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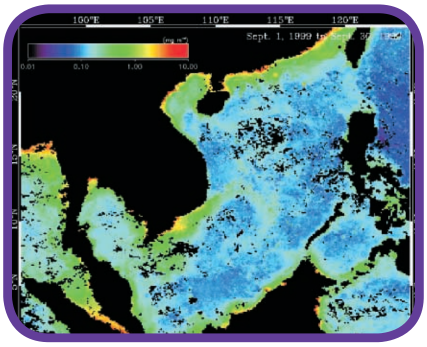
Farewell to BAHC

After more than a decade of exciting and important science, IGBP's BAHC project has now come to an end, although its science will live on in a variety of projects in IGBP II (p22). One of BAHC's major achievements was demonstrating the important role of the biosphere in Earth System dynamics. In the first Science Feature, Andi Andreae describes two crucial aspects of biosphere-atmosphere interactions, and looks ahead to future research in this field in IGBP (p2).



The other Science Features bring you articles from right across the spectrum of IGBP research. Arthur Chen explains how damming rivers can have widespread effects in coastal systems (p 7), and Gregory Beaugrand takes us further offshore to see how marine ecosystems are being affected by climate change (p11). Lastly (p 17), Marisa Montoya gives a fascinating overview into how palaeo- and modelling studies can work together to provide insights into future conditions on Earth.

from page 2

Integration

The sustainability theme is continued in the Integration section where we outline the ESSP's contribution to the World Summit on Sustainable Development (WSSD) earlier this year.

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Humanity: passenger or pilot on spaceship earth?

by Meinrat O. Andreae

In the second half of the 20th century, when humans were able for the first time to see the Earth as a sphere suspended in space, they acquired a new perspective of their home planet. The view from space gave a sense of unity, with oceans, clouds, deserts, forests, and even some signs of human activity all being part of one Earth System. It is therefore no coincidence that the image of the "Spaceship Earth" entered the public mind at the same time that the scientific paradigm of the Earth System evolved, which became the fundamental concept underlying the international global change programmes. For all but the last 100-200 years of human history, humanity was clearly only a passenger on Spaceship Earth. But now, humankind has stepped out of its passenger seat and is wrestling the previous "pilots" for control of the ship. This seems a dangerous course of action, as long as we don't know how the craft responds to perturbations, how the controls are wired, and what all the indicators signalling change are really trying to tell us.

The central role of the biosphere in controlling conditions on Spaceship Earth stands out clearly when we look at the chemical composition of the atmosphere, where major and minor gases show a composition very far from chemical equilibrium, a condition that could not persist long without life's influence. The history of climate and atmospheric composition as recorded in ice cores reveals a tight coupling between biogenic trace gases in the atmosphere and global climate [1], suggesting that the biota and their geophysical and geochemical environments are linked through strong and complex feedbacks. The first decade of IGBP has identified some of these feedbacks and teleconnections, and at the same time made it clear that Global Change research in the next decade will require even broader integration to enhance our understanding of the Earth System. In this article, I will provide some examples of the linkages between biological activity, atmospheric constituents, and climate, and discuss how human activity is perturbing the natural feedbacks. Based on this discussion, I also make some suggestions for possible research directions within an integrated land-atmosphere-hydrosphere project (Box).

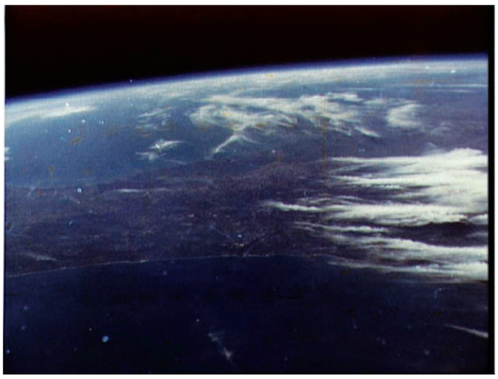

Figure 1.
View of Earth taken by Astronaut John Glenn during his Mercury MA-6 spaceflight, 20 February 1962. Photo: NASA

Biota, aerosols, clouds, and climate

In 1987, we proposed a biosphere/climate feedback loop in which marine phytoplankton emits a volatile sulphur-containing substance (dimethylsulfide, DMS) that escapes from seawater into the atmosphere [2]. There, DMS is oxidised to sulphate aerosol particles that serve as cloud condensation nuclei (CCN). Increased CCN numbers produce more cloud droplets, making clouds brighter, and reducing the amount of sunlight absorbed by the Earth. This albedo increase cools the Earth, changing the living conditions for plankton, and thus their rate of DMS emission. This natural DMS/CCN/cloud/climate feedback is still the subject of a large research effort, but in recent years the possibility of climate effects from the addition of anthropogenic CCN has entered the limelight.

Three different mechanisms for CCN/cloud/climate interactions can be distinguished. Since they involve modifications of cloud properties to amplify the effects of aerosol particles on climate, they are called "indirect effects", in contrast to the "direct effect" that is due to the interaction of sunlight with the aerosol particles themselves.

First, the addition of anthropogenically produced aerosol particles, which originate mostly from biomass burning and from the oxidation of sulphur dioxide from fossil-fuel burning, will enhance cloud droplet numbers and thus increase cloud albedo in the same way as discussed above for changes in DMS emissions. This effect, called the "first indirect aerosol effect", is possibly the largest climate forcing due to anthropogenic aerosol emissions, of the order of –1 W m-2 [3]. Unfortunately, at our present level of understanding it is also very difficult to quantify this effect with any reliability, but it is expected to be much more pronounced over the ocean than over land because of the type of clouds occurring there.

"Increased cloud albedo due to enhanced cloud droplet numbers...is possibly the largest climate forcing due to anthropogenic aerosol emissions..."

Second, since the amount of water available for droplet formation in a given cloud is more or less fixed, producing more droplets in a cloud also means that the droplets have to be smaller. This has consequences for the production of raindrops, since, for a cloud droplet to become large enough to be able to fall out of a cloud and turn into rain, it has to collect other droplets. This process only occurs when the biggest drops in a cloud can sink fast enough to collect smaller droplets in their path, and so keep growing and falling faster, until they rain out. However, when there are no droplets larger that the critical radius of about 15 mm, this coalescence process will not occur, and the cloud is left to dissipate without rainfall [4]. This will enhance the lifetime of the cloud, and thereby increase the total amount of cloud present in the atmosphere, again increasing planetary albedo and cooling the planet – the "second indirect effect". All the aerosol effects mentioned so far lead to a reduction of solar radiation at the Earth's surface, which reduces ground heating and evaporation, and thus influences the hydrological cycle [5], besides exerting a negative climate forcing.

A third effect occurs, if such an "overseeded" cloud has enough convective potential energy to rise high enough for ice particles to form. Then, alternative rain production mechanisms involving ice can take over, and rainfall can occur from such polluted clouds. This shift of rain production from lower-level water clouds to higher-level ice clouds has several consequences: rainfall intensity increases, lightning is enhanced, additional energy from the freezing of water is released, and the level of conversion of latent to sensible heat is shifted upwards. This perturbation of rainfall production and the associated energy conversion processes affects large-scale climate dynamics – the "third indirect effect".

At first, the effects of anthropogenic CCN on climate were thought to be important mostly over the oceans, because continental regions were considered always to have high levels of CCN, so that clouds would never be "CCN-starved" and any additional CCN would have little effect. Recent work in the Amazon, however, has shown this assumption to be false [6]. During the wet season in the remote Amazon Basin, when there is essentially no detectable

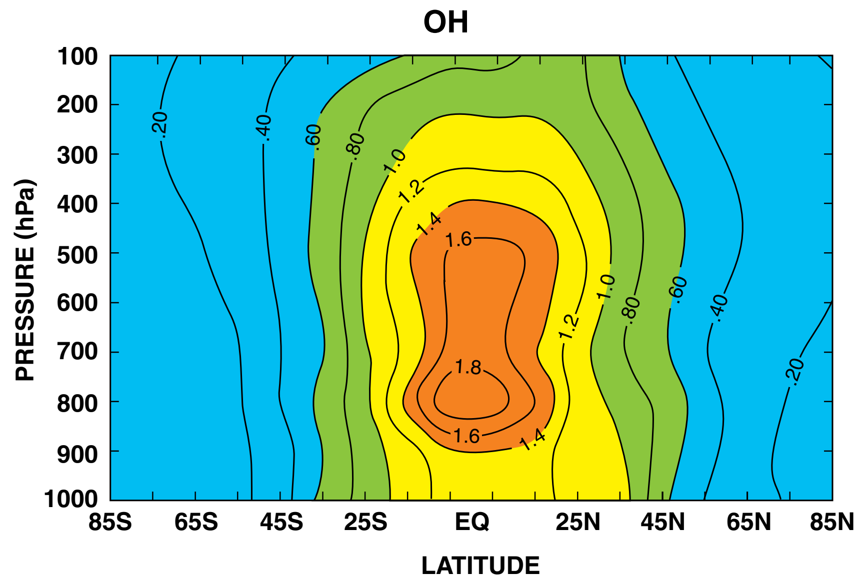

Figure 2. Model-derived longitudinally and diurnally averaged values of annual mean OH concentration (in units of 106 molecule cm^{-3}) (adapted from Andreae and Crutzen, 1997 [10]).

anthropogenic input and most CCN are of biological origin, the balance of natural sources and sinks produces a CCN number concentration almost identical to marine values – a condition we call the "Green Ocean". It thus appears that in the pristine state both marine and terrestrial biota regulate CCN concentrations to remain at fairly low values.

Increased CCN over previously pristine continental regions therefore also have climatic effects. A particularly powerful perturbation results from the third indirect effect, when CCN are added in the tropics, because this region is the "power plant" of global circulation. The injection of smoke into tropical deep convection results in a perturbation of the Hadley and Walker cells that resembles an El Niño-like phenomenon, with changes in large-scale lifting and sinking tendencies in the atmosphere. By this mechanism, deforestation burning in Brazil may modify rainfall as far away as Indonesia and West Africa, and storm behaviour over the North Atlantic [7].

In summary, we find that by providing most of the CCN to the natural atmosphere, the biosphere has a strong influence on cloud radiative and microphysical properties, and thereby on both climate and the hydrological cycle. We also observe that this natural regulation mechanism is now in the process of being overwhelmed by anthropogenic emissions.

The biota and the self-cleaning mechanism of the atmosphere

Vast amounts of chemical compounds are emitted into the atmosphere at any moment, the largest share being methane and other hydrocarbons from bio-

Box: A regional approach to land-atmosphere experiments

The past decade of research on atmospheric chemistry and its interactions with the other parts of the Earth System has brought substantial progress, much of which is summarised in the IGAC synthesis volume [12]. It has also brought about a close interaction between previously unconnected scientific communities, particularly atmospheric chemists, biogeochemists, and ecologists. But this work has also shown a clear need for closer integration with hydrology and the socio-economic sciences in future investigations. Setting such a broad compass for scientific research will also require a judicious choice of focus, as it will not be possible to simultaneously study the entire Earth System in all its dimensions with limited available financial and human resources. A promising way to proceed might be the selection of some key regions for integrated investigations, regions that represent crucial aspects of present and future global change. A focus on the regional scale would have the advantage that interactions (physical, chemical, ecological, economical, social) are reasonably homogeneous and can be studied in a fairly comprehensive way. This scale also lends itself well to upscaling from local measurements. On the other hand, the regional scale is large enough to contribute meaningfully to an understanding of global-scale phenomena.

Most suitable for such integrated studies would be regions where change is presently occurring at a rapid and large scale, and where, therefore, its impact might be most visible. Clearly, the tropical regions fulfil these criteria. In the tropical forest regions, land use change in the form of deforestation and colonisation is progressing at a rapid and undiminished pace. In more developed parts of the tropics and subtropics, rapid population growth, and industrial and economic development cause large emissions of air and water pollutants. This has a profound impact on environmental quality, on human and ecosystem health, and on regional and global climate. At the other extreme, the boreal region is of key importance for future studies. Here, observable climate change is progressing at a rapid pace. The region is warming significantly and rapidly, providing us with the ability to investigate the effect of climate change on the coupled systems of physical climate, the carbon cycle and the biogeochemical cycles of trace substances, including the nutrient elements.

The ILEAPS (Integrated Land Ecosystem - Atmosphere Processes) project, which is presently being developed as part of the next phase of the IGBP, intends to implement some of this integrated research. It will focus on feedbacks and teleconnections between ecology, hydrology, biogeochemistry and atmospheric chemistry (see IGBP NewsLetter No 50). For more information on ILEAPS, please contact the author.

genic sources, with a combined flux of over 1000 Million tons per year [8]. These and other compounds would soon accumulate to unacceptable concentrations, were it not for an extremely rapid and effective self-cleaning mechanism of the atmosphere. Since hydrocarbons are very poorly soluble in water, they cannot be removed effectively by being incorporated in rain. Their removal thus

> "...methane and other hydrocarbons from biogenic sources ... would soon accumulate to unacceptable concentrations, were it not for an extremely rapid and effective self-cleaning mechanism of the atmosphere."

requires one or more oxidative reaction steps to be transformed into water-soluble compounds, either polar organics or CO_2. The most important first reaction step is the reaction with the hydroxyl radical, OH, dubbed the "detergent" of the atmosphere [9]. This short-lived, very reactive molecule is formed from the photodissociation of ozone (O_3) to dioxygen (O_2) and an oxygen atom (O), and the subsequent reaction of this O atom with water vapour (H_2O). Because of the high levels of UV-radiation and water vapour in the tropics, OH concentrations are highest in the tropics, and most of the oxidation of CH_4, CO, and other trace gases occurs in the "Great Tropical Reactor", the region of high OH in the tropical troposphere (Figure 2, [10]). The tropical region thus plays a key role not only in regulating physical climate, but also in maintaining the chemical composition of the atmosphere.

