub-systems and act as triggers that alter the structure and pattern of these systems in time and space. These structural changes in turn alter the behaviour of these sub-systems, and become imbedded in the dynamics of the larger system. Disturbances, and the long-term response of the affected sub-systems, thus play an integral role in linking across scales of time and space. Can this paradigm help us to understand not just the internal dynamics of the terrestrial, ocean, atmospheric, and social systems but also the coupling between them?

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Earth System science in the Early Anthropocene

J. Finnigan

The human race has entered the Anthropocene – the geological epoch where human influence on the planet is as profound as that of natural forces [1]. However, it is currently not possible to rigorously determine whether or not the human-dominated ecosystem will maintain relative stability or undergo a transition to a new, and possibly less desirable state. This is because the human-dominated ecosystem is highly non-linear and largely unpredictable. While traditional approaches for the analysis of non-linear systems are inadequate for this problem, advances in computer technology are providing new and potentially powerful alternatives. In this article the potential of these advances for tackling the emerging questions in Earth System science are discussed.

The recognition of the advent of the Anthropocene has seen governments around the world advocate the principle of sustainable development or simply sustainability. However, there is no commonly agreed definition of sustainability, much less any real science of sustainability inasmuch as we cannot in general apply rigorous analysis to decide whether a given human dominated ecosystem is likely to maintain its current state or undergo a transition to a different, often less desirable state. This is because most human ecosystems are 'Complex Adaptive Systems' (CAS) [2], whose agents (humans) learn, individually and in groups, adapt their behaviour to their environment, and change it. As such, they are quintessentially non-linear with all the unpredictability this entails.

> ....most human ecosystems are 'Complex Adaptive Systems' whose agents (humans) learn, individually and in groups, adapt their behaviour to their environment, and change it.

The traditional mathematical approach to non-linear problems is to analyse them using coupled differential equations, and substantial advances have been made in this field of 'dynamical systems theory' in the last few decades. We can recognise and characterise attractors in the solution space based on the structure of the equations even though our ability to find particular solutions is limited. However, we are unable to deal with problems with many degrees of freedom. In fact the upper limit is usually two or three! Most problems addressed by classical mathematics have many more degrees of freedom in reality, and we make drastic assumptions to reduce them to low-dimensional models. The most successful technique is the use of equilibrium thermodynamics to replace Avagadro's Number-like clouds of particles with continua. The key to doing this is the very short space and time scales of the inter-particle interactions compared with our scale of interest. But such approaches fail when we have only hundreds or thousands of agents with complex non-linear interactions, so that the laws of large numbers and classical thermodynamics cannot help.

Advances in computer technology have now given us an alternative in 'Agent-based modelling' (ABM). In this approach, the agents in a human ecosystem are represented explicitly as individuals. Their characteristics and the rules by which they interact with the biophysical world and with each other are specified. The person-to-person interactions in the virtual world of the computer generate the emergent behav-

Networks can be classified as regular, homogeneous, or heterogeneous (or scale-free) (Figure 1.) In regular networks each node has the same number of connections. In homogeneous networks the number of connections per node varies, but there is a clear average value. Networks like this can result from randomly connecting nodes. Near the phase transition (Figure 3) they are vulnerable to random removal of links. In heterogeneous networks there is no average number of connections per node. Living networks that grow by accretion often have this dendritic form; they are resilient to random removal of links but vulnerable to a targeted attack that removes a key node.

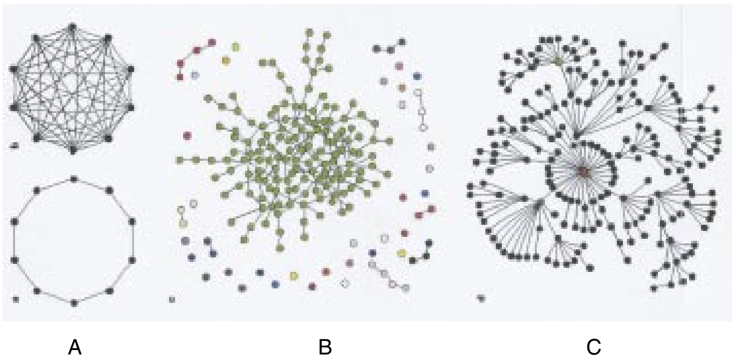

Figure 1: Network types: A – regular, B – homogeneous, C – heterogeneous or 'scale-free'. (Reproduced from S.Strogatz (2001) Nature 410, 268-276; original figure by D. Callaway, Cornell University, NY.)

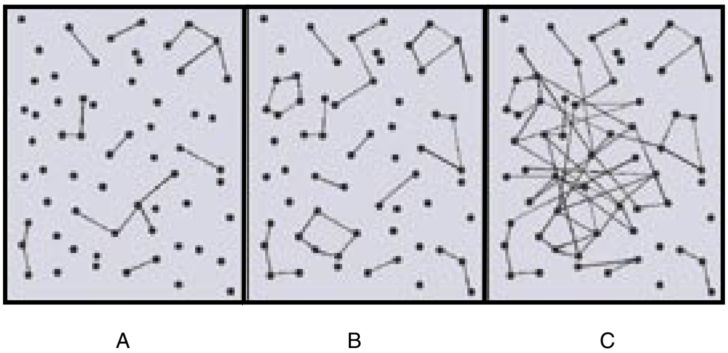

Figure 2: connectivity of random networks. A: trees', B: feedback loops or cycles, C: emergence of a 'giant' structure.

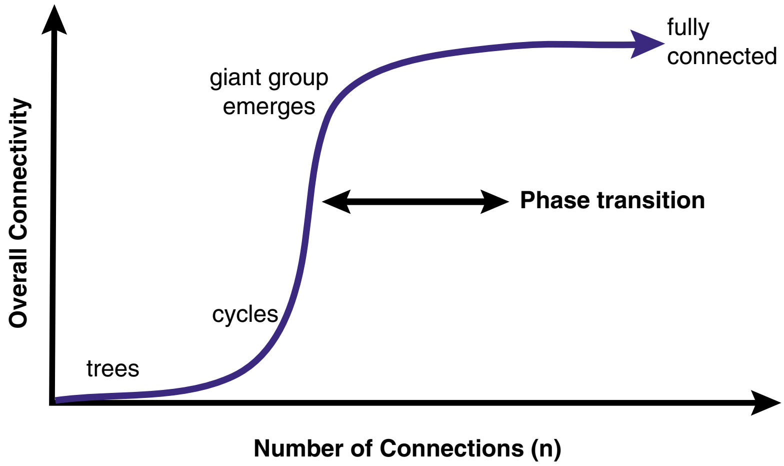

Figure 3: Phase transition and emergence of a "giant" occurs when the number of connections in a random network is about equal to half the number of nodes.

iour of the community of agents, such as its economy and other social attributes. The approach is predicated on the assumption that individual interaction rules can be discovered, tested (for example, by anthropological study), and parameterised whereas at present, we cannot do this for the behaviour of groups. The approach is now being used with considerable success in modelling a variety of human ecosystems [2,3]. Agent based simulations of complex adaptive human systems yield models that are no different in kind from familiar biophysical models – global climate models (GCMs) for example. Like GCMs, agent based simulations are a mixture of well-founded and more speculative parameterisations of component processes. Unlike GCMs, there exist at this stage few common protocols for testing the models or data sets against which to compare them.

Although these ABMs allow us to ask 'what-if' questions about the model societies and their interaction with their physical environment, we need to go much further to answer questions about their sustainability and resilience, either to external influences, or to internally generated forcing. For this we need to perform a proper meta-analysis of the model dynamics, and the burgeoning field of complex system science is beginning to provide tools that permit this. The human, non-human, and inanimate agents in a complex adaptive system can be represented as nodes in a network, and the totality of the system's dynamics represented by the interactions across the links of this network. The nature of the interactions between the agents and the topology of their connections, both affect the system dynamics, and these two aspects of the system place strong constraints on each other. To an extent, what can happen in a system is determined by the interactions irrespective of the topology of the network. Conversely, the topology of the network puts limits on how a system can operate, whatever the nature of the interactions.

So far at least, the effect of complex non-linear interactions has only been studied on simple lattices [4]. In contrast, simple interactions like Boolean decisions (e.g. IF-THEN decisions) or disease transmission have been modelled on random networks whose properties are quite different to regular lattices. Random networks or *graphs* were added to the ambit of graph theory in 1960 [5], jolting this branch of mathematics from its preoccupations with simple grids. The phase change in connectivity of random graphs that occurs at a certain ratio of the number of links to the number of nodes was surprising, and led to the new field of percolation theory. The number of links attached to any node in a random graph follows a Poisson distribution with a clear average number of links per node. However, many natural or human social networks have a more complex structure than random graphs. They are 'scale-free', which means that the probability of the number of links connected to any node follows a power law, leading to a few highly connected and many less connected nodes [6]. We now know that the difference in network topology between random and scale-free graphs has a profound effect on the dynamics of processes occurring across the network [7].

With homogeneous networks, as connections are added to a random set of nodes, we see firstly, the emergence of 'trees', then feedback loops or cycles, and when the number of connections is equal to about the number of nodes, a 'giant' structure appears (Figure 1). At this point the network is already nearly fully connected (Figure 2).

Once a model of a CAS has been translated into network dynamics, it can be studied using a variety of techniques. It can be represented as a cellular automaton (CA), with the interactions across the network links becoming the update rules of the CA, and the topology of the network dictating the cells that are consulted in updating a given cell each time step. Dynamics on networks modelled as CAs exhibit many characteristics of continuum non-linear systems such as attractors. In addition, evolution of cell update rules using Darwinian 'genetic algorithms' is now a standard technique of evolutionary computing, adding behaviour characteristic of living systems to these computer generated mathematical structures.

> .....evolution of cell update rules using Darwinian 'genetic algorithms' is now a standard technique of evolutionary computing......