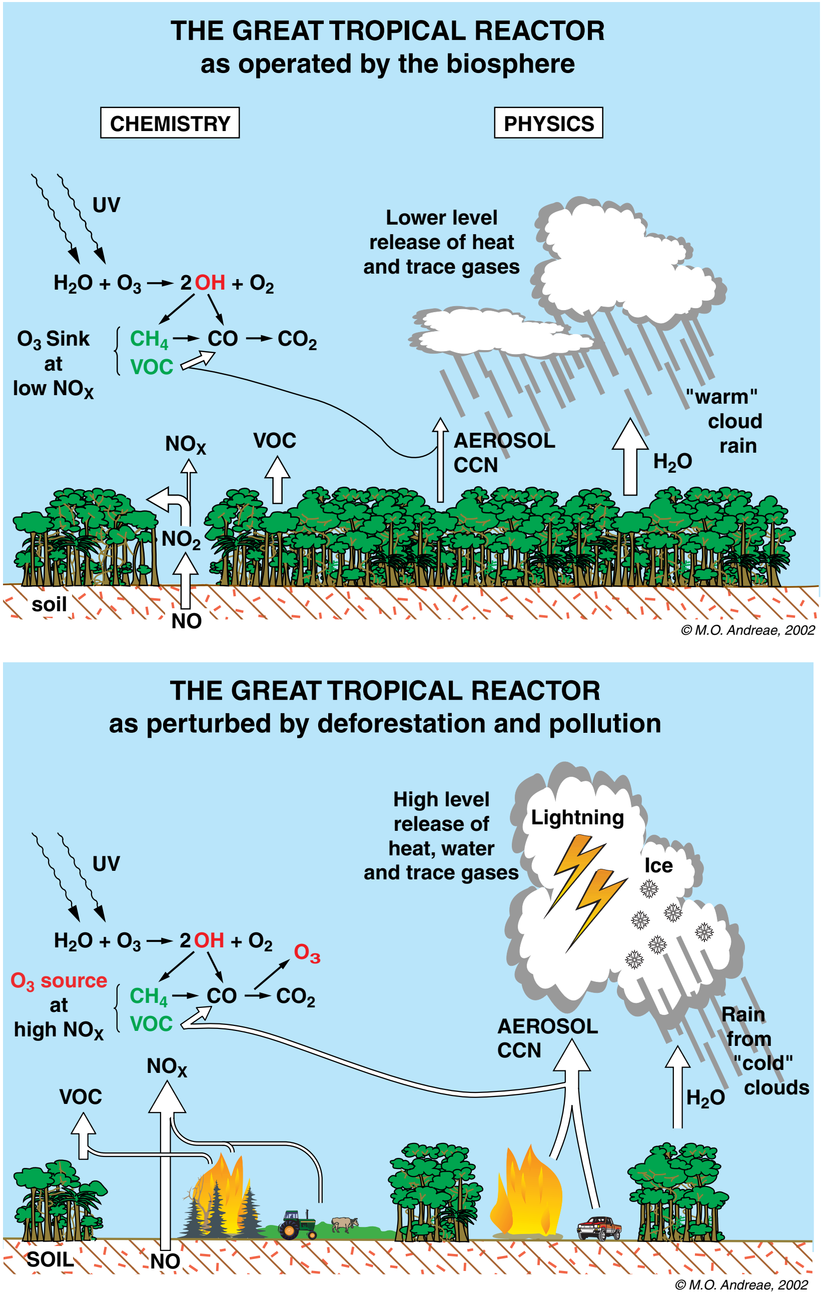

Figure 3. Schematic model of the biosphere/atmosphere interactions for trace gases, aerosols and clouds over the tropics ("The Great Tropical Reactor"), a) under natural conditions and b) following deforestation and development.

When we take a somewhat closer look at the chemical processes of the photochemical oxidation of hydrocarbons, we see that besides the presence of water and UV light, the abundance of O_3 and the relative amounts of hydrocarbons and nitrogen oxides (NOx = NO + NO_2) also play crucial and interrelated roles. At very low levels of NO_x, hydrocarbon oxidation removes O_3 and consumes OH, while at higher NO_x levels more O_3 and reactive radicals are produced. Under pristine conditions, the biosphere is the dominant source of both hydrocarbons and NO_x in the lower and mid-troposphere, and their relative amounts emitted are such that NO_x concentrations are low and consequently the troposphere is in a low-ozone state (Figure 3a).

In the rainforest regions of the tropics, this is achieved by a tight interaction of biological, chemical and physical processes, which allow efficient turnover of nitrogen, an important nutrient element, but prevent it from escaping easily into the atmosphere. NO is produced during the nitrogen turnover that accompanies the breakdown of biological matter in soils, and part of this gas can escape into the air layers over the soil. Here, it can react with ozone to form NO_2, which is efficiently deposited on plant surfaces in the canopy space of the forest, and made available for plant growth. Only a modest fraction of the NO emitted from the soil can therefore escape into the atmosphere over the forest and contribute to ozone formation.

The conversion of rainforest to grass- and croplands (deforestation) and the resulting removal of the tree canopy break open this tight NO_x recycling system (Figure 3b). Because of the short distance from the soil to the top of the grass canopy, there is much less chance for oxidation of NO to NO_2, and for the deposition of NO_2 to leaf surfaces. At the same time as more NO_x can escape, the biogenic hydrocarbon emissions are reduced because of the change of vegetation from trees to grass or crops. Biomass burning for deforestation and land management supplies additional NO_x and hydrocarbons to the regional atmosphere. The consequence is a transition from a low-ozone state of the Great Tropical Reactor to a high-ozone photochemical smog situation.

This change in gas phase chemistry also has consequences for aerosol production. Under natural conditions, the aerosol yield from the photooxidation of terpenes is quite low, because the prevailing reaction chains lead to relatively volatile compounds that do not readily condense into particles. However, at higher O_3 concentrations more low-volatility compounds are formed, which can then form aerosol particles [11]. Tropical deforestation and land-use change thus enhances aerosol loading in three ways, by biomass burning, by emissions from fossil fuel combustion in vehicles, power plants, etc., and by increasing the aerosol yield from the oxidation of biogenic hydrocarbons. As we have discussed in the previous section, elevated aerosol levels change cloud dynamics and enhance lightning frequency. The changed cloud microphysics in polluted clouds makes them less effective at cleaning the atmosphere, and enhanced lightning results in increased NOx formation, both factors that drives up ozone production and pollution of the upper troposphere.

In this and the preceding sections, we have only explored

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some of the complex interactions between biology, chemistry, and physical processes, with an emphasis on the tropics as a key region. Even this brief and superficial exploration, however, reveals some of the intricate web of feedbacks that remain to be scientifically investigated. At present, our level of knowledge of land-use change, the resulting ecological and chemical transformations, and their interactions with physical climate are still inadequate to model them reliably. But given the critical role of the tropics in chemical and physical climate we can expect them to have serious consequences for the well-being of Spaceship Earth and its passengers.

Meinrat (Andi) O. Andreae,
Biogeochemistry Department,
Max Planck Institute for Chemistry,
P.O. Box 3060,
D-55020 Mainz,
Germany.
E-mail: andreae@mpch-mainz.mpg.de

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Carbon cycles in the fluvial and oceanic systems of Southeast Asia

by Chen-Tung Arthur Chen

Human intervention in the carbon cycle over the last two centuries has generated anthropogenic carbon fluxes that are comparable in magnitude to major natural fluxes in the global carbon cycle. During this period, river basin development, most notably from the construction of dams and irrigation systems, has had a profound impact on riverine inputs of freshwater and carbon to the oceans. On a global scale, approximately 40% of the freshwater and particulate matter entering the oceans is transported by the ten largest rivers, in the form of a buoyant plume on the open continental shelves (Figure 1). However, the number of dams higher than 15m has increased by a startling seven-fold since 1950, and within the next few decades more than 50% of total global river flow to the seas may be dammed or diverted [1,2,3]. Given these facts, the export of carbon to the atmosphere and oceans from fluvial systems will most certainly be severely affected, a perturbation that must now be included in analyses of the global carbon cycle.

The effect of river basin development does not only affect the carbon cycle. In addition, the reduction of freshwater outflow and its alteration of the buoyancy effect, caused ultimately by damming or irrigation, means that the continental shelves will operate under a much less efficient biological pump and a smaller delivery of nutrients from deep waters onto the shelves will occur. Thus fish production will decrease accordingly. This is a classic example of a single human activity driving multiple and interacting impacts on Earth System functioning.

Fluvial systems and the global carbon cycle

The major biogeochemical role of river systems in the global carbon cycle is usually considered to be the fluvial export of total organic carbon and dissolved inorganic carbon to the oceans (0.4 - 0.8 and 0.4 Gt C yr^{-1}, respectively). It is true that these fluxes represent small components of the global C cycle, but they are nonetheless significant when compared to the net oceanic uptake of anthropogenic CO_2. Aquatic carbon exports from terrestrial ecosys-

> "...flux-based estimates of large terrestrial sinks in the Amazon Basin may be balanced by outgassing from rivers, thus rendering the entire Basin close to neutral in terms of net carbon flux."

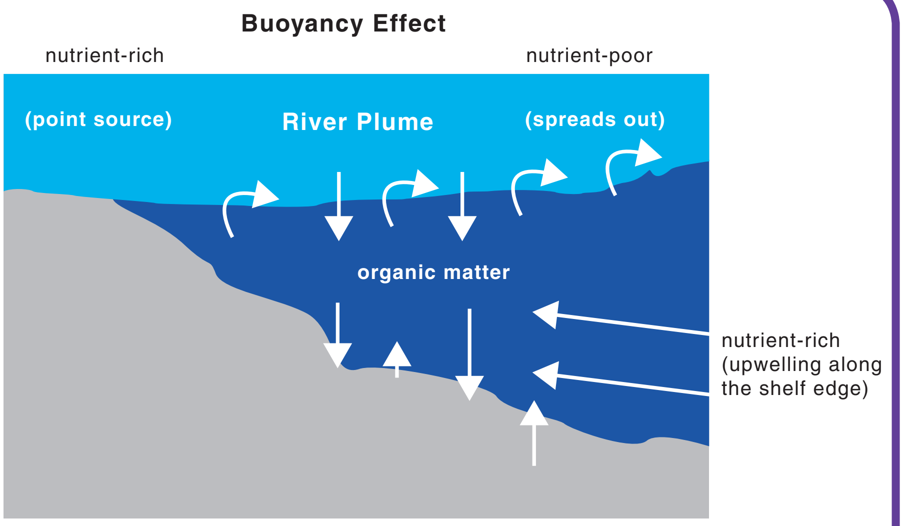

Figure 1. On a global scale, approximately 40% of the freshwater and particulate matter entering the oceans is transported by the ten largest rivers, in the form of a buoyant plume on the open continental shelves.

tems, however, are not solely limited to fluvial discharge; on the contrary, early measurements, for example in the Amazon, suggest that global CO_2 efflux (fluvial export plus respiration) from the world's rivers could be as large as 1 Gt C yr^{-1}. Richey et al. [4] have recently demonstrated that the outgassing of CO_2 from rivers and wetlands of the Amazon Basin constitutes an important process of carbon loss, equal to 1.2 ± 0.3 Mg C ha^{-1} yr^{-1}. This carbon probably originates from organic matter transported from upland and flooded forests, and is then respired and outgassed downstream. If extrapolated across the entire basin, the resulting flux is about 0.5 Gt C yr^{-1}. This is a very significant value, as it suggests that flux-based estimates of large terrestrial sinks in the Amazon Basin may be balanced by outgassing from rivers, thus rendering the entire Basin close to neutral in terms of net carbon flux.

While the computations of fluvial and evasion flux are becoming progressively better constrained for the Amazon, elsewhere in the humid tropics, such as Southeast Asia, this is not the case. In terms of development, Southeast Asia sharply contrasts with the Amazon, on account of the extraordinarily rapid pace of development and population growth in the former, hence the need for reservoirs and irrigation. Obviously, this has placed dramatically increasing pressure on its river basins and downstream coastal ecosystems.

Damming and its potential impact on productivities beyond the estuaries

In addition to affecting the carbon cycle, the human alteration of fluvial systems impacts productivity of coastal fisheries. Although we cannot ignore the longer-term changes in regional weather patterns and climate that result in altered hydrological flow regimes, the most significant changes in hydrology now, and for the next decade or two, are an immediate consequence of dam construction and large-scale water diversion for irrigation. These changes undoubtedly have significant effects on water resources. In addition, rivers are the major conduits for the passage of water, nutrients, organic mate-

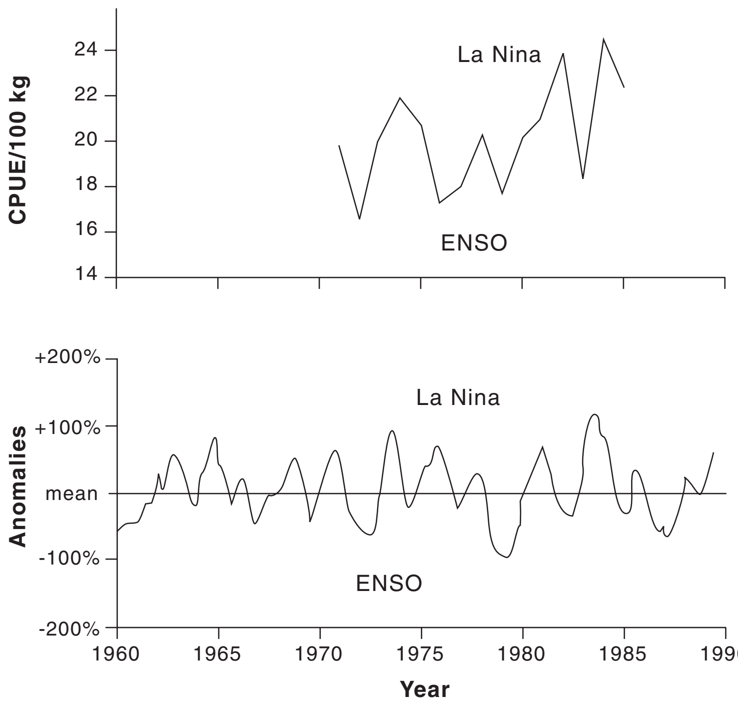

Figure 2. El Niño conditions result in a decrease in fish catches in the East China Sea (catch per unit effort: CPUE). This is due to decreased outflow from the Changjiang River reducing the cross-shelf water exchange and diminishing the onshore nutrient supply. Primary production and fish catches decrease in turn.

Box: The South China Sea Regional Carbon Pilot Project

Through the formation of the Global Carbon Project (GCP), IGBP, IHDP and WCRP have established formal collaborative research to describe, understand and predict the evolution of the global carbon cycle [9, and www.globalcarbonproject.org]. The South China Sea Regional Carbon Pilot Project is a newly-formed contribution to the GCP agenda for pilot research in the South China Sea (SCS) region. The approach is to provide initial funding in order to develop several theories regarding carbon cycle dynamics and fisheries productivity in the SCS region, with a focus on biogeochemical dimensions and fisheries along with their interactions and feedback. This will be achieved by determining and explaining the following:

- Patterns and Variability: the current geographical and temporal distributions of the major stores and fluxes of carbon and associated elements in the SCS region, including the deep SCS basin, shelves, estuaries and river basins;
- Processes, Controls and Interactions: the underlying mechanisms and feedbacks that control the dynamics of the regional aquatic carbon cycle, encompassing its interactions with water and nutrient cycles as well as fisheries; and
- Future Dynamics of the Carbon Cycle: the range of plausible trajectories in the future as concerns the dynamics of the regional aquatic carbon cycle.

The proposed work of the SCS Regional Carbon Pilot Project was approved by the SARCS Regional Council in Hanoi on 12 Oct., 2002. It will be organised around rapid-turnaround Pilot Activities with funding to Southeast Asia Regional Center for START (SARCS: www.sarcs.org) nations being provided by the National Science Council of China-Taipei (Calls for proposals - with a mid-February 2003 deadline - are available at maywang@sarcs.org.tw); an 18-month time frame will be allotted for the delivery of the initial results. The initial Pilot Activities will cover:

- Rapid assessment - literature review of the SCS regional carbon cycles.
- Enhanced understanding of space-time patterns in contemporary carbon cycles.
- Training programmes for scientists in the SARCS region.
- Consequences of regional reservoir and water diversion developments to the carbon cycle.
- Emergent properties of the coupled human-carbon-water-fishery system.
- Evolution of future aquatic carbon sources and sinks through the 21st century.

Major stakeholders of the SCS Regional Carbon Pilot Project are the scientific, assessment, and policy communities dealing with quantifying and predicting carbon budgets and fishery resources on regional, national and local scales; and specialists in regional development with regard to mitigation measures so as to minimise the impact on environmental, economic and social issues. Because of the integrative nature of the project, there will be a need to build upon many existing projects under the umbrella of the SCS Regional Carbon Pilot Project and to work closely with many communities whose spheres of interest intersect but do not overlap. It is particularly important to work with research communities coordinated through SARCS, IGBP (in particular, LOICZ, SOLAS and GLOBEC/OCEANS), IHDP, WCRP and through the GCP as well as with assessment and policy communities dealing with the consequences of changes in the carbon cycle, vulnerability, and the links to water resources and food systems.

rial and particulate matter from land to sea, and naturally the input of nutrients and organic matter (total and dissolved organic carbon) nurtures fish-breeding in the estuaries. Thus, the completion of a large dam (e.g. the Aswan Dam on the River Nile) is most important in driving the observed dramatic reductions in fish stocks in many connecting estuaries. Briefly put, dams block the downstream transport of particulate matter, including carbon, which is an important source of nutrients and food for aquatic biota. The effects, however, go far beyond the estuaries. The Three Gorges Dam in China is a case in point. Clear evidence has shown that,

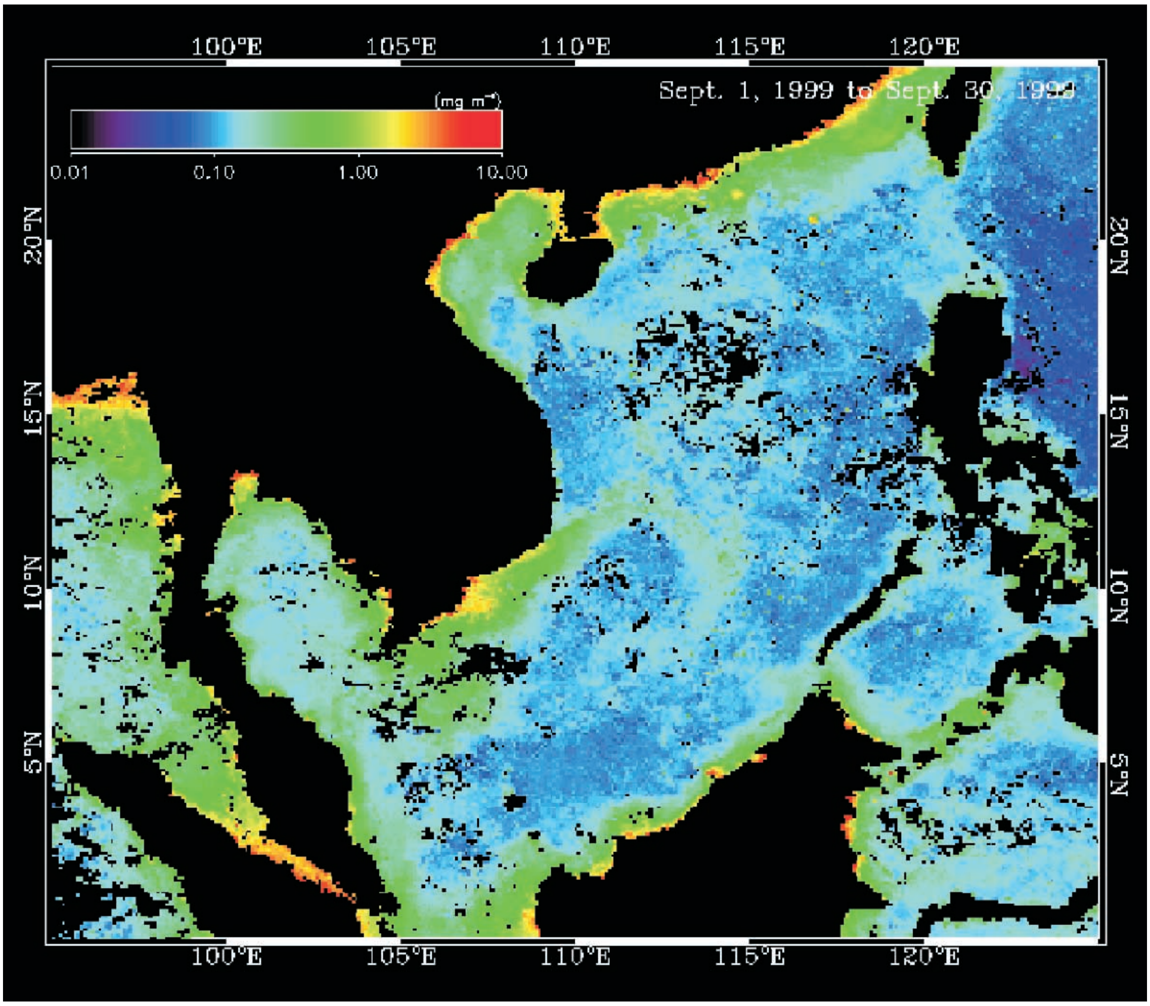

Figure 3. Composite image of chlorophyll a distribution in the South China Sea in September 1999. Nutrient rich waters, where primary production is high, are visible as green areas along the coasts of SE Asia. Derived from SeaWiFS data provided by NASA. Data and image processing done by C. Hu of USF and I-I Lin and C. Lian of National Center for Ocean Research, Taipei.

despite a large riverine input of nutrients to the East China Sea (ECS), only a small fraction (7% for P and 33% for N) of the external nutrient supply supporting new production is actually derived from that input. The major nutrient supply originates from the on-shore advection of subsurface Kuroshio waters [5]. Similarly, upwelling of subsurface waters from the South China Sea basin supports more than twice as much P to the euphotic zone than the riverine input [6].

Chen [7] has additionally documented that the completion of the Three Gorges Dam on the Changjiang (Yangtze) River is most likely to result in considerably diminished productivity in the ECS, currently home to the largest fishing grounds in the world. Cutting back the Changjiang River outflow by a mere 10% will not only reduce the cross-shelf water exchange by about 9% because of a reduced buoyancy effect, but also simultaneously diminish the onshore nutrient supply by almost the same amount. It thus follows that primary production and fish catch in the ECS will decrease proportionately, a fact supported by the decrease in catch per unit effort (CPUE) of fisheries in El Niño years when the Changjiang River outflow was reduced (Figure 2). As a further example, a ~50% reduction in the Huanghe (Yellow) River discharge from 1982-1983 and 1992-1993 resulted in a ~35% decrease in chlorophyll concentration, phytoplankton and zooplankton biomass, primary productivity and even Index of Species Diversity in the Bohai Sea [8].

From a global perspective, as stated earlier, approximately 40% of the freshwater and particulate matter entering the oceans are transported by the 10 largest rivers by means of a buoyant plume (Figure 1) on the open shelves. Hence, these shelves also, of course, face diminished fish production when damming reduces fresh-water outflow.

The impacts of human alteration of the continental hydrological cycle on the Earth System are only beginning to be explored. There is now good evidence that both the global carbon cycle and the productivity of coastal fisheries are affected. Understanding how these impacts interact and what might be other cascading effects of damming and water diversion will require integrative, regionally-based research that can be compared and aggregated to give a global picture. Fluvial research within LBA (Large-scale Biosphere-Atmosphere Experiment in Amazonia) is the first attempt at tackling this complex issue. A companion study - the South China Sea Regional Carbon Pilot Project - promises to further improve our understanding in another critical region of the Earth System (see Box).

Chen-Tung Arthur Chen
Institute of Marine Geology and Chemistry,
National Sun Yat-sen University,
Kaohsiung 804, Taiwan,
Republic of China
E-mail: ctchen@mail.nsysu.edu.tw

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Major reorganisation of North Atlantic pelagic ecosystems linked to climate change

by G. Beaugrand, P. C. Reid and F. Ibañez

Human activities have now become so pervasive that they influence all Earth's compartments and processes. In particular, the atmospheric concentration of carbon dioxide has risen from 280 ppm (parts per million) in 1750 to 367 ppm in 1999 [1]. The effects of this increase in CO_2 concentration are very likely to be responsible for the global increase in temperature seen over the last 50 years. Effects of both the increase in CO_2 concentration and global warming on ecosystems have just started to emerge. These may influence organisms in a direct way by acting on the physiology (e.g., photosynthesis; [2, 3]) or on the species phenology (e.g., seasonal cycle; [4, 5]). The may also affect biological systems through indirect ways by modifying abiotic factors, in turn affecting the spatial distribution of species.