There has also been a series of recent advances in understanding the origins of network topologies. A sufficient condition for the scale-free node-link distribution of natural networks to emerge is for the network to grow with new nodes linking preferentially to the most connected existing nodes, and/or to nodes recognised as 'fitter' in some sense. Mathematical descriptions of networks evolving in this way have been recognised as analogous to models of quantum gases and exhibit phase changes, that correspond to abrupt and radical changes in network topology [8]. Like the evolution of CA update rules, networks with different topologies can also be evolved by defining fitness functions such as the energy expanded in moving around the network [9], showing that in CASs, both the network structure and the interaction rules may evolve dynamically.

Although this approach is in an early stage, with attention concentrating on relatively simple CASs such as game-theoretic models of competing organisms in 'landscapes' [10], it offers real hope of methods to understand and predict the new problems posed by Earth System science in the 21st century. By using agent-based modelling, we can produce detailed simulations of human ecosystems in silico, that can be tested against reality and shown to exhibit the observed features of these complex adaptive systems. These computer models can be analysed in turn as dynamics on networks, whose behaviour is determined both by the network topology, and by the nature of the interactions between the nodes. At this point formal analysis of the dynamics is possible. Abrupt, hysteretic, and other characteristically non-linear behaviour of the network topology and interaction rules, can be mapped back onto the original human ecosystem, and recognised as changes in social-biophysical interactions – the building blocks of a science of sustainability.

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Non-linearities in the Earth System

by R.A. Pielke Sr, H.J. Schellnhuber, and D. Sahagian

The complex non-linear physical, chemical, and biological interactions among the components of the Earth System are becoming an increasingly important focus in global change research [1]. These interactions between atmosphere, oceans, ice, and land are driven externally by the solar input of heat, and internally by geologic activity and the myriad processes that control the behaviour of each sub-system (Figure 1). Human activity is an integral component of these interactions. At the 3rd IGBP Congress, Banff, Canada, a working group entitled "Development of Earth System models to predict non-linear responses/switches" was convened to review our understanding of this non-linear system. The session built upon an earlier IGBP workshop entitled "Non-linear responses to global environmental change: critical thresholds and feedbacks", held at Duke University, North Carolina, USA, in May 2001. At these meetings, a diverse group of scientists confirmed that each component of the Earth System itself includes complex non-linear feedbacks, in addition to the non-linear interactions between the components. This article draws on the above two meetings to discuss the implications of Earth System complexity for Earth System research, modelling, and prediction.

The complexity of the Earth System's behaviour makes it extremely difficult to accurately forecast the future of the Earth System, and presents a major challenge to the global change research community. New mathematical approaches to assess non-linear behaviour have been explored in recent years to address the problem. Such approaches are taking advantage of advances in the theory of chaotic behaviour and deterministic and stochastic predictability. The goal is to develop techniques for prediction of a system in which many of the components, processes, and thresholds are uncertain or even unknown.

As such, one of the main conclusions of the above-mentioned IGBP meetings was the recognition that the evaluation of key vulnerabilities and sensitivities of the Earth System to human

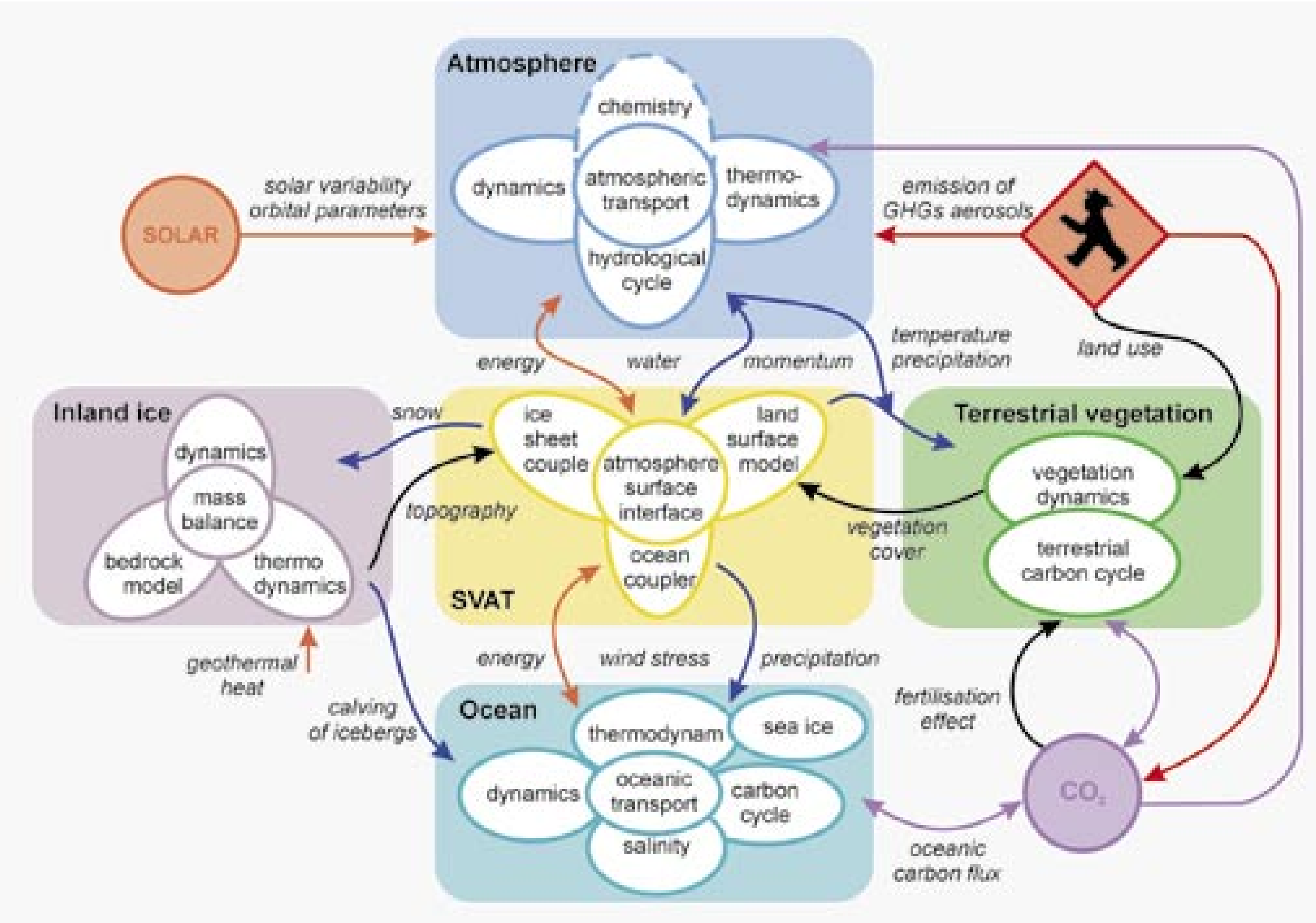

Figure 1: Structure of the CLIMBER-2 model, illustrating the complexity and interactive character of the Earth System [from 1].

and natural perturbation will be of considerable value to policy-makers. Even if skilful forecasts of the behaviour of specific components of the Earth System are not possible, the focus on a vulnerability paradigm permits decision makers to assess the landscape of intolerable domains that exist beyond certain thresholds. These domains can be mapped in "society" versus "natural" phase space, and the various paths by which human civilisation can navigate within the accessible domain, while avoiding intolerable regions, can shed light on the effectiveness of potential global environmental management schemes [2].

The non-linear interactions within the Earth System are on a variety of time and space scales. Abrupt cooling and warming events, for example, are well documented in continental ice cores. Rapid changes in temperature recorded in the cores appear to be associated with changes in fresh water influx into the North Atlantic Ocean, that resulted in circulation changes in the planetary thermohaline ocean circulation [3]. Thus, because the ocean circulation plays a key role in the distribution of the planetary heat budget, fresh water fluxes in the North Atlantic trigger changes in the global climate system. Evidence for very rapid desertification of the Sahara in the mid-Holocene has been found in the geologic record and has been realistically simulated in models of intermediate complexity [4]. The sudden desertification of the Sahara has been attributed to an atmosphere-ocean-vegetation feedback in which the vegetation served to maintain the hydrologic system in the face of decreasing insolation until a critical threshold was passed, after which the vegetation – and the associated hydrology – collapsed suddenly [5]. This latter example demonstrates that vegetation dynamics play an important role in non-linear aspects of the climate system, and must be considered along with atmospheric and ocean processes.

On shorter time scales, irregular variations of the North Atlantic Oscillation, the El Niño Southern Oscillation, and the

Pacific Decadal Oscillation are well documented [6,7,8]. While the reasons for the temporal changes in these climate features are not fully understood, the close coupling between the ocean and the atmosphere has clearly been demonstrated by observations and modelling. Such temporal variations in the Earth System may partly explain the large changes observed in some regional hydrologic and ecological systems during the 20th century. For example, an abrupt change in the annual outflows from African equatorial lakes occurred in 1961, followed by a slow downward trend (Figure 2).

On all time scales, the various non-linear interactions are characterised by drivers and responses that are not proportional. Changes in state are often episodic and abrupt, and multiple equilibria commonly exist. One consequence of such a non-linear system is that forecasts based on current modelling tools should be viewed sceptically. For example, since none of the general circulation models (GCMs) used to project climate change over the next hundred years include all of the important forcings and feedbacks, they should be considered as sensitivity studies rather than forecasts [10]. In Earth System science, climate is not the long term average of weather statistics, but involves the non-linear interactions between the atmosphere, oceans, continental ice, and land surface processes, including vegetation, on all time scales.

Examples of drivers and feedbacks that are typically not accounted for sufficiently in models include land-use change [11], the indirect effect of aerosols [12,13], stratospheric-tropospheric exchanges [14], and vegetation dynamics [15,16]. The ability of clouds to produce precipitation is critically dependent on the available concentrations of cloud condensation nuclei [12,17]. In polluted air masses, clouds rain less and last longer, thus significantly influencing the hydrologic cycle and the radiative forcing of the climate system. Tropical deforestation, and the resultant effect on thunderstorm patterning, alters long-term weather patterns thousands of kilometres from the landscape disturbance [18,19]. Without including non-linear effects such as these, GCM projections of the response of the climate system to increased greenhouse gases are incomplete, and should only be communicated to policymakers with that critical caveat.