To investigate the potential impact of climate change on marine ecosystems, a new kind of biological indicator is needed, which allows the whole community structure to be monitored. Beaugrand et al. [6] have recently decomposed the diversity of calanoid copepods, one of the best-represented taxonomic groups sampled by the Continuous Plankton Recorder (CPR) survey, into species assemblages. This decomposition was done utilising geostatistics and multivariate analyses, in combination with 'Indicator Values' designed by Dufrêne and Legendre [7]. At the scale of the North Atlantic basin and a spatial resolution approaching the meso-scale, nine species assem-

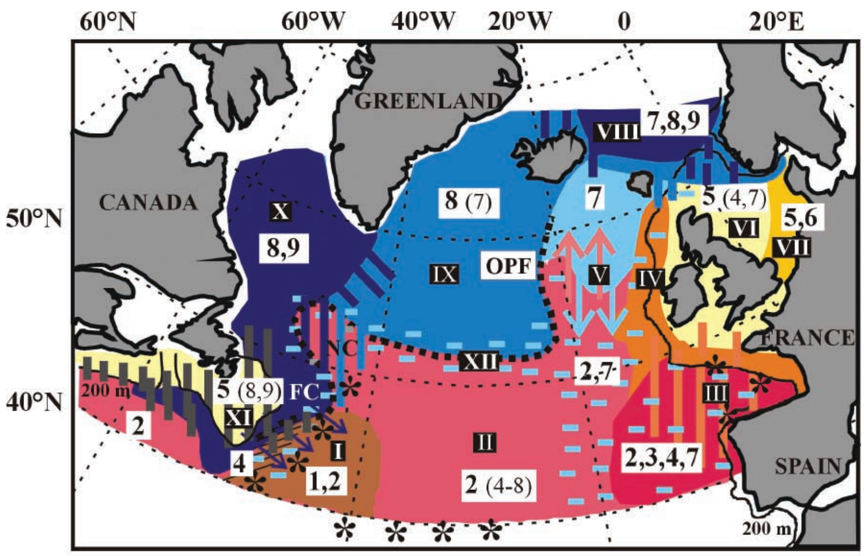

Figure 1. Scheme of the geographical position of centres of distribution of the associations, ecosystems and ecotones. A number identifies each association. In some areas such as in the Bay of Biscay, several assemblages overlap. Asterisk indicates the location where very rare species were found during the 40 years CPR sampling. Grey arrows (west of Great Britain) denote the seasonal change in the northern position of Species Association 2. Black arrows (above the Canadian shelf) indicate that extrusion of water related to the high hydrodynamics of this region happen and lead to expatriation of species belonging to assemblages 4, 5, 8 and 9 towards the Gulf Stream Extension region. The thick black dotted line indicates the position of the Oceanic Polar Front. Numbers into brackets indicate the possibility to find species belonging to adjacent species association. OPF: Oceanic Polar Front; FC: Flemish Cap; NC: Worthington's Northern Corner. Species associations 4 and 7 seasonally progress northwards with a high aggregation of species in the south in spring and in the North in autumn. Modified from Beaugrand et al. [6].

blages were identified using three criteria: (1) spatial distribution of species, (2) similarity in the seasonal variability of species and (3) diel and ontogenic variations. The nine species assemblages were closely related to a stable-biotope component or a substrate-biotope component [8]. As a result, a new partition of the North Atlantic pelagic environment was outlined (Figure 1). This led Beaugrand et al. [7] to propose using the mean number of species belonging to each species assemblage as an indicator to monitor modifications in the structural organisation of North Atlantic marine ecosystems.

Using these species assemblage indicators, Beaugrand et al. [9] have recently reported substantial changes during the period 1960-1999 in the spatial distribution of calanoid copepod assemblages at an ocean basin scale, and have provided evidence that this might have been influenced by the combined effect of the climatic warming of the Northern Hemisphere and the North Atlantic Oscillation. The number of species per assemblage was used as an indicator (1) of change in the biogeographical range of copepod communities and (2) of ecosystem modification.

"...there have been substantial changes during the period 1960-1999 in the spatial distribution of calanoid copepod assemblages at an ocean basin scale..."

Maps of the mean number of species present in an area for all species assemblages (Figure 2) demonstrate that major biogeographical shifts for all species assemblages have taken place since the early 1980s to the south-west of the British Isles and from the mid 1980s in the North Sea. The mean number of warm-temperate, temperate pseudo-oceanic species increased by about 10° of latitude. In contrast, the diversity of colder-temperate, subarctic and Arctic species have decreased towards the north. All the biological associations show consistent long-term changes, including neritic species assemblages. These changes have been linked to Northern Hemisphere Temperature (NHT) anomalies and to a lesser extent the winter North Atlantic Oscillation (NAO) index. Other studies have also revealed a northward extension of the ranges of many warm-water fish in the same region [10, 11]. This evidence tends to indicate a shift of marine pelagic ecosystems towards a warmer dynamic regime in the north-eastern North Atlantic.

West of the mid-Atlantic ridge, especially in the Labrador Sea, the trend is opposite and the number of subarctic arctic species has increased while the number of warm-water oceanic species has decreased (Figure 3). This result indicates a possible move of north-west Atlantic ecosystems towards a cooler dynamic regime.

To better understand how large-scale hydrometeorological processes may have influenced the biogeographical shifts observed in the studied area, long-term changes in sea surface

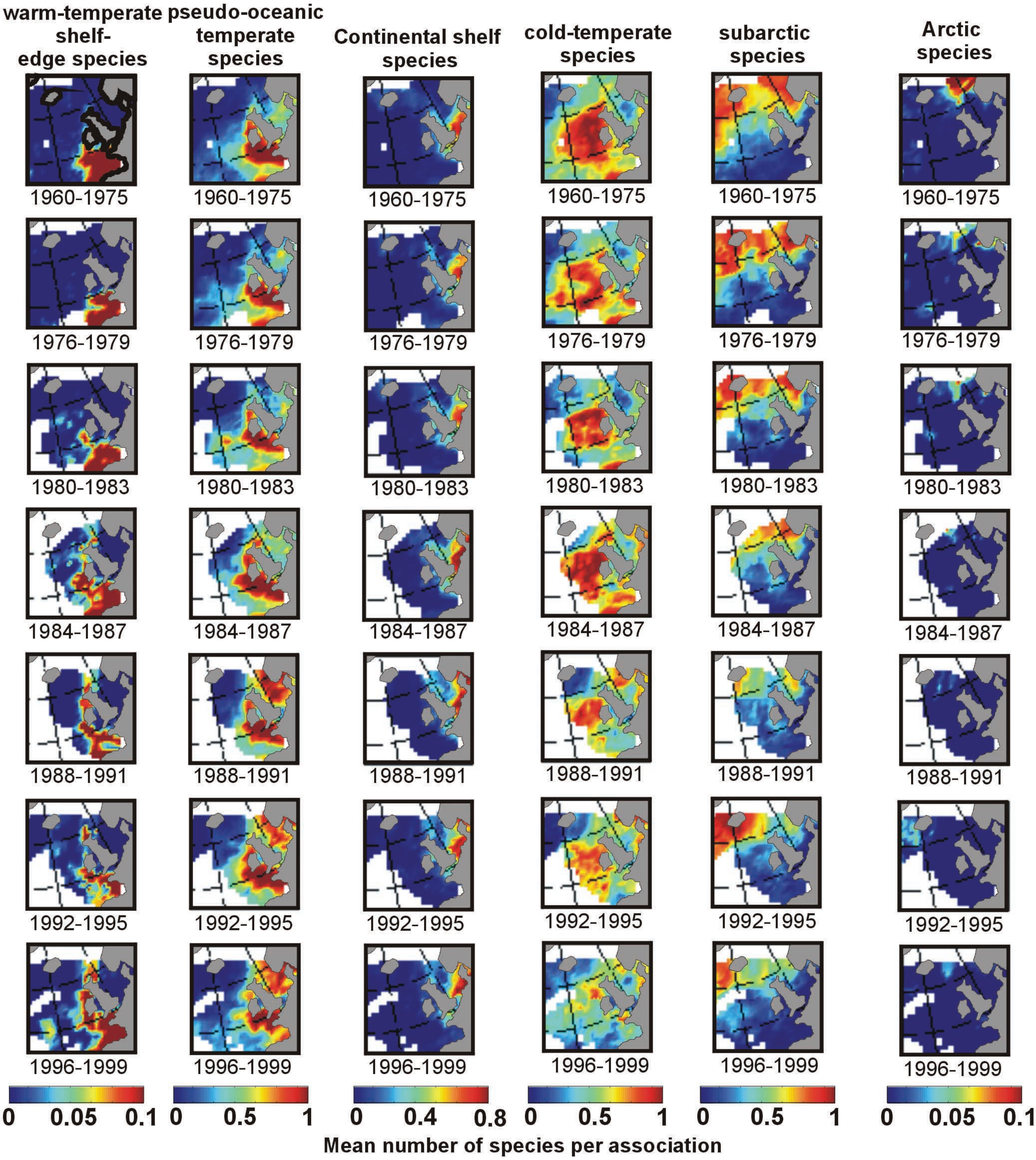

Figure 2. Long-term changes in the mean number of copepod species per association from 1960 to 1999, showing the northwards displacement of temperate copepod species and the reduction of cold and sub-arctic species over the last 40 years. Average maximum values were not more than 1. This can be explained by the fact that for all the 4-year periods, every month was considered for daylight and dark periods. A number of species are not found near the surface during the daylight period (e.g., *Pleuromamma robusta, Metridia lucens*) while others overwinter in deep water (e.g., *Calanus helgolandicus*). Modified from Beaugrand et al. [9].

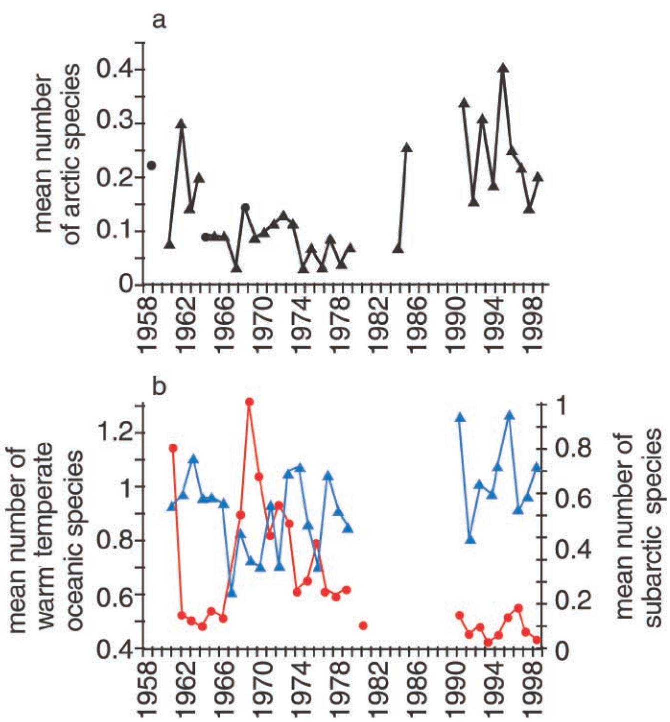

Figure 3.

Long-term changes in the mean number of arctic species in the Labrador Sea (a) and the mean number of subarctic (blue) and warm-temperate (red) species in an area around the Oceanic Polar Front area (b). Modified from Beaugrand et al [9].

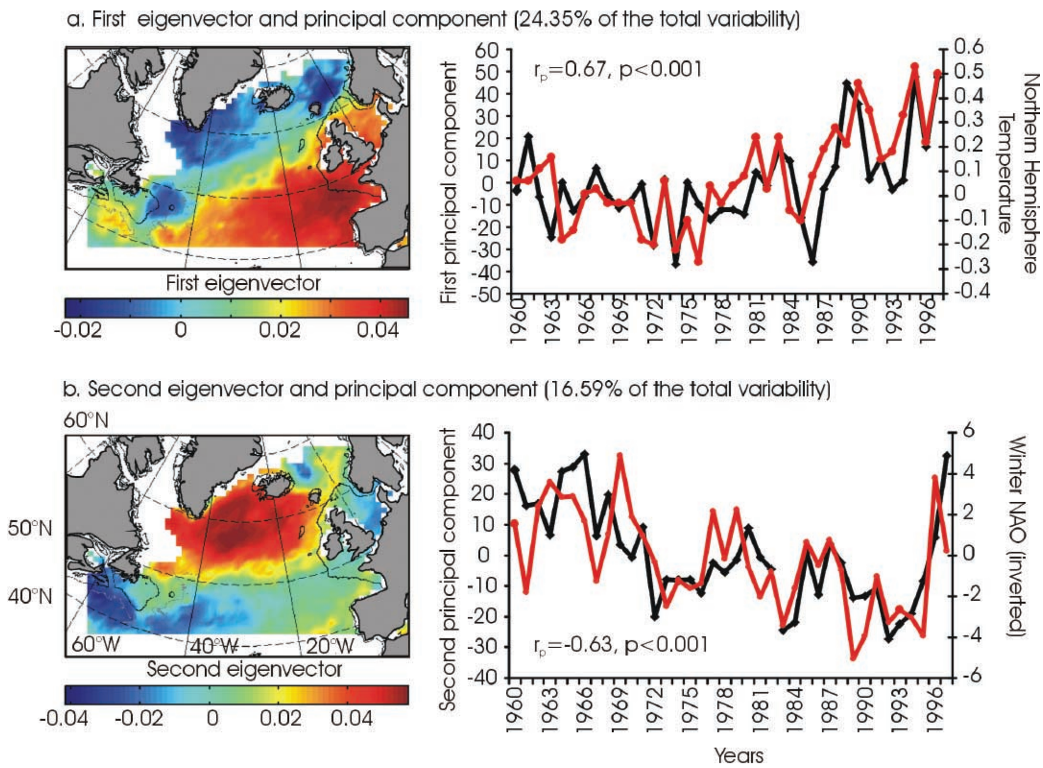

Figure 4. Standardised Principal Component Analysis of long-term changes in sea surface temperature in the North Atlantic Ocean. a) First eigenvector and principal component. Long-term changes in NHT anomalies and Pearson correlation coefficient between the first principal component and NHT anomalies are indicated. b) Second eigenvector and principal component. The long-term changes in the winter NAO and the Pearson correlation coefficient between the second principal component and the NAO index are indicated. The signal displayed by the first principal component (PC) is highly correlated positively with NHT anomalies (rp=0.69, p<0.001). In the subarctic gyre,the values of the second PC decreased until about 1993 and then increased. The long-term change in the second PC is highly correlated negatively with the NAO index (rp=-0.63, p<0.001). Modified from Beaugrand et al. [9].

temperature (SST) were investigated. Figure 4 displays the first two eigenvectors and principal components representing 40.9% of the total variability. The region south of a line from 40°N, 45°W to 60°N, 5°E and especially in the West European Basin was characterised by a decrease in SST from 1960 to about 1975 and then a strong continuous increase until 1997. Long-term changes in this signal are correlated positively with NHT anomalies. In the subarctic gyre the second principal component negatively covaried with the NAO, showing a decrease until 1993 and then an increase.

This analysis suggests that the shift in northeast Atlantic marine ecosystems towards a warmer dynamic regime has been influenced by the increasing trend in Northern Hemisphere temperature. However, the positive influence of the NAO on SST in the North Sea [12] must have played a synergistic role with NHT anomalies. Our results are concordant with other biological changes reported for the European region in the terrestrial realm. In the subarctic gyre, the shift in northwest Atlantic marine ecosystems towards a colder dynamic equilibrium tends to be more related to the influence of the North Atlantic Oscillation.

Climate warming therefore appears to be an important parameter that is at present governing the dynamic equilibrium of pelagic ecosystems in the northeast Atlantic. If the increase in Northern Hemisphere temperature predicted by the Intergovernmental Panel on Climate Change (2001) continues, a marked change in the organisation of pelagic ecosystems from phytoplankton to fish can be expected with a possible impact on biogeochemical cycles.

Grégory Beaugrand and Philip C. Reid,
Sir Alister Hardy Foundation for Ocean Science,
Plymouth,
UK
E-mail: gbea@mail.pml.ac.uk

Frederic Ibañez,
Observatoire Océanologique,
Villefranche-sur-mer,
France

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Palaeoperspectives on Global Sustainability

by M. Montoya, V. Brovkin, S. Rahmstorf and M. Claussen

Exploration of palaeoclimate is a challenge for both data and modelling scientific communities. Among scientists, there are sometimes different opinions about the reliability of palaeodata and model simulations. However, in one point there is a strong consensus between both communities: the past, on different time scales, provides us with the best way of validating climate models. Until we can successfully "predict" the past, our models cannot be relied upon for the future. This article discusses research on a broad spectrum of palaeodata archives (ice-core, marine, terrestrial and palynological), as well as climate modelling.

Ice cores provide excellent annual records including both local and global signatures, like CO_2 and CH_4 concentrations. The latter allow a synchronisation of Greenland and Antarctic records, helping to establish the phasing between events in both hemispheres. Marine sediment records, with their extensive coverage, constitute an archive of both surface and deep-ocean conditions, which can be related to past climate and ocean circulation. Terrestrial records allow reconstructions of vegetation, lake levels, and dust, and are hence crucial to obtain information about spatially heterogeneous climatic responses. Varved (annually resolved) lake sediment records, together with tree-ring data, are the major source of information on inter-annual variability in the past for large areas and could provide invaluable information on natural climate variability and its dependence on the mean climatic state.

Palaeoclimate simulations provide insight into the sensitivity of the climate system and hints about the processes and feedbacks responsible for past climatic change, both crucial aspects for future potential anthropogenic climate change. For example, intensified summer monsoons and northward shift of forests in the northern hemisphere at the mid-Holocene (c. 6000 BP) and the last interglacial period (c. 120-130 kyr BP) are evident in many palaeodata. These can be explained, respectively, by the enhanced land-sea temperature gradient and the enhanced summer insolation through the positive sea-ice albedo and vegetation-snow feedback at those times compared to the present. In addition, palaeoclimate simulations provide a tool for model validation, helping to highlight deficiencies of climate models. This is a prerequisite for assessing potential climate impacts due to anthropogenic perturbations of the climate system. One of the main conclusions of the Paleoclimate Modelling Intercomparison Project (PMIP, a PAGES-CLIVAR project, www-lsce.cea.fr/pmip) for the mid-Holocene climate is that although all models simulate wetter conditions over North Africa, most underestimate the precipitation increase estimated necessary to sustain Sahara vegetation and lake levels as pointed by data. In contrast, simulations with intermediate complexity climate models which include an interactive vegetation component reproduce much wetter conditions, suggesting an important role for vegetation and its interaction with the other components of the climate system [1]. A general agreement is also emerging within the palaeoclimatic community that there is a need for a wide range of climate models of different complexity, from conceptual to comprehensive general circulation models, and that it is crucial to incorporate proxies into models that can be directly compared with the palaeodata.

Climatic archives, especially ice-core records, provide a fascinating picture of the past climate of the Earth during the last 400 kyr [2]. The most dramatic features are the glacial-interglacial cycles. Temperature, greenhouse gases and ice-sheet volume show cyclic variations characterised by long cold periods and shorter warm interglacials, within apparently stable bounds. After decades of research, the strength of the astronomical theory of climate, which states that variations in the orbital parameters of the Earth are the ultimate drivers of glacial-interglacial cycles [3], has been clearly demonstrated through a wealth of data. Yet, it remains unclear which processes and feedbacks have maintained the natural Earth System within

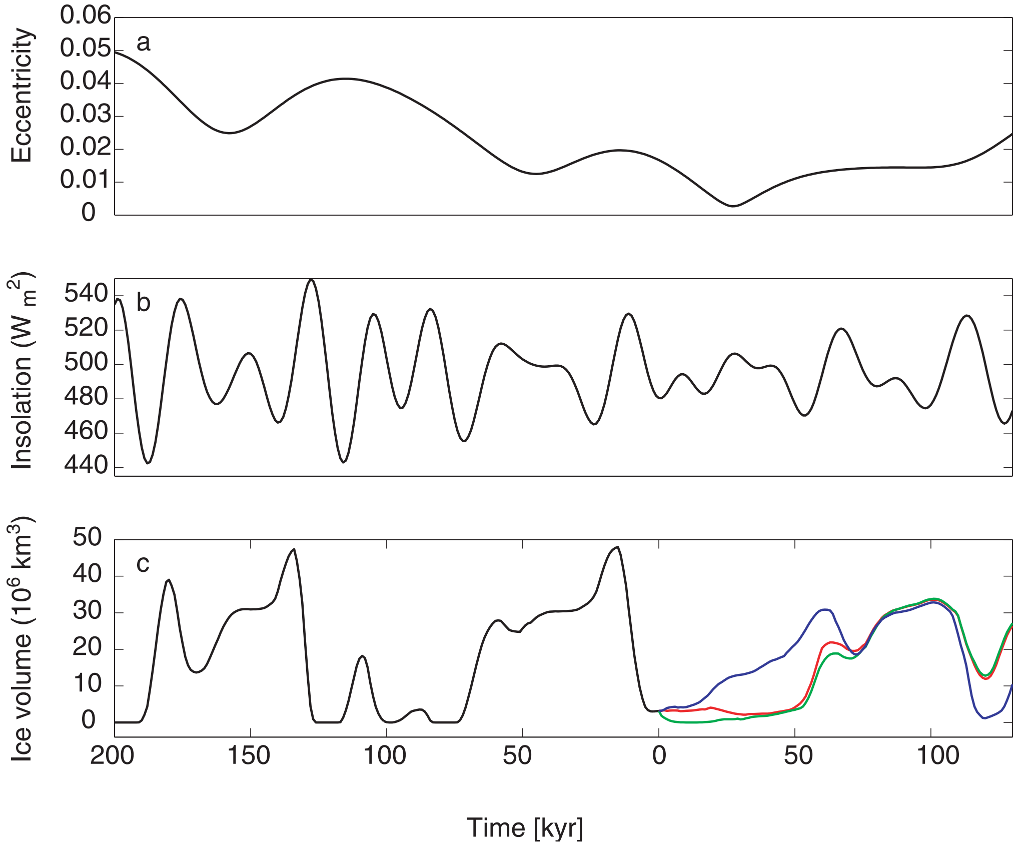

Figure 1. Long term variations of (a) eccentricity and (b) June insolation at 65°N (from [4]) and (c) simulated ice volume for the past (black, from [10]) and future (from [5]). For the future, three CO_2 scenarios were used: last glacial-interglacial values (red), a concentration of 750 ppmv (green) and a concentration of 210 ppmv (blue). Data kindly provided by M.-F. Loutre.

its bounds during the last 400 kyr. Identifying these would be a major step in our understanding of the dynamics and the resilience of the climate system, and whether human activity might perturb the Earth System from its current apparently stable mode of operation.

A question related to global sustainability concerns is when the next glaciation can be expected. The fact that the length of the Holocene (i.e. the last c. 10 kyr) has already surpassed that of some previous interglacials has led some previous authors to speculate that this should imply its imminent end. In contrast, the astronomical theory of climate predicts an exceptionally long duration of the present interglacial as a consequence of the particular orbital forcing during the next 50 kyr [4,5]: eccentricity is approaching a value close to zero, its minimum value being attained in 20 kyr (Figure 1). Based on this, an important message for the future is the fact that we might be entering a very special period in which one of the forcing mechanisms, insolation, will scarcely vary, leaving a main role for CO_2. Model simulations [5] suggest a threshold CO_2 value exists above which the Greenland Ice Sheet disappears (Figure 1). This would mark the end of the Quaternary ice-age and the beginning of the so-called "Quinternary", an almost ice-free climate regime.

In spite of the impressive achievements of the astronomical theory of climate, some crucial aspects require further research into the dynamics of the climate system. The amplifying feedbacks contributing to glacial inception are not fully understood. In addition, the processes behind glacial-interglacial CO_2 fluctuations, which are an intrinsic component of glacial-interglacial cycles, remain unclear. A number of mechanisms have been proposed, yet all of them are beset with problems. In reality, several different mechanisms might operate in combination.

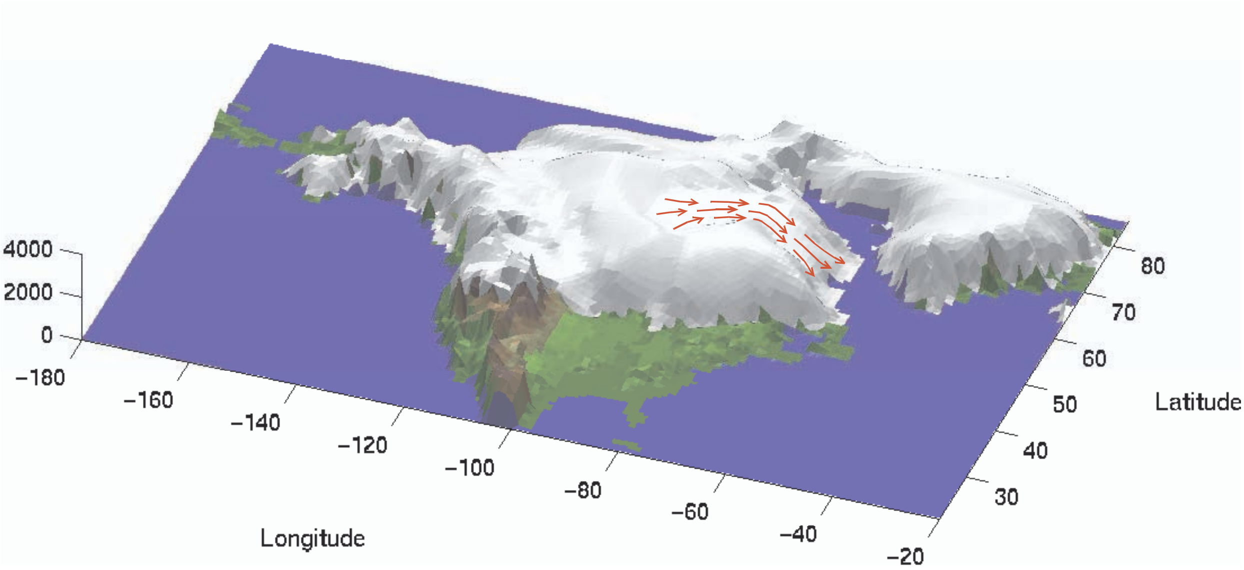

Figure 2: Laurentide ice-sheet thickness and extent simulated by the CLIMBER-2 Earth System Model including the SICOPOLIS ice-sheet model for constant Last Glacial Maximum climatic conditions. The red arrows indicate the major ice flow path during the Heinrich event shown in this snapshot. Data kindly provided by R. Calov [9] and plotted by I. Schramm.

Solving this puzzle is a key to answer the question of how much CO_2 can be sequestered by the ocean on a long time scale.

An additional fascinating feature revealed by the ice-core record and established as well in high resolution marine sediment cores is the large and abrupt climatic changes, Dansgaard-Oeschger (D/O) and Heinrich (H) events, evident during the past glacial period. In contrast, the Holocene appears as a comparatively stable period, and it is thought that the development of human agriculture within the Holocene did not occur by chance, but was favoured by the optimal climatic conditions. Could large-scale perturbations drive the system into a different mode of operation? Answering this question requires an understanding of the reasons for the different stability of the climate of the last glacial cycle compared to today's, and, ultimately, the mechanisms behind abrupt climate change. A consistent picture is emerging from the palaeorecord and simulations with intermediate complexity climate models in which the Atlantic ocean circulation plays the role of a non-linear amplifier. D/O events are characterised by different modes of the Atlantic thermohaline circulation, which are linked to different convective sites in the North Atlantic [6]. Some discussions concern the role played by the tropics. As evidenced by the ice-core records, almost all D/O events in Greenland were associated with CH_4 variations. Due to the fact that, during the last glacial period, high latitude CH_4 sources were covered by ice sheets, low latitude wetlands were initially assumed to have been responsible for such CH_4 variations. However, box models suggest that CH_4 changes during the D/O events originated through a very strong

> "Model simulations suggest a threshold CO_2 value exists above which the Greenland Ice Sheet disappears. This would mark the beginning of the so-called "Quinternary", an almost ice-free climate regime."

reaction of wetlands from high latitude sources, probably from Eurasia [7].