As more complete Earth System models are developed – at various levels of complexity [e.g. 4] – one goal is to develop system understanding to the point that the vulnerability of various regions to natural and anthropogenic perturbations can be quantified. Humans are an integral part of this system, hence the interaction of abrupt and extreme events with society is a growing focus of Earth System science [20]. However, unlike other parts of the Earth System, humans can make decisions based on information beyond immediate environmental sensory perception. If Earth System models become more robust, such that their predictions of the environmental impacts of anthropogenic perturbations are considered reliable by the public and policy sector, model results may lead to changes in human behaviour. By doing so, the models themselves alter the system about which they make predictions, although the extent of the alteration of human behaviour on the basis of model results is in itself very difficult to predict. This non-linear feedback loop – that involves the models themselves – can be considered a type of environmental "Heisenberg uncertainty" in which the observer affects that which is observed.

........model results may lead to changes in human behaviour. By doing so, the models themselves alter the system about which they make predictions....

Research to-date has revealed the need to establish the limits to predictability within the Earth System. It has been shown that climate prediction needs to be treated as an initial value problem with chaotic behaviour. This perspective acknowledges that beyond some time period, our ability to provide reliable quantitative and detailed projections of climate must deteriorate to a level that no longer provides useful information to policymakers. Even in the absence of the ability to provide skilful forecasts, there is, however, a critical societal need to identify parts of the Earth System that are particularly vulnerable to environmental variability. As such, the assessment of certain critical components – in the context of the overall non-linear system, may be useful. For example, one critical issue is water resource development, because it is influenced by environmental variability and change, and because it alters the climate system through irrigation, impoundment, draining of wetlands, and deforestation. Such "hot spots" of Earth System vulnerability need to be identified and monitored so that their non-linear interactions with the rest of the Earth System can be understood in support of policy, strategic land use practices, and general water resource planning [21,22].

The issue of uncertainty also needs to be addressed. There are three types of uncertainty to consider: (i) removable cognitive uncertainty – that can be reduced by targeted scientific research; (ii) irremediable cognitive uncertainty – that cannot be reduced even though individual sub-components follow predictable physical laws; this is typical of many heterogeneous non-linear systems; and (iii) voluntative uncertainty – that is fundamentally insoluble because of the "free will" of large numbers of actors [23]. Plotting any path *a priori* through a realm that includes any or all of these uncertainties is impossible, unless one relaxes control so that the path can be refined and corrected while underway. There are numerous small-scale examples that reflect the "fuzzy control" involved in decision-making under uncertainty. Consider the person walking across a crowded plaza or shopping mall, with a destination in sight, but with no clear path to follow. Setting out the correct general direction, the walker must constantly readjust both speed and direction in order to avoid collisions that would produce unknowable, but generally undesirable consequences. In a similar fashion, general strategies involving management of the Earth System can be adopted initially, with the provision that they be readjusted through time in response to numerous factors, including the documentation of cost and benefit, which are unknown *a priori*. This "soft" decision-making involves the existence of leeway, at least a moderate level of responsiveness, and an overall, or panoramic view of the situation so that decisions can be made in the correct "direction" [24]. This bears strongly on national and international policy-making and the "precautionary principle", yet is poorly understood by policy-makers, the public, and even a large portion of the scientific community.

It is also necessary to train future scientists in this new interdisciplinary non-linear Earth System science. These scientists, while retaining disciplinary expertise, need to become fluent in physical, chemical, and biological sciences, as well as in the science-policy interface. The questions that society needs answered must be identified, so that these scientists can undertake appropriate investigations of the non-linear dynamics of the Earth System [25].

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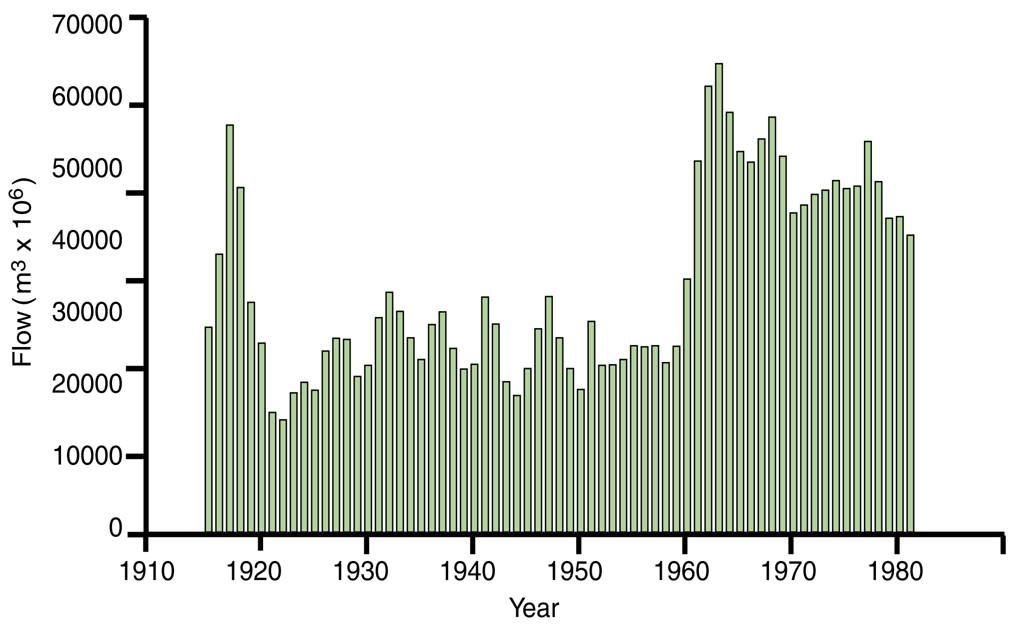

Figure 2: Time series of annual outflows from the African equatorial lakes measured at the Mongala station for the period 1915-1983 showing an abrupt shift around 1961 and a subsequent downward trend [after 9].

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The Changing Role of IGBP National Committees

by J. Gash, C. Nobre, J. Malo and J. Srinivasan

IGBP promotes global change research, has a global mandate, and is based on a global network of scientists. Although IGBP attempts to have a balance of nations on its committees, the unequal distribution of scientists around the world means its committees tend to be dominated by scientists from what is conveniently called the North – that is, the developed world. As an almost inevitable consequence, the research that these committees propose is northern research – research that addresses northern problems from a northern perspective. To overcome this current bias IGBP needs to become more inclusive and more global, in the sense that it must become more accessible to scientists from all nations of the world.

The IGBP Steering Committee recognises that to be truly global IGBP must somehow move away from the rather narrow view of the world as seen from the developed world (the northern perspective), and must develop a more globally inclusive and all-embracing agenda. A first step was to invite the chairs of the IGBP National Committees to participate in the 3rd IGBP Congress, in Banff, Canada. IGBP has about seventy National Committees and recognises this as a major strength that it is determined to build on. The National Committees, and the chairs of the National Committees, are a resource because they are not only a way into the scientific communities of the countries they represent, but are also a way out for the ideas and research-identification of those scientific communities. If IGBP is to be more globally inclusive, including the National Committee chairs in the planning process will be a good start.

North and South Perspectives

IGBP's modus operandi is to gather together the best, or at least some of the most effective, global change scientists. After a series of meetings (in rooms without windows!) these scientists eventually come up with a research agenda, which is then promoted to the rest of the research community and to funding agencies. The problem that arises is that when the members of the group are drawn predominately from the North, the agenda drawn up is likely to be a northern, rather than a global agenda. There is no conspiracy, it is simply that where you are determines what you see. Your point of view depends on just that – your point of view.

The perspective from the North can be very different from the perspective from the South (the developing world). In the North global change is happening slowly. Although temperatures may be slowly rising and glaciers may be slowly retreating, one can still argue about whether the latest flood or drought was a result of climate change, or just the sort of extreme event that should be expected in a stationary time series. In the South the pace of change is fast. The effects of climate change are entwined with the effects of land use change caused by rapid demographic change. Change that includes not just population growth, but also large population movements from rural areas to cities, or into previously uncultivated areas (such as Amazonian rainforest, and savanna, or miombo woodland in southern Africa), as well as AIDS-induced changes in the age structure of entire populations. These changes are both concurrent with, and contributing to, global change.

> "In the South it is difficult to separate the problems of development from the problems of the changing global environment – it is probably not even sensible to try."

However, above all of this is the over-arching and urgent need to eliminate world poverty. The point is that in the South it is difficult to separate the problems of development from the problems of the changing global environment – it is probably not even sensible to try.

IGBP is of course, not a development agency – its role is to foster global change research. But to do that in a complete way it must consider the problems of global change from both northern and southern perspectives. There is no easy or instant way to do this. But the first steps are clear: we must create an awareness of the problem, and change the way we think about and the way we conduct international science. Then we must achieve dialogue and partnerships. The required approach will be different in each case: larger or more-developed countries can offer more opportunities than smaller or less-developed countries. The poorest or smallest countries

Two fictitious examples of collaborative, international field research illustrate the sort of thinking that is needed to make progress in developing a more inclusive IGBP research portfolio. The first example is of well-meaning, enthusiastic northern scientists, with short-term research funding, getting it wrong.

Example 1

1. Northern scientists have an idea for a new land-atmosphere interaction experiment in the South.
2. A workshop is held to bring in more northern scientists.
3. Endorsement is sought from IGBP.
4. IGBP requests a more integrated approach.
5. IHDP socio-economists are invited to collaborate.
6. Short-term funding is obtained.
7. Northern scientists travel to the South and "sell" the project to their southern counterparts.
8. A training programme for PhDs is included.
9. Northern scientists fly in, collect data, and fly out.
10. Data is analysed and research is written-up in the North.
11. Data is distributed to southern scientists.
12. Trained PhDs return to the South.

The second example suggests how the faults of the first example might be overcome:

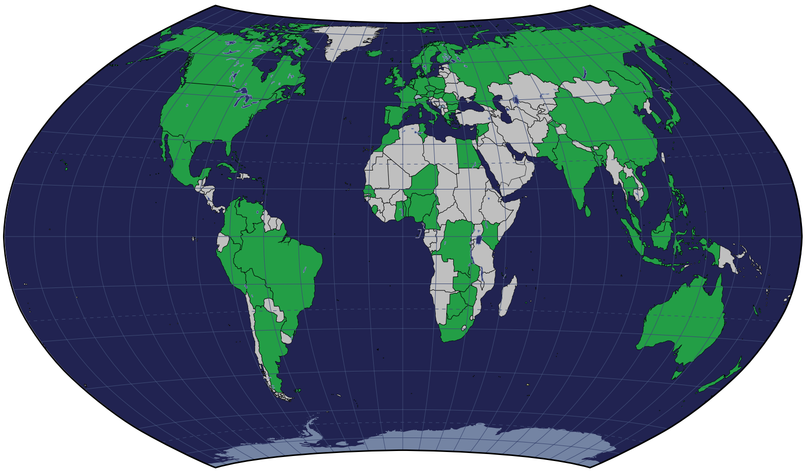
Example 2

1. Southern scientists (natural & social) contact a southern National Committee with a concept.
2. The National Committee identifies interested scientists both in the South and the North; the latter via the northern National Committees.
3. A workshop is held in the South to identify the researchable problems.
4. Key collaborations are identified.
5. Potential North-South and South-South sister institutions are identified.
6. Endorsement is sought from ESSP.
7. Long-term funding is obtained.
8. A capacity-building programme by long-term institutional strengthening is instigated.
9. Data collection is shared through long-term collaboration.
10. A programme of North-South and South-South exchange visits is established.
11. Analysis tools are shared between northern and southern collaborators.
12. Data is analysed and written-up during exchange visit programme.
13. Next experiment planned…..

These are merely examples and every case is different. Certainly, putting ticks in boxes on lists is not a formula for success. The only sure rule is the basic rule of team management: shared project design and shared decision-making leads to shared project ownership, motivation, and commitment. A key difference between the two examples is that the second has long term funding. Research funders are nervous of long-term commitments, but it is possible. There is a role for the International Group of Funding Agencies (IGFA) to influence national agencies to fund networks that will facilitate long-term inter-institutional collaboration.

National Committees

Argentina
Australia
Austria
Bangladesh
Belgium
Benin
Bolivia
Botswana
Brazil
Bulgaria
Cameroon
Canada
Chile
China (Beijing)
China (Taiwan)
Colombia
Comoros
Congo, Democratic Republic of
Cuba
Czech Republic
Denmark
Egypt
Estonia
Finland
France
Germany
Ghana
Greece
Hungary
Iceland
India
Indonesia
Ireland
Israel
Italy
Jamaica
Japan
Kenya
Korea, Republic of
Lebanon
Malaysia
Mexico
Morocco
The Netherlands
New Zealand
Niger
Nigeria
Norway
Pakistan
Peru
Philippines
Poland
Portugal
Romania
Russia
Senegal
Sierra Leone
Singapore
Slovak Republic
South Africa
Spain
Sri Lanka
Sweden
Switzerland
Syria
Thailand
Togo
Tunisia
Uganda
UK
USA
Venezuela
Vietnam
Zambia
Zimbabwe



may not even have the resources and infrastructure needed to enable collaboration to begin. On the other hand, larger countries or those with transitional economies often have sizeable scientific communities, but which are often chronically under-resourced.

The Role of National Committees

IGBP is a non-governmental organisation belonging to the "ICSU family", and is one of a number of international, interdisciplinary scientific bodies that are supported by contributions from various national academies of science. Each national academy is invited by ICSU to form an IGBP (or Global Change) National Committee. The main function of these committees is to act as conduits between national scientific communities and the global IGBP community. These should be two way connections with the twin objectives of (i) making the national scientific communities aware of, and involved in, the IGBP science agenda, and (ii) influencing the IGBP planning process through involvement of a nations' scientists in IGBP meetings and committees. National Committees are thus an important resource because they represent, and are a way into, each nation's global change science community.

To exploit this resource IGBP must raise the profile of National Committees. Initially this is happening via the IGBP NewsLetter and web sites, and via invitations for National Committee representatives to attend IGBP meetings – particularly meetings that take place in a country or region relevant to a given National Committee. These are actions that the IGBP executive are taking, but

> "National Committees are thus a important resource because they represent, and are a way into, each nation's global change science community."

National Committee chairs must also be proactive. They must communicate with each other and contact each other when travelling – that is, they must build a network. They should not be shy of using that network to promote the scientific interests and perspectives of their own scientific communities, nor should they under-estimate the influence of National Committees. At the 3rd IGBP Congress, Will Steffen – Executive Director of IGBP said: "Having the chairs of the National Committees at this meeting was a tremendous success – it has exposed us to a breadth of insight and opinion which we would not otherwise have had. I look forward to working with the chairs of the National Committees and to their increasing the involvement in IGBP."

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The Common Land Model Experience

Within the Earth System the exchanges of energy and materials between the land and the atmosphere have major influences on the biophysical process in both of these system compartments. Modelling these exchanges therefore helps advance the understanding of both within- and between- compartment dynamics of the Earth System. Over the last few years several land modelling groups in the USA have worked together to develop a "Common Land Model" (CLM), to consolidate the best elements of several existing models that consider this land-atmosphere coupling. Many delegates at the 3rd IGBP Congress in Banff, Canada, discussed the difficulty they had experienced in attempting to develop common models, or model components among different scientific groups or communities. To help people deal with these difficulties I describe here the CLM experience and the lessons learnt from this cross-discipline model development and integration endeavour.

Many models have been developed in the past 20 years to simulate various biophysical processes within the biosphere, and many share common components. The CLM derives from the premise that if the common components could be assembled as a "Common Land Model", individual land modelling groups could focus on modelling new aspects without excessive repetition of past efforts. Furthermore, in the spirit of "open source-code" development, users of a CLM could then share the improvements and refinements provided by individual groups to advance modelling capabilities more rapidly.

The CLM effort dates back to the mid-1990s and evolved through workshops and email communications. Participants of the CLM code development and/or beta testing included scientists from the following USA institutions: Center for Ocean-Land-Atmosphere Studies, Colorado State University, Georgia Institute of Technology, Goddard Space Flight Center, NCAR, University of Arizona, and University of Texas-Austin, together with a visiting scientist from China. The initial goal was to provide a framework for a community-developed land component of the National Center for Atmospheric Research (NCAR) Community Climate System Model (CCSM). While the CLM project was initiated in early 1996, no progress was made in the first two years because the initial goal of developing a truly community land model was too ambitious. Initial CLM code was completed in late 1998 by combining the best features of three existing successful and relatively well documented and modular land models: the Biosphere-Atmosphere Transfer Scheme (BATS) [1], the Land Surface Model (LSM) [2], and the land model developed at the Institute of Atmospheric Physics (IAP) in Beijing [3]. This CLM prototype was thus based on the efforts of several motivated and willing modelling groups, rather than the whole modelling community. The necessary pre-condition for CLM development was the willingness of leading modellers to allow free access to their source-code, and to contribute to model integration.

Model integration was followed by four rigorous beta tests using point, regional, continental, and global data-sets [4,5]. The CLM has also been tested in offline simulations, land-atmosphere coupled simulations, and land data assimilations [6]. The land-atmosphere coupled climate simulations [4] showed that compared with the original NCAR LSM, CLM significantly improved the simulation of surface air temperature and the hydrological cycle over land. Furthermore, the extensive testing and refinements of CLM prior to the coupled simulations enabled us to achieve the above improvements without any tuning of CLM in the coupled simulations, which is rare when developing this type of model. Comprehensive CLM documentation is now available [5], as is the CLM code [7].

While the initial CLM effort focused on biophysical processes, attention was also given to the diverse needs of biophysical, hydrological, biogeochemical, and ecological modelling communities. For instance, ten layers of soil and up to five layers of snow are used in CLM (in contrast to 2-4 layers of soil and one layer of snow for a typical land model) to obtain realistic simulations over a range of time scales, and thus be useful for applications such as model-data assimilation of surface properties, and for determining soil temperatures under snow to predict soil respiration. Similarly, recognising the importance of frozen soil in global change research, both soil water and soil ice (in contrast to simply soil water in a typical land model) are predicted at each time step in CLM.

The scaling from point to climate model-grid spacing (typically 100-300 km) is an interdisciplinary and challenging problem. Because of a lack of consensus amongst modellers, this issue was bypassed by defining three logically separate elements: the core single-point model process code, land boundary data, and an interface linking the land model to the atmosphere (including the scaling procedure). Partly because of this separation, the original interface was later replaced by a more sophisticated interface, with little change in other elements, to better facilitate the integration of biophysical, biogeochemical, and dynamic vegetation models. This interface divides each atmospheric model grid cell into land-units, which are then sub-divided into different soil/snow columns. For each column, multiple plant functional types can compete for soil water [7].

CLM was delivered to NCAR in 2000, with NCAR agreeing to take lead responsibility for CLM maintenance and continued improvement that also involves the broader community through the land and biogeochemistry working groups of the CCSM. The letter "C" in CLM now refers to "community", to be consistent with the NCAR convention in naming individual components of the CCSM. It is likely that CLM will not only be the next generation model for the land component of CCSM, but will also be used as the next generation model used by other modelling groups requiring extensive revisions of their current land models. The biophysical core provided by CLM is therefore encouraging other modelling groups (both CCSM and others) to develop new biogeochemical, dynamical vegetation, and carbon cycle components, which are particularly relevant to global change research.