Heinrich events, in turn, have been simulated by a variety of models by invoking instabilities of the ice-sheets once a given ice-volume threshold has been surpassed [8]. Recently, an intermediate complexity climate model has been able to simulate, for the first time, Heinrich events as a result of internal ice-sheet instabilities (Figure 2, [9]). But crucial questions remain: even if this picture of abrupt climate change and the crucial role of the thermohaline circulation were correct, the challenge is to determine what is the ultimate trigger of the thermohaline variations. An additional puzzle refers to the mechanisms behind the Younger Dryas (a rapid climate change event that occurred during the last deglaciation of the North Atlantic region, c. 11,6 kyr BP): which mechanisms, together with meltwater discharges, were responsible for the extreme cooling given the high CO_2 concentrations at that time?

The 21st century will either witness the transition to global sustainability or the further separation of cultures and generations into winners and losers under accumulating environmental and developmental pressure. One important aspect in the discussion of global sustainability concerns the resilience of the natural Earth System to large-scale natural and anthropogenic perturbations such as those related to variations in solar luminosity, volcanic activity, land use, and greenhouse gas emissions. Further exploration of the role these forcings played in the past requires a joint effort by the data and modelling communities. It is now generally recognised that there is no direct palaeoanalogue of potential future climate change. Nevertheless, there is much to be learnt about the dynamics of the Earth System by exploring its history.

Marisa Montoya
Victor Brovkin
Stefan Rahmstorf
Martin Claussen
Potsdam Institute for Climate Impact Research, P.O. Box 601203, Telegrafenberg, D-14412 Potsdam, Germany
E-mail: montoya@pik-potsdam.de

Footnote: This article is based on discussions at a workshop titled ‘Paleoperspectives on Global Sustainability’ in the framework of the First Sustainability Days at the Potsdam Institute for Climate Impact Research (September 28th - October 5th 2001). The meeting brought together about forty palaeoclimatologists in an attempt to extract the main lessons that can be learnt from the past.

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Earth System science for sustainable development

The World Summit on Sustainable Development (WSSD) in Johannesburg (26 August – 4 September 2002), and the process leading up to it, caught the attention and engagement of governments, and a multitude of other actors. The purpose of the Summit was to review progress on implementing the Rio Declaration and Agenda 21 from the United Nations Conference on Environment and Development in Rio de Janeiro (1992), and readjust the focus for the years ahead. Despite the media hype that condemned the Summit as a failure, there were good results in many areas. Ambitious time-bound targets were agreed upon, for example, in areas of poverty reduction, access to water and sanitation, biodiversity loss, fishery stocks, and chemicals [1].

In the action plan Agenda 21, adopted by the Rio conference, scientists are identified as one of the Major Groups. Other groups include women, children and youth, indigenous peoples, NGOs, local authorities, workers and trade unions, business and industry, and farmers, each one with their own Chapter outlining their specific role for sustainable development [2]. The WSSD process included the official participation of representatives of all these groups to levels not seen before in UN conferences. They were included, for example, in Multi-Stakeholder Dialogues with governments, invited to submit reports and take part in Round Table discussions with Heads of State. The International Council for Science (ICSU) together with the World Federation of Engineering Organization was asked by the UN to facilitate the input from the Scientific and Technological community.

Why is science essential for sustainable development?

Sustainable development at local, regional and global scales represents perhaps the most daunting challenge that humanity has ever faced. Central to all of the many approaches aimed at both identifying unsustainable practices and achieving sustainability are scientific knowledge, access to that knowledge and its application. The great sustainability problems of the 21st century – e.g., poverty alleviation, sustainable food production, clean and accessible water resources, the health of ecosystems and maintenance of biodiversity – all require, as one critical component of their solution, usable scientific knowledge. Thus, whatever the cultural, geographical, economic or environmental setting, a partnership between science and society is a fundamental prerequisite for sustainable development.

How can the scientific community improve its contribution to sustainable development?

In the decade since the adoption of Agenda 21, the scientific community has vastly increased its potential for contributing to sustainable development. Improved understanding of climate variability through time and the ability to make some predictions is, among other things, providing better warnings of natural phenomena such as El Niño and improving agricultural production. For example, the causes of the ozone hole are understood and an effective societal response has been developed; and understanding of terrestrial carbon dynamics is enabling policy makers to establish CO_2 mitigation measures aimed at limiting climate change and its consequences.

Nevertheless, the challenges of the next decade and beyond will require significant changes to the scientific enterprise to improve further its capability to contribute to sustainable development. Accordingly, IGBP, together with its partners IHDP and WCRP, organised a workshop ("Sustainable Development — The Role of International Science, Paris, February 2002") to which representatives from core projects of the programmes as well as from other ICSU environment-related bodies were invited. The objective of the workshop was to review past achievements and to provide some insights on how science and scientists in the ICSU family may better contribute to sustainable development. Following the Global Change Open Science Meeting in Amsterdam (July 2001) concrete steps are being made to develop a science which is more relevant for sustainable development. The discussions at the Paris Workshop were intense and productive. It agreed that in the decade since the drafting of Agenda 21, the scientific community has vastly increased its role in supporting sustainable development but highlighted a new set of challenges, particularly the need for:

- More and better science. Research must move beyond a disciplinary focus to address sustainability issues in the framework of complex dynamical systems.

- Long-term perspectives. Archives from the past - ice cores, tree rings, archaeological and historical records - must be studied more vigorously to provide trajectories of change, baseline conditions, insights into past societal resilience or fragility and perspectives on projections of future change.

- Broad-based, participatory approaches to research. Traditional divides in the scientific enterprise - among disciplines; between science and policy, business and civil society; between contemporary and traditional approaches - must be bridged from the outset of work to its final applications.

- Capacity building and communication. Science for sustainability must be undertaken globally; the scientific community in the North must better engage and support colleagues in the South.

- Education and communication: The wider need for education in sustainability issues implies increased engagement by scientists in primary education, teacher training and public communication of scientific results. The value and results of science in meeting the sustainability challenge in all parts of the globe must be communicated effectively.

Merging agendas

The results of the Paris workshop discussions were summarised in a short document [3] that was sent to ICSU as input to the report they were preparing for the fourth and last preparatory meeting of the WSSD in Bali in June 2002. ICSU incorporated a significant part of the suggestions from the workshop [4].

The major outcome of the WSSD is the Johannesburg Plan of Implementation. It is a 54-page document [5] and in the area of science the Plan puts emphasis on:

- capacity building in developing countries

- improving decision-making through improved collaboration between natural and social sciences, and scientists and policy makers

- local and indigenous knowledge

- making more use of integrated and international scientific assessments

The discussions from our research community and from the global policy community are thus clearly converging around shared priorities. A major challenge to the Earth System Science Partnership (ESSP, which comprises IGBP, IHDP, WCRP and DIVERSITAS) is then how we move ahead to

1) broaden the engagement from our scientists and projects in discussing how we can improve the relevance of our science for sustainable development and

2) set priorities and implement them the coming ten to fifteen years.

Can we unite around a common vision and together develop 'our own Agenda 21'? As a first step to support this, a longer report from the Paris workshop is being prepared as a discussion document for the Scientific Committee meetings of the four ESSP programmes in 2003. Initiatives already undertaken by the ESSP include the three joint projects on carbon, food systems and water. There are also some thoughts on working on global scale indicators for sustainable development. In an effort to increase the direct dialogue between our programmes and the global policy-making community, IGBP, IHDP and WCRP were invited to the 17th meeting of the Subsidiary Body on Scientific and Technological Advice (SBSTA) of the United Nations Framework Convention on Climate Change in Delhi in October 2002. The above ESSP programmes provided statements to the plenary, as well as actively contributing to the discussions in an official question-and-answer side event. SBSTA particularly had in mind to collect inputs on the content for the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

Science has already achieved much in support of sustainable development. To ensure sustainable development for all of the planet's people and for the Earth as a whole, now and into the future, the Earth System Science community should commit to helping to build an improved, integrative, participatory and usable science that is applicable from local to global scales.

ICSU, at its 27th General Assembly in Rio de Janeiro in September 2002, adopted several resolutions aimed at raising the attention of the scientific community to such fundamental commitments. ICSU has just launched a "Priority Area Assessment of Environment in Relation to Sustainable Development". The review will include participation from all four ESSP programmes and will be finalised in June 2003. Furthermore, ICSU in consultation with other partners is setting up an ad hoc planning committee for developing a science plan for sustainable development [6]. There is thus a larger context within which the ESSP activities in this area are taking place. For comments and input on the results of the Paris workshop and ideas for future action please contact João Morais (morais@igbp.kva.se) or Sylvia Karlsson (karlsson.ihdp@uni-bonn.de).

This article is based on the ESSP statement to ICSU, which was a summary of the conclusions from the workshop "Sustainable Development—The Role of International Science", 4-6 February 2002, Paris [3]. It has been updated by Sylvia Karlsson (IHDP Secretariat) and João Morais (IGBP Secretariat).

References

1. For a summary of major outcomes of the WSSD see http://www.johannesburgsummit.org/html/documents/summit_docs/2009_keyoutcomes_commitments.doc).

2. ESSP statement to ICSU: http://www.ihdp.uni-bonn.de/html/initiatives/initiatives.html

3. Agenda 21: http://www.un.org/esa/sustdev/agenda21text.htm. (Chapter 31 addresses the role of scientists and Chapter 35 the role of science for implementation).

4. For ICSU's report to the 4th Preparatory Meeting of the WSSD see http://www.icsu.org, where you can also see a report on all the ICSU-related activities before and during the WSSD.

5. Johannesburg Plan of Implementation: http://www.johannesburgsummit.org/html/documents/summit_docs/2309_planfinal.htm

6. see http://www.icsu.org - Resolution 6 of the 27th GA Resolutions.

IGBP in Transition

As IGBP is restructuring and entering a new phase, we would like to inform you about final stages of the BAHC core project, its major achievements, and its contributions to the new activities that IGBP has initiated in its second phase.

BAHC: Biospheric Aspects of the Hydrological Cycle

The original aim of BAHC (http://www.pik-potsdam.de/~bahc/, http://www.igbp.kva.se), which was established as an IGBP core project in the late 1980s, was to improve our understanding of how ecosystems and their components affect the water cycle, freshwater resources and partitioning of energy on Earth. To address this overall goal, the project had four quite specific objectives:

1. Development, testing and validation of models representing the transfer of water and energy through the soil, vegetation and atmosphere
2. How to aggregate the land-surface properties and fluxes from a varied landscape up to the regional scale
3. To better understand temporal and spatial diversity of biosphere-hydrosphere interactions at the global scale
4. To develop techniques to downscale general circulation model ouput for impact studies (the weather generator).

These objectives reflect the state of understanding at that time. The dominant paradigm then was that the Earth's environment was largely controlled by the coupled dynamics of the planet's two great fluids - the atmosphere and the oceans. There was much debate in the global change community on whether biology had any significant role at all to play in Earth System dynamics. The terrestrial biosphere was considered to be a passive recipient of the impacts of changes in ocean-atmosphere dynamics; it was a spectator rather than a player in the functioning of the Earth System. Water and energy exchange between the land and the atmosphere was regarded in the same way. Indeed, the specific BAHC objectives listed above are highly suggestive of the terrestrial biosphere being thought of as a lower boundary condition for the atmosphere, where all of the action occurred.

Now, a bit more than a decade later, one the most important overall findings of IGBP research, highlighted at the Global Change Open Science Conference in Amsterdam in July 2001 and in the Amsterdam Declaration on Global Change, is that biology is a much more important player in Earth System dynamics than was earlier thought. More than any other core project in IGBP, BAHC research had led to that conclusion. The achievements of BAHC over the past decade (as presented in the BAHC Science Synthesis book [1], in the forthcoming BAHC Science Series [2] and a planned special section for the journal Science) thus go well beyond its original, more narrow remit; rather, they provide a new perspective on the interplay between two important components of the Earth System - the hydrological cycle and the terrestrial biosphere.

In particular, we highlight four major aspects of the science presented in the BAHC Synthesis volume that exemplify this new perspective.

First, the role of the biosphere as an active player in the dynamics of the Earth System has not only been demonstrated in general but has been described in some detail. Several aspects of this work are particularly important. The relative (and often opposing) roles of biophysical and biogeochemical feedbacks of the terrestrial biosphere to the climate system have been outlined clearly. The interaction between biosphere and atmosphere via the hydrological cycle has been elucidated, through both measurement and modelling, and at scales from local to global, including the often troublesome meso- or landscape scale. This understanding has allowed the importance of feedbacks of land-use and land-cover change to the physical climate system to be understood in ways not appreciated a decade ago.