In summary, the CLM effort has been overall a successful endeavour, and some of the lessons for a successful model integration are summarised below. While the sub-grid treatment of land processes is emphasised in CLM, insufficient attention has been paid to the treatment of atmospheric heterogeneity in energy (e.g. solar radiation) and materials (e.g. precipitation). Understanding and representing both atmospheric and land heterogeneities and their interactions present one of the biggest challenges that would benefit from an even broader community effort than the current CLM endeavour.

Although the CLM project also interacted with Japanese and Chinese scientists, to make the CLM effort truly international would require wider collaboration through international projects such as the Integrated Land Ecosystem-Atmosphere Processes Study (ILEAPS) of the IGBP. As it was already too ambitious to achieve a common land model across the entire modelling community of a single country, it is unlikely and probably undesirable to attempt a single international CLM. Rather, several international and interdisciplinary teams should be organised and encouraged to develop different and complementary common models of the Earth System or its components. The legacy of IGBP would be strengthened by the delivery of several common models.

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Lessons Learned

Successful model integration requires:

- A clear need for end product – by model developers or users
- A shared view of critical processes that must be represented in models that couple Earth System compartments
- Contributors willing to provide access to model intellectual property
- Modellers committed to working collaboratively
- Rigorous offline and land-atmosphere coupled testing and model refinement, and reporting of model performance in refereed publications
- Full and accessible documentation of final model
- Free access to model and related datasets amongst model developers and users
- An organisation willing to act as custodian of integrated model and willing to maintain and further develop model that also involves a broader community

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7. URL: http://www.ccsm.ucar.edu/models/

Ecosystem impacts of the world's marine fisheries

It was in the 1990s that fisheries emerged from their sectoral backwaters, and became one of the environmental concerns of the public at large – at least in the developed countries of the world. This transition in public perception, similar to that involving forestry in the 1980s, was probably due to long established trends suddenly generating media events. For example, the revelation of the enormous quantity of 'by-catch' that is discarded by industrial fisheries – around 30 MT/yr, or one quarter of the world marine catch [1], the demonstration that fisheries are "fishing-down marine food-webs" [2] (Figure 1), the reporting of the collapse of Northern cod in Canada [3], and the presentation of first estimates of the subsidies that contribute to maintaining the global fishing effort at three or more times the optimal level [4,5]. These reports were only the tip of a gigantic iceberg: fisheries, an industry that had long operated beyond public scrutiny, emerged, to an amazed public, as worse for ocean health than pollution about which so much is written [6], and fishers, whose daring and ingenuity had for centuries justified the public's romantic view of their profession [7], have become cogs in the high-tech machine that reduces any stock it touches, almost instantly to a shadow of its former self.

The onset of the 21st Century only heightened these concerns. It was demonstrated that present depletions are only accelerating trends that started millennia ago [8], that, contrary to official data suggesting continuous increases, global fisheries catches have been declining since the late 1980s [9], and that modern industrial fisheries do indeed generally require only 15 years or less to reduce the biomass of larger fish, such as cod, or tuna, by a factor of ten. Fishing-down marine food-webs [2] occurs when fisheries, faced with decreasing biomass and catch of large, high trophic level fish (i.e. fish feeding at the top of marine food-chains), target small fish and invertebrates (shrimp, crab, squid) – that is, the prey of the larger fish. In marine ecosystems these 'forage' fish usually consist of

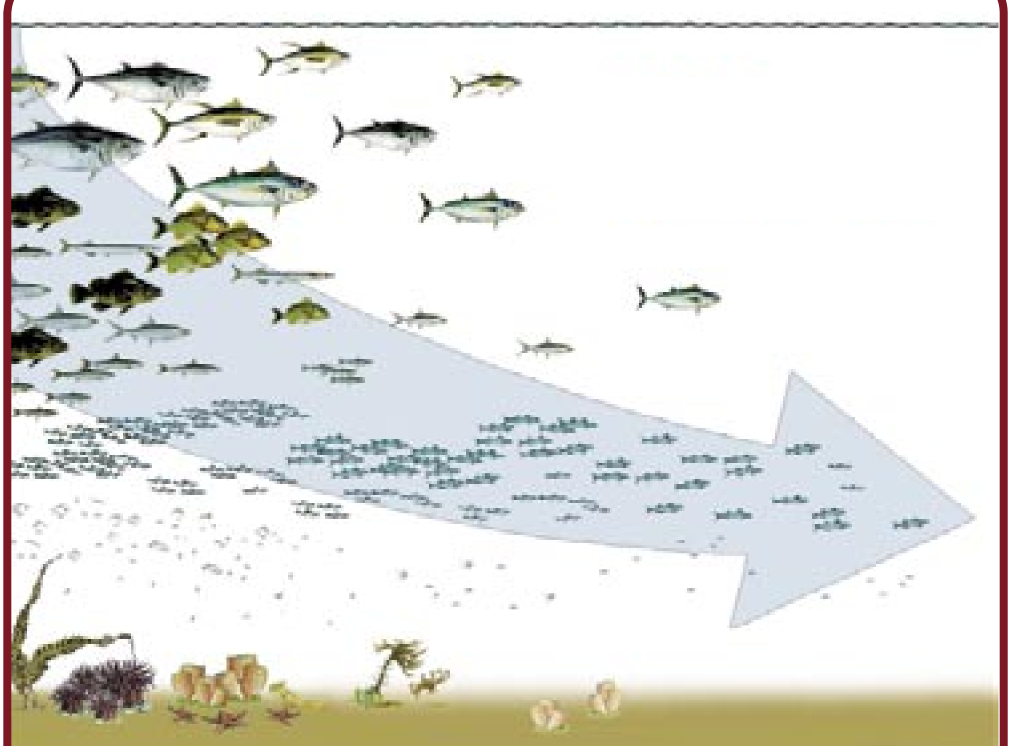

Figure 1: Fishing-down marine food webs, where fisheries, after depleting the large fish at the top of marine food chains (trophic level 3.5-4.5), target the small fish and invertebrates at lower trophic levels. Note the disappearance of biogenic sea bottom structures due to bottom trawling [11].

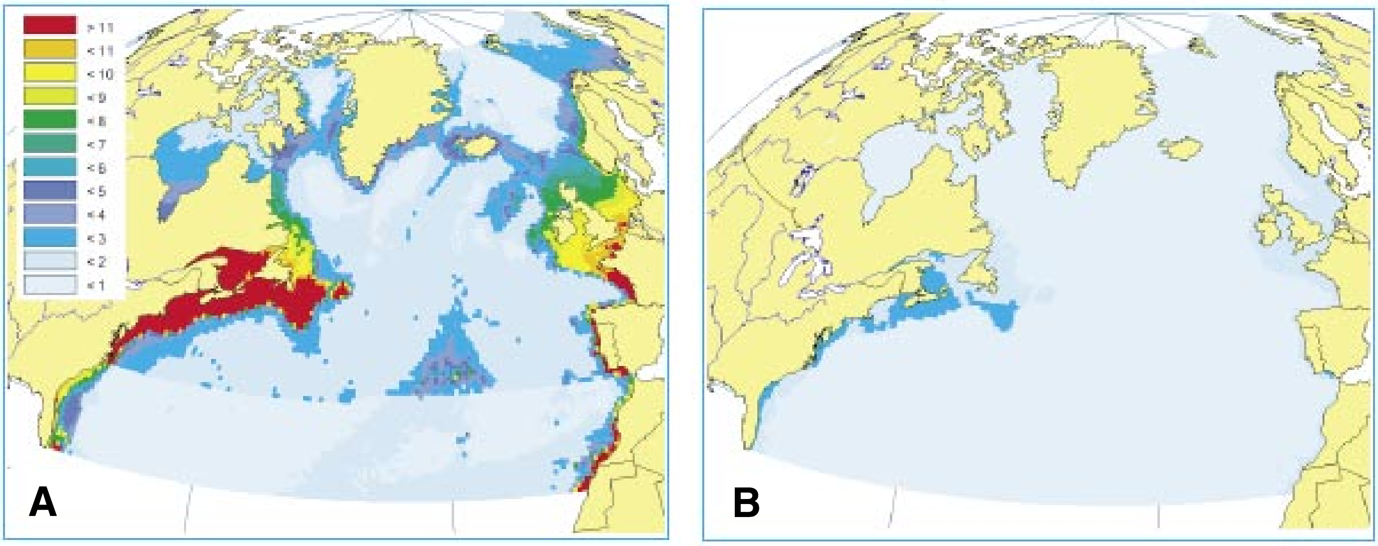

Figure 2: Fisheries-induced change in the biomass (t/km^2) of 'table' fish (trophic levels 3.75 and above) in the North Atlantic. A: 1900, B: 2000 [12].

species of the families *Clupeidae* (herrings, sardines, anchovies), *Scombridae* (mackerels), and *Osmeridae* (capelins and other smelts). These species are commonly referred to as 'small pelagics', because they tend to be only 10-30cm in length and live in open or pelagic waters. Small pelagics tend to form large, dense schools, making them easy to catch with a small expenditure of fuel, especially in comparison with bottom fish, that are typically caught by bottom trawling. Small pelagics play a crucial role in most ecosystems because they transfer energy from plankton to the larger fish and marine mammals. The direct dependence of small pelagics on plankton – itself impacted by environmental fluctuations, often causes their biomass to fluctuate wildly. This has led many fisheries scientists to conclude, erroneously, that fisheries have essentially no impact on small pelagics, and that their abundance is determined overwhelmingly by environmental factors.

Presently the global marine catch of small pelagics is about 40 MT/yr – about one third of the total global marine catch. Most of this catch is used to produce fish meal and fish oil for use in agriculture and aquaculture. The expanding aquaculture industry, especially salmon farming, is increasing the demand for fish meal. This is met in part, by a greater fraction of the mean global fish supply being diverted to aquaculture and away from agriculture, and in part, by increasing the pressure on small pelagics, including species that were previously unexploited. The intense pressure on small pelagics has several consequences, but most notably a depletion of the food base for marine mammals and seabirds. Indeed, this effect is so strong that in many parts of the world it has caused massive declines in seabird and/or marine mammal populations, for example, in the Mediterranean and in the coastal waters of Peru.

Another worrisome aspect of fishing-down marine food-webs is that it involves a reduction in the number and length of the pathways linking food fish and primary producers, and hence causes simplification of food-webs. Diversified food-webs allow predators to switch between different prey as their abundance fluctuates. Given a global decline of 0.05-0.10 per decade in the trophic level of catches, the chance of empirically demonstrating ecosystem-level shortening of food-webs is slim. This does not mean however, that the process is not taking place – a problem similar to the demonstration of global climate change effects.

As the food-webs are simplified by the removal of mid-trophic level components, the large predators find themselves at the top of short, linear food chains that are incapable of buffering environmental fluctuations. This effect, combined with the drastic reduction in the number of year classes in predator populations, makes their overall biomass strongly dependent on annual recruitment. This contributes to increasing variability, and to a lack of predictability in population sizes and hence in catch predictions. The net effect is ironic: it will increasingly look like environmental fluctuations drive fisheries, even where they originally did not.

Among professional fisheries scientists the crisis of fisheries is still often denied. Despite frequent and fashionable references to the need for a methodological 'paradigm shift', many believe, for example, that rigorous quantification of the uncertainties involved in stock assessment, and the communication of the results to fisheries managers in the form of risk assessments, would be largely sufficient to resolve the above-mentioned problems. Our key problem however, is not 'uncertainty', or lack of knowledge by fisheries managers. Indeed, the problem is not even one of management but one of public policy. This refers to the excessive role played, in allocation debates, by the users of fisheries resources vis-à-vis the true owners of these resources: the citizens of the various countries whose fish stocks are pillaged. Resolving this allocation issue requires public involvement, as occurred for example, with the reclaiming of public waters, long perceived to 'belong' to those who used such waters to cheaply dispose of toxic effluents. Indeed, reclaiming the sea from its abusers will be a key task for the 21st century, second only to avoiding the massive climatic change that will result from the increasing emission of greenhouse gases.

Informing the public, and the law-makers who represent them, of the true status of the impact of fisheries on ocean health is however difficult, because a strong lobby exists which, like the Tobacco Institute with regards to the effects of cigarettes, challenges the obvious to maintain the unacceptable. A similar situation prevailed in the 1950s with regards to the indiscriminate use of pesticides. This was challenged by a compelling case, articulated in Rachel Carson's *Silent Spring*, which affected public policy via its public impact [13].

This was the reason why in 1999 the USA-based Pew Charitable Trusts initiated the *Sea Around Us* Project, based at the Fisheries Centre, University of British Columbia, Vancouver, Canada. The project is named after one of Rachel Carson's other books [14] and is devoted to documenting, both for scientific and for lay audiences, the global impact of fisheries on marine ecosystems, and to contributing to policy debates on how to help mitigate those impacts (www.saup.fisheries.ubc.ca). The project differs from many other fisheries projects in that it has a global scope and a long timescale – most of the time series produced range from 1950 to the present, with the result that long-term fisheries trends at basin and global scales can be documented. For example, the project re-evaluated world fisheries catch trends to establish that fisheries catches have been declining since the late 1980s, contrary to statistics published by the Food and Agriculture Organisation of the United Nations [9]. The results of the *Sea Around Us* project are perhaps best illustrated by Figure 2, and are further documented at www.saup.fisheries.ubc.ca. Comments and collaborations are invited.

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People and Events

New Roles and Faces

Co-Chairs of the Joint Health Project

We are pleased to introduce the recently appointed Co-Chairs of the Joint Health Project – Professor Tony McMichael and Professor Ulisses Confalonieri. Initially, the Co-Chairs will be working closely with the DIVERSITAS Secretariat to finalise the project's science and implementation plan.

Tony McMichael is Director of the National Centre for Epidemiology and Population Health at the Australian National University, Canberra, Australia. Tony has undertaken epidemiological studies of occupational diseases, dietary influences on non-communicable diseases, socio-economic health differentials, and environmental health problems. From 1994 until 2001 he was Professor of Epidemiology at the London School of Hygiene and Tropical Medicine, while maintaining his research interests in social epidemiology and the health consequences of conditions at work. From 1993 until 2001 Tony chaired the assessment of health impacts for the UN's Intergovernmental Panel on Climate Change. His recent book – *Human Frontiers, Environments and Disease: Past Patterns, Uncertain Futures* – was published in 2001 by Cambridge University Press.

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Ulisses Confalonieri is a Professor at the National School of Public Health of the Oswaldo Cruz Foundation (FIOCRUZ), Brazilian Ministry of Health, and a Professor at the Federal University in Rio de Janeiro. At FIOCRUZ Ulisses coordinates the Program on Global Environmental Changes and Health (PMAGS). His current research focuses on the influences of climate variability and change, and ecosystem, biodiversity, and land cover changes, on human population health. He has contributed to the reports of the Intergovernmental Panel on Climate Change (IPCC), both as lead author and Review Editor, and is a convening lead author for the Millennium Ecosystem Assessment.

Email: mepaisde@alternex.com.br

New Research Assistant for IMBER

Recently, Claire Hamilton took over from Penny Cooke as Research Assistant to the IMBER Project. IMBER – the Integrated Marine Biogeochemistry and Ecosystem Research project – is a collaboration between IGBP and SCOR (Scientific Committee on Oceanic Research).

Claire is based at the National Institute of Water and Atmosphere, in Hamilton, New Zealand, with Julie Hall, Chair of the IMBER Transition Team.

Email: c.hamilton@niwa.co.nz

New Science Editor at IGBP Secretariat

Bill Young has started recently at the IGBP Secretariat in the role of Science Editor. He will be responsible for the Global Change Newsletters and the IGBP Science Series. Bill is on secondment for three years from CSIRO Land and Water, Australia, and comes with a background is in river system science and water resource management. He is editor and lead author of the recently published book *Rivers as Ecological Systems: the Murray-Darling Basin*, and is a member of the World Bank's Environmental Flow Advisory Team funded by the Bank Netherlands Water Partnership Program.

Email: bill@igbp.kva.se

IGBP and Related Global Change Meetings

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

GLOBEC:2nd Planning meeting of the GLOBEC regional activity on Ecosystem Studies of SubArctic Seas (ESSAS)

31 October -01 November, Seattle, USA

Contact: George Hunt, glhunt@uci.edu

The CGIAR Challenge Program on water and food Baseline Conference

02-06 November, Nairobi, Kenya

Contact: http://www.waterforfood.org/firstAnno.asp

DIVERSITAS: DIVERSITAS Scientific Steering Committee Meeting

03-05 November, Mexico City, Mexico

Contact: DIVERSITAS Secretariat, diversitas.web@icsu.org

GLOBEC: GLOBEC-CLIOTOP (large Pelagics)

04-07 November, Sete, France

Contact: Olivier Maury, omaury@sfa.sc

30th International Symposium on Remote Sensing of Environment

10-14 November, Honolulu, Hawaii

Contact: Conference email, irse@email.arizona.edu or http://www.symposia.org/

WCRP: Final Conference on the WCRP ACSYS Project

11-14 November, St. Petersburg, Russia

Contact: WCRP Secretariat, dwcrp@gateway.wmo.ch

START: Young Scientists 1st International Global Change Conference

16-19 November, Trieste, Italy

Contact: Amy Freise, afreise@agu.org or Kristy Ross, kristy@crg.bpb.wits.ac.za

START/GCP: Training Workshop on South China Sea Regional Carbon Pilot Project

16-28 November, Chung-li/Kaoshiung, Taiwan

Contact: Eric Odada, eodada@uonbi.ac.ke or http://www.sarcs.org

GEOHAB Open Science Meeting

17-20 November, Lisbon, Portugal

Contact: Ed Urban, SCOR, scor@jhu.edu

START: 17th START Scientific Steering Committee Meeting

19-22 November, Trieste, Italy

Contact: Chavonne Stallard, cstallard@agu.org

SPACC Workshop on Long-term Dynamics of Small Pelagic Fish and Zooplankton in Japanese waters

TBA, Tokyo, Japan

Contact: Juergen Alheit, juergen.alheit@io-warnemuende.de or Takashige Sugimoto, sugimoto@ori.u-tokyo.ac.jp

GCTE: GCTE Symposium

01 December, Morelia, Mexico

Contact: Rowena Foster, Rowena.Foster@csiro.au

GECAFS/GLOBEC/IAI-EPCOR Workshop on Environmental Uncertainty and Information Flow in Fisheries Management in the Humboldt Current System

01-02 December, Guayaquil, Ecuador

Contact: John Ingram, jsii@ceh.ac.uk or Manuel Barange, m.barange@pml.ac.uk

Transition in Agriculture and Future Land Use Patterns

01-03 December, Wageningen, The Netherlands

Contact: Floor Brouwer, F.M.Brouwer@LEI.DLO.NL

GCTE, LUCC: LAND Open Science Meeting "Global Change and the Terrestrial Human Environment System" (Land Core Project)

02-05 December, Morelia, Mexico

Contact: Dennis Ojima, dennis@nrel.colostate.edu, dennis@sacc harum.nrel.colost or Victor Jaramillo, luque@ate.oikos.unam.mx or http://www.oikos.unam.mx/landOSC/ or http://cuencas.oikos.unam.mx/landOSC

START: START Pan-Africa Regional Committee Meeting (PACOM)

04-06 December, Guayaquil, Ethiopia

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

IGBP, SCOR: SCOR/IGBP Oceanographic Data Management

08-10 December, London, UK

Contact: Ed Urban, scor@jhu.edu

START START Oceania Committee Meeting

10 December, Wellington, New Zealand

Contact: Kanayathy Koshy, koshy_k@usp.ac.fj

APN Steering Committee Meeting

11-12 December, Wellington, New Zealand

Contact: Yukihiro Imanari, yimanari@apn.gr.jp

Water Resources in South Asia: An Assessment of Climate Change-associated Vulnerabilities and Coping Mechanisms Year-End Project Meeting