Second, the role of the terrestrial biosphere in modulating the lateral transfer of water and materials between the land and the ocean has been emphasised. Although the lateral transport of water has long been recognised as critical in the functioning of the physical climate system, its role in biogeochemical cycling is often overshadowed by a focus on the fluxes of trace gases and aerosols between the land surface and the atmosphere. BAHC science goes a long way towards redressing that imbalance.

Third, this work makes important contributions to the development of an holistic Earth System science approach. One of the strengths of BAHC has been its ability to place its work in the broader context of the Earth System and to engage and collaborate with others to generate new insights into the workings of our life support system. The research on the coupled ocean-atmosphere-land dynamics has produced some of the most exciting results within IGBP over the past decade. It shows how the nonlinear dynamics of the Earth System, revealed through the increasingly rich palaeo-record, can only be understood by considering the interactive coupling of components of the Earth System.

Finally, BAHC's research also reaches out towards the water resource management community in a number of ways. Perhaps most significantly, BAHC has developed a new vulnerability-based approach towards projecting the effects of a rapidly changing global environment on water resource systems. The strength of the approach lies in its focus on the internal structure and dynamics of the water resource systems themselves, and on the multiple and interacting nature of the various factors, local to global, that impact on these systems.

The past decade has been one of achievement, excitement and surprise, and it has raised new questions and challenges that have caused us to reflect on the nature of global change science and its ability to rise to these new challenges. The outstanding success of BAHC encourages us to meet these challenges. The science presented in the BAHC Synthesis volume provides a critical underpinning for, and acts as a bridge to, the new approaches and structures needed to build a more integrative Earth System science. Significant parts of the BAHC community are spearheading the development of a new IGBP project focused on the Land-Atmosphere interface (ILEAPS), which is to be launched at the beginning 2004. The objective of the Land-Atmosphere project within the framework or IGBP II (ILEAPS stands for Integrated Land Ecosystem – Atmosphere Processes Study) is to provide further understanding of how interacting physical, chemical and biological processes transport and transform energy and matter through the land-atmosphere interface. ILEAPS specifically addresses the implications for the dynamics of the Earth System, and the role the human component of the Earth System plays in it. In that scientific context ILEAPS naturally has multiple points of contact with the new Land project, IGAC II, LOICZ, GAIM and PAGES; and will closely interact with WCRP (GEWEX).

Another large segment of the BAHC community is playing a significant role in the development of a project on global change and the water system – The Joint Water Project (JWP) of the Earth System Science Partnership (www.jointwaterproject.net). The JWP addresses the question of how are humans changing the global water cycle, the associated biogeochemical cycles, and the biological components of the global water system, and what are the feedbacks to socio-economic systems and to the Earth System arising from these changes.

We wish to acknowledge that the results and successes of the BAHC programme are based on hard work of many individual scientists and teams around the world, who associated their research objectives with those of IGBP-BAHC.

We would like to thank you for your continued interest and support for the BAHC project and we hope that you share with us the excitement about the new phase of IGBP and the innovative research that will be undertaken.

Pavel Kabat
Chairman, BAHC Scientific Steering Committee,
Co-Chair, ILEAPS Transition Team
E-mail: P.Kabat@Alterra.wag-ur.nl

Holger Hoff
Executive Officer, BAHC International Project Office
E-mail: hhoff@pik-potsdam.de

Sabine Lütkemeier
BAHC International Project Office
E-mail: sabine.luetkemeier@pikpotsdam.de

For more information about BAHC, see also http://www.pik-potsdam.de/~bahc/

References

1. Kabat P, Claussen M, Dirmeyer PA, Gash JHC, Bravo de Guenni L, Meybeck M, Pielke Sr RA, Vörösmarty CJ, Hutjes RWA. and Lütkemeier S. (eds), 2003. Vegetation, Water, Humans and the Climate: A New Perspective on an Interactive System. The IGBP Series. Springer Verlag, Heidelberg, 650 pp, ISBN 3-540-42400-8

2. The BAHC Science Series is a 30-page illustrated summary of the Synthesis volume, to be published in the IGBP Science Series in 2003. This brochure makes BAHC's results available to a wider range of audiences, in particular the policy and resource management communities. A version will be available on the IGBP web site (http://www.igbp.kva.se) or in hard copy from the IGBP Secretariat in 2003.

People and events

The IGAC project (International Global Atmospheric Chemistry) has two new co-Chairs, Sandro Fuzzi and Shaw Chen Liu, who will join Tim Bates (introduced in NewsLetter 49):

Sandro Fuzzi is presently Research Director at the Institute of Atmospheric Sciences and Climate of the Italian National Research Council, in charge of the Atmospheric Chemistry Program. His main research interests are the physical and chemical processes in multiphase atmospheric systems, aerosols and clouds, and their effects on atmospheric composition change and climate. Over the past ten years, Dr. Fuzzi has been co-ordinator of the projects "Ground-based Cloud Experiments" (GCE) and "Processing of Trace Constituents in Clouds over Europe and the Consequences for Cloud Properties" (PROCLOUD) within the EUREKA Program EUROTRAC. He is also member of the Science Panel of the European Commission on Atmospheric Composition Change and of the International Commission on Clouds and Precipitation. Dr. Fuzzi has been involved within the IGAC activity "Aerosol-Cloud Interaction" for several years and has been a member of the IGAC Steering Committee since 2000. He is also a member of the Italian IGBP Committee.

Dr. Shaw Chen Liu is a Distinguished Research Fellow and the chief of Environmental Change Research Project of Institute of Earth Sciences, Academia Sinica, Taipei, Taiwan. He also serves as a joint-professor at the Department of Atmospheric Sciences, National Central University. Before joining Academia Sinica, Dr. Liu taught at Georgia Institute of Technology where he held the Georgia Power/Georgia Research Alliance Eminent Scholar Chair and Professorship at the School of Earth and Atmospheric Sciences. Before that Dr. Liu served for about 15 years as the chief of Theoretical Aeronomy Program at Aeronomy Laboratory of the National Oceanic and Atmospheric Administration.

Dr. Liu is a Fellow of the American Geophysical Union. He was Editor-in Chief of the Journal of Geophysical Research-Atmospheres from 1988 to 1991. Dr. Liu's research interests focus on the understanding of atmospheric chemistry and global and regional budgets of trace gases and aerosols that affect air quality and climate. He has worked extensively on a number of IGBP/IGAC research activities since early 1990s, particularly on atmospheric chemistry field experiments over the Pacific. He has been serving as a member of the IGAC Scientific Steering Committee since 2000. In addition, he is currently co-chairing the SPARC/IGAC Climate-Chemistry Initiative.

Cisco Werner is the new Chair of GLOBEC. He first became associated with GLOBEC in 1999 when he joined the GLOBEC SSC and became Chairman of its Modeling and Predictive Capabilities Focus Working Group. He serves on the US GLOBEC SSC and is co-Chair of the PICES (North Pacific Marine Science Organization) MODEL Task Team.

Dr. Werner is presently at the University of North Carolina at Chapel Hill, USA, where he is a Professor and Chairman of the Department of Marine Sciences. Originally from Venezuela, Dr. Werner completed his graduate work in oceanography at the University of Washington in Seattle. His research, conducted also at Dartmouth College (Hanover, New Hampshire) and the Skidaway Institute of Oceanography (Savannah, Georgia), has focused on the development of circulation of coastal ocean models and their coupling to trophodynamic individual-based models of planktonic and early life stages of marine organisms. Recent research efforts also include the implementation of real-time modelling of circulation on continental shelf region of the southeastern US with the aim of establishing an operational coastal ocean observing system with forecasting capabilities. Dr. Werner has led training programmes in Chile, Venezuela and Mexico on modelling coupled physical-biological interactions in marine systems and he serves on the editorial board of Fisheries Oceanography.

The New Chair of PAGES will be Dr Julie Brigham-Grette, although she will not take up the post fully until 2004. Until then, Dr Vera Markgraf will be interim Chair for 2003.

Vera Markgraf is Research Professor of Geography and Fellow of the Institute of Arctic and Alpine Research, University of Colorado, Boulder, USA. Her speciality is South America and Southern Hemisphere palaeoclimates and inter-hemispheric palaeoclimate correlations. She has been involved with PAGES for many years, including chairing the PEP 1 (Pole-Equator-Pole Americas Transect) IGBP-PAGES research initiative, from 1990 to 1999, and working with past climate linkages between the three PEP transects (PAGES-INTERPEP).

Julie Brigham-Grette is a Professor of Geology at the University of Massachusetts Amherst, USA. She specialises in Quaternary stratigraphy, with a strong interest in the climate evolution of the Arctic regions on all time scales. Her research interests focus on the glacial and sea level history of NE Russia, Quaternary palaeoclimate history of El'gygytgyn Crater Lake in NE Siberia, and the palaeoceanography and sea level history of the Bering Straits region.

IGBP and Related Global Change Meetings

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

IGBP: OCEANS Transition Team Meeting

6 January, Paris, France (also 12-13 January)

Contact: Wendy Broadgate, wendy@igbp.kva.se

JGOFS: 4th North Atlantic Synthesis Group (NASG) Meeting

7 January, Toulouse, France

Contact: Véronique.Garçon, Veronique.Garcon@cnes.fr

Joint Water Project: Meeting in collaboration with IGOS-P Water Cycle theme workshop

7-8 January, Washington DC, USA

Contact: Rick Lawford, richard.lawford@noaa.gov

Workshop on Water Resources in South Asia: An Assessment of Climate Change-Associated Vulnerabilities and Coping Mechanisms

7-9 January, Kathmandu, Nepal

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

IGBP: SCOR International Open Science Conference "OCEANS": Ocean Biogeochemistry and Ecosystems Analysis

7-10 January, Paris, France

Contact: Wendy Broadgate, wendy@igbp.kva.se or
Ed Urban, scor@jhu.edu or http://www.igbp.kva.se/obe/

IGBP: Ocean Vision Workshop

11 January, Paris, France

Contact: Karin Lochte, klochte@ifm.uni-kiel.de

IOC-SCOR-GCP International Ocean Carbon Coordination Workshop

13-15 January, Paris, France

Contact: Maria Hood, m.hood@unesco.org

IGBP Book Series

The aim of the Series is to present major results of IGBP research – at both the project and programme-wide level – in a single series. The volumes emphasise the key findings of the programme and each is based on an integration of a large body of work carried out around the world under the auspices of IGBP.

The IGBP Synthesis project, involving most IGBP projects, is currently in progress, and is producing a set of state-of-the-science volumes on the nature of the changing environment of the Earth and prospects for the future.

IGBP Newsletter readers are entitled to a 10% discount. To take advantage of this special offer, please use the order forms available through the IGBP website:

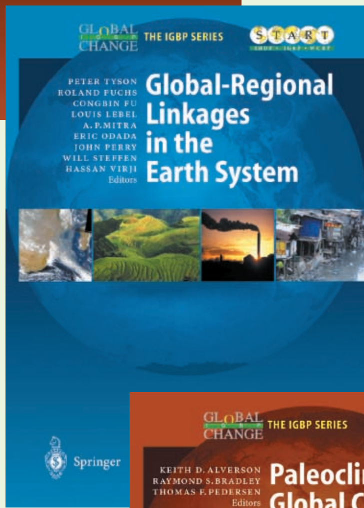
www.igbp.kva.se/books/

Either follow the links to order online, or print and fax or post the order to the address given.

Challenges of a Changing Earth (Proceedings of the Global Change Open Science Conference, Amsterdam, the Netherlands,10-13 July 2001).

An overview of global change and its consequences for human societies.

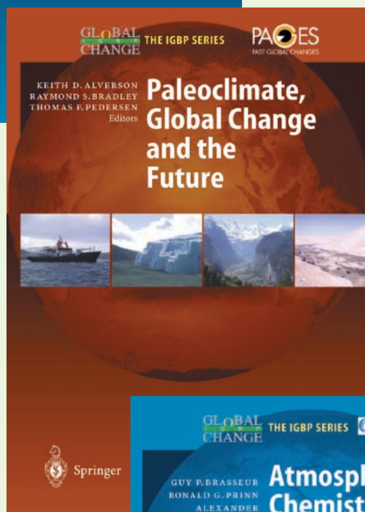
Steffen W, Jäger J, Carson DJ, Bradshaw C (Eds.)



Global-Regional Linkages in the Earth System

Synthesises current knowledge of regional-global linkages to demonstrate that change on a regional scale can enhance understanding of global-scale environmental changes (START).

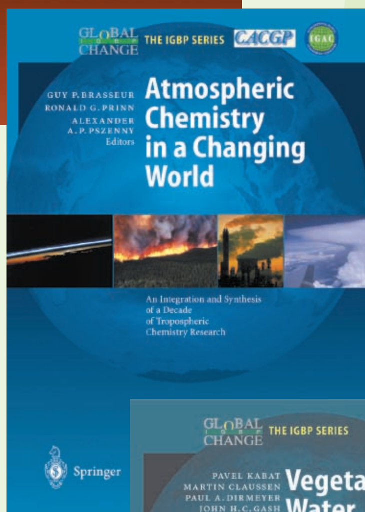
Tyson PD, Fuchs R, Fu C, Lebel L, Mitra AP, Odada E, Perry J, Steffen W, Virji H (Eds.)



Paleoclimate, Global Change and the Future

A synthesis of a decade of research into global changes that occurred in the Earth System in the past (PAGES).