16-18 December, Kathmandu, Nepal

Contact: Amir Muhammed, amir@nu.edu.pk

Global Change Impact Assessment for Himalayan Mountain Region for Environmental Management and Sustainable Development Project Meeting

18-20 December, Kathmandu, Nepal

Contact: Kedar L. Shrestha, klshrestha@wlink.com.np

International Colloquium on LUCC Contribution to Asian Environmental Problems

19-21 December, Bogor Agricultural University, Indonesia

Contact: Dr. Ernan Rustiadi, ernan@indo.net.id

2004

SPACC Workshop: Characterizing and comparing the spawning habitats of small pelagic fish

12-13 January, Concepcion, Chile

Contact: Carl van der Lingen, vdlingen@mcm.wcape.gov.za or http://www.pml.ac.uk/globec/Structure/RegProgs/SPACC/concepcion.htm

SPACC Meeting: Spawning habitat quality and dynamics and the daily egg production method

14-16 January, Concepcion, Chile

Contact: Leonardo Castro, lecastro@udec.cl or http://www.pml.ac.uk/globec/Structure/RegProgs/SPACC/concepcion.htm

SPACC Executive Meeting

17-18 January, Concepcion, Chile

Contact: GLOBEC IPO, globec@pml.ac.uk or http://www.pml.ac.uk/globec/Structure/RegProgs/SPACC/concepcion.htm

International Workshop on Global Change, Sustainable Development and Environmental Management in Central Asia

20-22 January, Tashkent, Uzbekistan

Contact: Svetlana Nikulina, svetlana.nikulina@envp.uzsci.net

GLOBEC: UK-GLOBEC Open Meeting

TBA, London, UK

Contact: Phil Williamson, p.williamson@uea.ac.uk or GLOBEC IPO, globec@pml.ac.uk

IGBP: 19th SC-IGBP Meeting (5 March, joint session with WCRP-JSC)

03-06 March, Moscow, Russia

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

WCRP: WCRP-JSC Meeting

01-06 March, Moscow, Russia

Contact: WCRP Secretariat, dwcrp@gateway.wmo.ch

GLOBEC: Meeting of ICES Working Group on Modelling Physical-Biological Interactions (WGMPBI)

10-11 March, Barcelona, Spain

Contact: Celia Marrase, celia@icm.csic.es

IHDP: 11th SC-IHDP Meeting

22-24 March, Bonn, Germany

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

IOC-SCOR-GLOBEC Symposium on 'Quantitative Ecosystem Indicators for Fisheries Management'

31 March -03 April, Paris, France

Contact: Philippe Cury, curypm@uctvms.uct.ac.za or Villy Christensen, v.christensen@fisheries.ubc.ca or http://www.ecosystemindicators.org/

4th World Fisheries Congress, Reconciling Fisheries with Conservation: The Challenges of Managing Aquatic Ecosystems

02-06 May, Vancouver, Canada

Contact: http://www.worldfisheries2004.org/

12th Annual Scientific Conference: International Boreal Forest Research Association

03-07 May, Fairbanks, Alaska

Contact: http://www.lter.uaf.edu/ibfra/default.cfm

Advanced Institute on Vulnerability to Global Environmental Change

03-21 May, Laxenberg, Austria

Contact: Sara Beresford, sberesford@agu.org

GLOBEC: ICES/GLOBEC CCC Working Group Meeting

07-10 May, Bergen, Norway

Contact: Ken Drinkwater, drinkwater@mar.dfo-mpo.gc.ca

After a decade of research, the GCTE and LUCC projects are working together to develop an integrated research agenda under the new LAND project. The goal is to build on the knowledge generated by these projects in order to elucidate the ecological and social responses to changes and feedbacks in the terrestrial biosphere.

Open Science Conference on

Global Change and the Terrestrial Human-Environment System

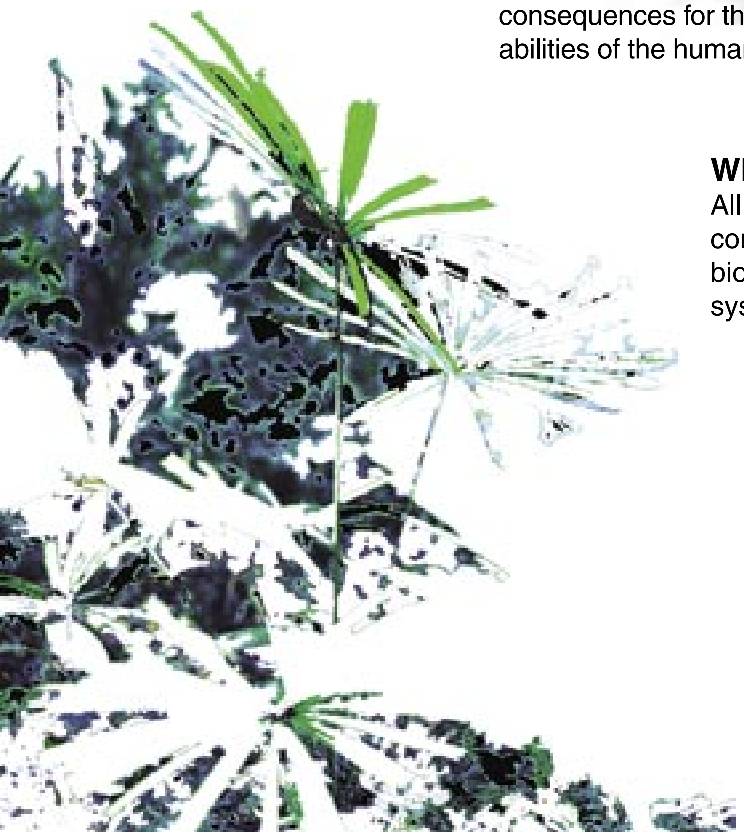
2-5 December 2003, Morelia, MEXICO

Conference Goals:

(i) To present the state-of-the art science on a number of research areas dealing with global change and the terrestrial biosphere with an emphasis on integrative projects addressing the coupled biophysical-human system.

(ii) To provide input into the development of the research agenda that will steer the new LAND project. The new project will be launched in early 2004 after feedback from the Conference has been taken into consideration.

(iii) To stimulate the scientific community to develop more integrative research on issues related to biogeochemical cycles, disturbances, and biodiversity under global change, with attention to consequences for the delivery of ecosystem services and vulnerabilities of the human-environment system.



Who should attend?

All scientists with an interest in understanding components or the totality of the terrestrial biosphere as a coupled biophysical-human system.

Further information and contact details see the websites of GCTE and LUCC:

GCTE: http://www.gcte.org

LUCC: http://www.geo.ucl.ac.be/LUCC/lucc.html

GLOBEC ICES-GLOBEC Symposium on 'The Influence of Climate Change on North Atlantic Fish Stocks'

11-14 May, Bergen, Norway

Contact: Harald Loeng, harald.loeng@imr.no or http://www.imr.no/2004symposium/

Quadrennial Ozone Symposium

01-08 June, Kos, Greece

Contact: Christos Zerefos, ozone2004@geol.uoa.gr

SOLAS: SOLAS SSC Meeting

3-5 June, Bergen, Norway

Contact: Casey Ryan, casey.ryan@uea.ac.uk

CLIVAR 2004: 1st International CLIVAR Science Conference

21-25 June, Baltimore, MD, USA

Contact: CLIVAR, info@clivar2004.org or http://www.clivar2004.org/

PAGES: PAGES SSC Meeting

16-20 July, Nairobi, Kenya

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

35th COSPAR Scientific Assembly and Associated Events

18-25 July, Paris, France

Contact: COSPAR Secretariat, cospar@cosparhq.org

SPARC General Assembly

01-06 August, Victor, BC, Candad

Contact: N McFarlane, norm.mcfarlane@ec.gc.ca, or http://sparc.seos.uvic.ca

Bjerknes Centenary 'Climate Change in High Latitudes'

01-03 September, Bergen, Norway

Contact: Bjerknes Centre, conference2004@bjernes.uib.no or Beatriz Balino, beatriz.balino@bjerknes.uib.no or http://www.bjerknes.uib.no/conference2004/

IGAC: 8th International Global Atmospheric Chemistry Conference

04-09 September, Christchurch, New Zealand

Contact: Kim Gerard, kim@conference.co.nz or http://www.IGAConference2004.co.nz

SOLAS: 1st SOLAS Open Science Conference

13-16 October, Nova Scotia, Canada

Contact: Daniela Turk, solas@dal.ca

2004 Annual Conference of New Zealand Coastal Society. Incorporating a LOICZ workshop in association with New Zealand IGBP National Committee. The Impact of Major Dams, Diversions and Water Abstraction on Coastal Sedimentation in New Zealand

18-20 October, Dunedin, New Zealand

Contact: http://www.coastalsociety.org.nz/conference2004.html

6th International Symposium on Plant Responses to Air Pollution and Global Changes: from Molecular Biology to Plant Production and Ecosystem

19-22 October, Ibaraki, Japan

Contact: Luit J. De Kok, l.j.de.kok@biol.run.nl or http://apgc2004.en.a.u-tokyo.ac.jp/, r.battarbee@ucl.ac.uk

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GLOBAL IGBP CHANGE

EXECUTIVE DIRECTOR

of the International Geosphere-Biosphere Programme

In the near future the International Council for Science (ISCU) expects to seek applications for the position of Executive Director of the International Geosphere-Biosshpere Programme (IGBP). IGBP is an international research programme that deals with the causes and effects of global change, and is organised under the aegis of ICSU. A position description and selection criteria are currently being finalised. The advertisement for the position will soon be posted on the IGBP web site (www.igbp.kva.se) and will be published in leading scientific journals.

It is anticipated that an appointment for a three year term will be made in the first quarter of 2004.

EXECUTIVE OFFICER

for the

Integrated Land Ecosystem – Atmosphere Processes Study

of the

International Geosphere-Biosphere Programme

Applications are invited for the position of Executive Officer for the Integrated Land Ecosystem – Atmosphere Processes Study (iLEAPS) of the International Geosphere-Biosphere Programme. iLEAPS is a new international project that will research the causes and effects of global change on linkages between land ecosystems and atmosphere processes. The iLEAPS International Project Office (IPO) will be based at the University of Helsinki, Finland. The key iLEAPS research questions are:

- How do interacting physical, chemical, and biological processes transport and transform energy, momentum, and materials through the land-atmosphere system?
- What are the implications for the Earth System?
- How did the land-atmosphere system function under pre-industrial conditions, and how are human activities influencing system functioning?
- To what extent does vegetation determine its own physical and chemical environment at various temporal and spatial scales?

Under the direction of the Scientific Steering Committee of iLEAPS, the Executive Officer will be responsible for guiding the development and implementation of iLEAPS. In particular, the Executive Officer will:

- Initiate and coordinate iLEAPS activities in collaboration with the Scientific Steering Committee and the wider iLEAPS community.
- Contribute to the scientific coherence of iLEAPS.
- Synthesize and publish key iLEAPS research.
- Widely represent iLEAPS and communicate its findings.
- Assist in raising project funds and be accountable for iLEAPS IPO finances.
- Supervise the scientific, communication, and administrative staff of the IPO (3-5 persons) and liaise as required with the University of Helsinki.

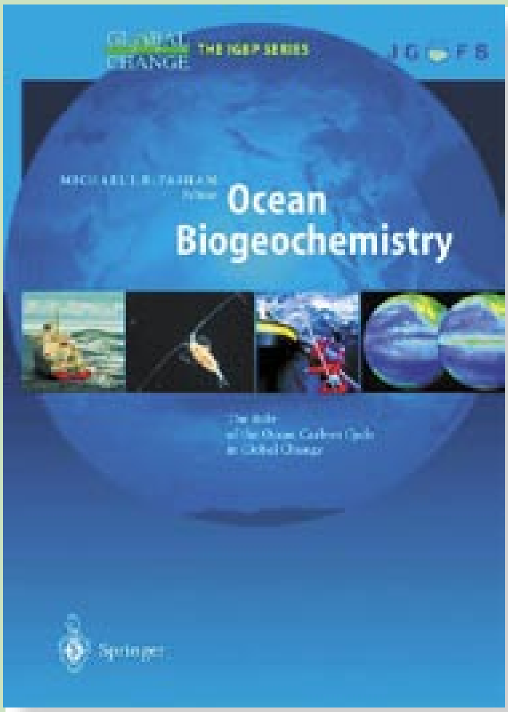
The successful candidate will:

- Have a distinguished research record in global change science.
- Be knowledgeable about the international global change research effort.
- Be experienced in scientific management, and have the skills and ability to lead a broad scientific community distributed around the world.
- Be prepared to undertake extensive international travel.
- Possess a full command of written and spoken English. (Knowledge of other languages would be an advantage).

The appointment will be for a 5 year renewable term, based at the University of Helsinki, Finland. The appointment will be made in the first half of 2004, or as soon as possible thereafter. The salary is negotiable, but will be in accordance with Finnish standards, and will take due account of the experience and qualifications of the successful candidate.

Letters of application together with a curriculum vitae including a publication list and letters from three referees should be received no later than 30 November 2003 by Professor Markku Kulmala either by post at the Department of Physical Sciences, University of Helsinki, PO Box 64, FIN-00014 Helsinki, Finland, or by email at markku.kulmala@helsinki.fi.

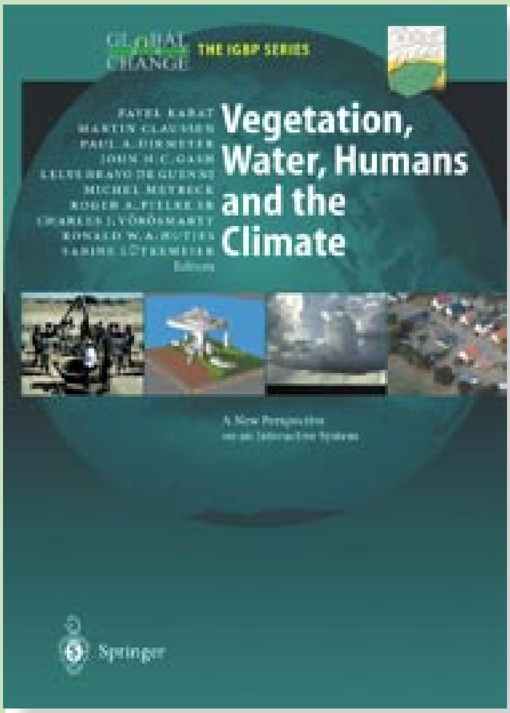
Further information on the position and on iLEAPS in general can be obtained either from Professor Markku Kulmala, ph +358-40-5962311 or from Dr Almut Arneth, Max Planck Institute for Meteorology, ph +49-41173132, email arneth@dkrz.de. Information on IGBP and iLEAPS can also be found at www.igbp.kva.se or www.atm.helsinki.fi/ILEAPS.



Ocean Biogeochemistry

MJR Fasham (Ed.)

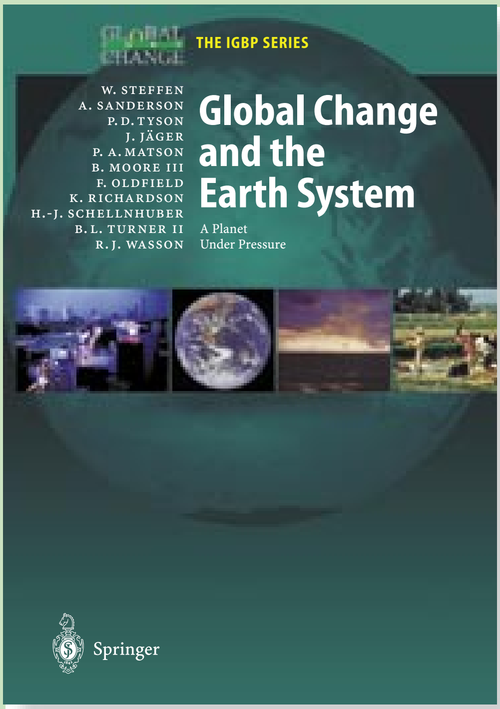
Presents an overview of the role of the ocean carbon cycle in global change, based on one of the largest multi-disciplinary studies of the oceans ever carried out. It covers air-sea exchanges of CO_2, the role of physical mixing, the uptake of CO_2 by marine algae, the fluxes of carbon and nitrogen through the marine food chain, and the subsequent export of carbon to the depths of the ocean.



Vegetation, Water, Humans and the Climate

P Kabat, M Claussen, PA Dirmeyer, JHC Gash, LB de Guenni, M Meybeck, CJ Vörösmarty, RWA Hutjes and S Lütkemeier S (Eds.)

Describes the interactions between the terrestrial biosphere and the atmosphere via the hydrological cycle, and their interactions with human activities. Measurements from field experiments are complemented by modelling studies simulating flows and transport in rivers, coupled land-cover and climate, and Earth System processes. The impact of humans on river basins is discussed, and a discussion of environmental vulnerability and methods for assessing the risks associated with global change is included.



Global Change and the Earth System: A Planet Under Pressure

W Steffen, A Sanderson, PD Tyson, J Jäger, A Matson, B Moore III, F Oldfield, K Richardson, H-J Schellnhuber, BL Turner II, RJ Wasson (Eds.)

This book presents our current understanding of the Earth's environment as a single, integrated system. It is based on a decade of IGBP and related research. It explores the functioning of the Earth System before humans, and the ways in which human activities have grown to cause changes that reverberate through the System. The book also considers the new science needed to tackle emerging scientific questions.

IOC-SCOR-GLOBEC Symposium

GLOBAL IGBP CHANGE

Quantitative Ecosystem Indicators for Fisheries Management

31 March – 3 April 2004

UNESCO Headquarters, Paris, France.

Objectives

This Symposium will the support scientific aspects of using indicators for an ecosystem approach to fisheries. It aims to review existing indicators and develop new indicators reflecting the exploitation and state of marine ecosystems.

Themes

- Indicators for an Ecosystem Approach to Fisheries
- Evaluating, Implementing, Communicating, and Using Indicators

Conference details: http://www.pml.ac.uk/globec/main.htm

GLOBEC

Scientific Committee on Oceanic Research

GLOBAL CHANGE NEWSLETTER

GLOBAL IGBP CHANGE

www.igbp.kva.se

IGBP's mission is to deliver scientific knowledge to help human societies develop in harmony with Earth's environment. The Global Change NewsLetter serves its readers as a forum for up-to-date information on IGBP science, programmatic development, people and events. Published quarterly since 1989, the NewsLetter is available free-of-charge from the IGBP Secretariat.

Note to contributors

"Science Features" should be balanced between solid scientific content, and appeal for the broad global change research and policy communities. Articles should be 800 to 1500 words in length, and be accompanied by one to three figures or photographs (colour or black and white).

Contributions for "Discussion Forum" should be 500 to 1000 words in length and address a broad issue in global change science. A "Discussion Forum" article can include up to 2 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 Newsletter, or relating to a specific global change issue. Please include name 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.

Figures must be either original and unpublished, or if previously published, the authors(s) must have obtained permission from the original publishers to re-use the figure. In the latter case, an appropriate credit must be included in the figure caption.

If you have queries regarding image quality for the Global Change NewsLetter please contact John Bellamy.

Email: john@igbp.kva.se

Deadlines for 2003 – 2004

Issue	Deadline for material
December	3 November 2003
March	2 February 2004
June	3 May 2004

Send contributions or correspondence by email to the Editor, Bill Young:

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GLOBAL CHANGE NEWSLETTER

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Technical Editing by John Bellamy and *Bergs Grafiska*

Full NewsLetter and individual articles can be downloaded in pdf format from:

http://www.igbp.kva.se

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E-mail: bill@igbp.kva.se

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