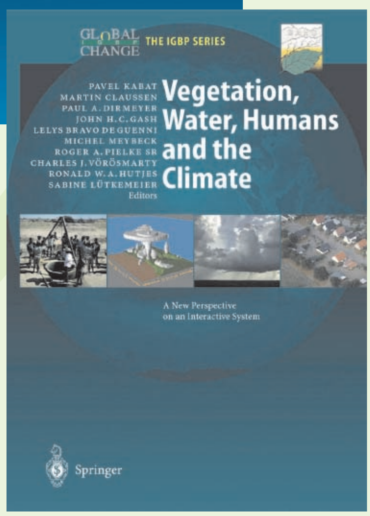
Alverson KD, Bradley RS,
Pedersen TF (Eds.)



Atmospheric Chemistry in a Changing World

Summary and integration of more than a decade of atmospheric chemistry research (IGAC).

Brasseur GP, Prinn, RG, Pszenny AAP (Eds.)



Vegetation, Water, Humans and the Climate

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

An overview of the influence of the terrestrial vegetation and soils within the Earth System (BAHC).

To pre-order this book (Kabat et al), please contact Cora Boesenach (Email: c.d.a.boesenach@alterra.wag-ur.nl) before 28 Feb 2003

Springer

GLOBAL IGBP CHANGE

GLOBEC: -NEP/CGOA Symposium on Marine Sciences in the Northeast Pacific: Science for Resource Dependent Communities

13-17 January, Anchorage, Alaska

Contact: Hal Batchelder, hbatchelder@coas.oregonstate.edu

IGBP: 18th SC-IGBP Meeting

20-23 January, Punta Arenas, Chile

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

IGBP: Symposium "Global Change: Toward a Systemic View"

23-25 January, Punta Arenas, Chile

Contact: Marìa Soledad Astorga, mastorga@aoniken.fc.umag.cl or Laura Gallardo, lgallard@dim.uchile.cl or http://www.cmm.uchile.cl/scc2003/

IGBP: IPO Meeting (in conjunction with 18th SC-IGBP)

25 January, Punta Arenas, Chile

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

IAI-IGBP Meeting

27-28 January, Mendoza, Argentina

Contact: Gerhard Breulmann, gerhard@dir.iai.int

JGOFS: PANGAEA-JGOFS Data Management Workshop

27-29 January, Bremen, Germany

Contact: Margarita Conkright, mconkright@nodc.noaa.gov or Bernard Avril, bernard.avril@jgofs.uib.no

Workshop and Symposium: The Budgets of GHGs, Urban Air Pollutants, and their Future Emission Scenarios in Selected Mega-Cities in Asia.

4-5 February, 2003

Contact: H. Imura, imura@genv.nagaoya-u.ac.jp

ASLO Aquatic Sciences Meeting

8-14 February, Utah, USA

Contact: Helen Schneider Lemay, business@aslo.org or http://www.aslo.org/slc2003

Synthesis Workshop on Sustainable Livelihoods and Biodiversity in the Uplands of Southeast Asia: a Multicultural Assessment of Resilience, Risks, and Opportunities.

27-28 February, TBA, TBA

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

ESSP: Scoping Meeting for a 4th Joint Project on Health

27 February-1 March, Paris, France

Contact: Anne-Hèlène Prieur Richard, prieur_richard@icsu.org

SC-IHDP Meeting

05-07 March, Bonn, Germany

Contact: Lisa Jibikilayi, jibikilayi.ihdp@uni-bonn.de

APN Science Planning Group Meeting

10-11 March, Hanoi, Vietnam

Contact: APN Secretariat, info@apn.gr.jp

APN Inter-Governmental Meeting

13-14 March, Hanoi, Vietnam

Contact: APN Secretariat, info@apn.gr.jp

JGOFS: The JGOFS Data Management Task Team (DMTT)

13-15 March, Bidston, UK

Contact: JGOFS IPO, jgofs@uib.no

3rd World Water Forum

16-23 March, Kyoto, Shiga and Osaka, Japan

Contact: http://www.worldwaterforum.org

START: Integrated Regional Study of Global Change in Asia Session in conjunction with the XX Pacific Science Congress

17-21 March, Bangkok, Thailand (tentative dates)

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

START: AIACC Regional Workshop for the Asia Pacific

24-28 March, Bangkok, Thailand

Contact: Sara Beresford, sberesford@agu.org

International Workshop on "Global Change, Sustainable Development"

26-28 March, Tashkent, Uzbekistan (tentative dates)

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

International Symposium on Climate Change (ISCC)

31 March-3 April, Beijing, China

Contact: Mr.Wang Bangzhong, Ms.Zhang Yan or Ms.Chao Qingchen, ISCC@cma.gov.cn

European Geophysical Society/AGU/EUG Joint Assembly 2003

6-11 April, Nice, France

Contact: EGS Office, egs@copernicus.org or http://www.copernicus.org/EGS/egsga/nice03/programme/overview.htm

Framing Land Use Dynamics: Integrating knowledge on spatial dynamics in socio-economic and environmental systems for spatial planning in western urbanized countries

16-18 April, Utrecht University, The Netherlands

Contact: Organising Congress Bureau, framingland@fbu.uu.nl or http://networks.geog.uu.nl/conference

JGOFS: 18th JGOFS Scientific Steering Committee Meeting

4 May, Washington, DC, USA

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

JGOFS: Final JGOFS Open Science Conference: "A Sea of Change: JGOFS accomplishments and the Future of Ocean Biogeochemistry"

5-8 May, Washington, DC, USA

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

GLOBEC: GLOBEC-PICES-ICES Zooplankton Production Symposium

21-23 May, Gijon, Spain

Contact: Luis Valdes, luis.valdes@gi.ieo.es

Rights and Duties in the Coastal Zone: Multidisciplinary Scientific Conference on Sustainable Coastal Zone Management

12-14 June, Stockholm, Sweden

Contact: Tore Söderqvist, tore@beijer.kva.se or Christina Leijonhufvud, chris@beijer.kva.se or http://www.beijer.kva.se/conference.htm

AGU Chapman Conference on Ecosystem Interactions with Land Use Change

14-18 June, Santa Fe, New Mexico, USA

Contact: Ruth DeFries, rd63@umail.umd.edu or Greg Asner, greg@globalecology.stanford.edu or http://www.agu.org/meetings/chapman.html

GLOBEC: 8th GLOBEC Scientific Steering Committee

18-19 and 24 June, Banff, Canada

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

IGBP: OCEANS Transition Team Meeting

18-19 and 24 June, Banff, Canada

Contact: Penny Cooke, p.cooke@niwa.co.nz

PAGES: PAGES Scientific Steering Committee Meeting

18-19 June, Banff, Canada

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

Global Carbon Project: Scientific Steering Committee Meeting

18-19 June, Banff, Canada

Contact: GCTE IPO, gcte@gcte.org

LUCC: LUCC Scientific Steering Committee Meeting

19 June, Banff, Canada

Contact: LUCC IPO, lucc.ipo@geog.ucl.ac.be

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GCTE: GCTE Scientific Steering Committee Meeting

19 June, Banff, Canada

Contact: GCTE IPO, gcte@gcte.org

SOLAS: SOLAS Scientific Steering Committee Meeting

19 and 24 June, Banff, Canada

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

LOICZ: LOICZ Scientific Steering Committee Meeting

19 and 24 June, Banff, Canada

Contact: LOICZ IPO, loicz@nioz.nl

IGBP: LAND Transition Team Meeting

24 June, Banff, Canada

Contact: gcte@gcte.org

IGBP: 3rd IGBP Congress

19-24 June, Banff, Canada

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

IGAC: IGAC Scientific Steering Committee Meeting

24 June, Banff, Canada

Contact: IGAC IPO, igac.cpo@unh.edu

LOICZ: 6th Regional Symposium PACON 2003: Ocean Capital Year

29 June-2 July, Kaohsiung, Taiwan

Contact: http://www.hawaii.edu/pacon

SOLAS: SOLAS Summer School

30 June-11 July, Corsica, France

Contact: Corinne Le Quèrè, lequere@bgc-jena.mpg.de or http://www.bgc.mpg.de/~corinne.lequere/solas/

IUGG 2003 (International Union of Geodesy and Geophysics)

1-9 July, Sapporo, Japan

Contact: http://www.jamstec.go.jp/jamstec-e/iugg/index.html

Coastal Zone 03: Coastal Zone Management Through Time

13-17 July, Baltimore, USA

Contact: http://www.csc.noaa.gov/cz2003

The Impact of Global Environmental Problems on Continental & Coastal Marine Waters

16-18 July, Geneva, Austria

Contact: http://www.unige.ch/sciences/near

XIVth Global Warming International Conference & Expo

27-30 July, Boston, USA

Contact: http://www.globalwarming.net

START: Urbanization, Emissions and the Carbon Cycle Institute

3-24 August, Boulder, CO, USA

Contact: Amy Freise, afreise@agu.org

START: Advanced Institute on Urbanization, Emissions and the Global Carbon Cycle

4-22 August, Boulder, CO, USA

Contact: Amy Freise or afreise@agu.org or http://www.start.org

Studying Land Use Effects in Coastal Zones with Remote Sensing and GIS

13-16 August, Kemer/Antalya, Turkey

Contact: http://www.ins.itu.edu.tr/rslucoast1/

PAGES: 9th International Paleolimnology Symposium

24-28 August, Otaniemi Espoo, Finland

Contact: Atte Korhola, Atte.Korhola@helsinki.fi or Veli-Pekka Salonen, Veli-Pekka.Salonen@helsinki.fi or Antti Ojala, antti.ojala@gsf.fi

2nd International Swiss NCCR Climate Summer School: 'Climate Change: Impacts on Terrestrial Ecosystems

30 August-6 September, Switzerland, Grindelwald

Contact: http://www.nccr-climate.unibe.ch/events/SummerScool/03/information.html

SCOR: SCOR Executive Committee Meeting

15-18 September, Moscow, Russia (tentative dates)

Contact: Ed Urban, scor@jhu.edu

GAIM: and WGCM, WCRP: - International Conference on Earth System Modelling

15-19 September, Hamburg, Germany

Contact: Annette Kirk, annette.kirk@dkrz.de

World System History and Global Environmental Change

19-22 September, Lund, Sweden

Contact: http://www.pages.unibe.ch/calendar/2003/lund.html

IHDP: Human Dimensions Open Science Meeting

16-18 October, Montreal, Canada

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

START: Young Scientists 1st International Global Change Conference

16-19 November, Trieste, Italy

Contact: Kristy Ross, kristy@crg.bpb.wits.ac.za

START: 17th START Scientific Steering Committee Meeting

19-22 November, 2003 Trieste, Italy

Contact: Ching Wang, xwang@agu.org

2004

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

31 March-3 April, Paris, France

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

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

2-6 May, Vancouver, Canada

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

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/

PAGES: PAGES Scientific Steering Committee Meeting

24-25 May, Beijing, China

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

PAGES: PAGES Open Science Meeting

26-28 May, Beijing, China

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

SOLAS: 1st SOLAS Science Conference

10-15 October, TBA, Canada (tentative dates)

Contact: Daniela Turk, solas@dal.ca

Correspondence

Sentinels For Severe Atmospheric Forcing Events

Letter to the Editor from Peter V. Hobbs

The International Global Atmospheric Chemistry (IGAC) project has proposed a new program of research (Global Change Newsletter, No. 50, June 2002). High on the list of IGAC goals is determination of climate forcing by changing emissions of gases and particles.

One of the most direct ways to investigate the susceptibility of the atmosphere to external forcings is to evaluate the effects of significant perturbations in particle and trace gas emissions, such as those produced by large volcanic eruptions and dust storms, or events such as the 1991 oil fires in Kuwait. To do this requires careful documentation of the nature of the emissions, their dispersal, their effects on the atmosphere, and their removal. At present there is no international organisational structure for the rapid deployment of observational facilities (e.g., research aircraft, and ground and space-based facilities) needed to obtain such information.

The International Geosphere-Biosphere Programme (IGBP), in combination perhaps with the World Meteorological Organization, is in an ideal position to organise an international rapid deployment capability. Appropriate components of the IGBP, such as IGAC, could determine the essential facilities needed to respond to a variety of perturbations with potentially large effects on the atmosphere. The IGBP could then request nations and organisations worldwide to commit to providing one or more of the needed facilities when called upon and at their own expense. Each such facility would become a sentinel for Severe Atmospheric Forcing Events (SAFE). Nations might even compete to provide the most sentinels!

The IGBP would be responsible for the designation of potentially severe atmospheric forcing events, and for deciding how the available sentinels should be deployed.

Sound fanciful? So did the Red Cross when it was proposed in 1862.

Peter V. Hobbs, Department of Atmospheric Sciences University of Washington,Seattle, Washington, USA,
E-mail: phobbs@atmos.washington.edu

Note to contributors

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

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

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

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

Required Image Quality for IGBP Publications

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

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

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

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

Deadlines for 2003:

March issue	Deadline for material: Feb 3, 2003
June issue	Deadline for material: May 5, 2003
September issue	Deadline for material: Aug 4, 2003

Send contributions by email to the Editor, Clare Bradshaw
E-mail: clare.bradshaw@igbp.kva.se;
Phone: +46 8 6739 593; Reception: +46 8 16 64 48;
Fax: +46 8 16 64 05

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Requests for reproduction of articles appearing in this distribution should be addressed to the Editor:

(E-mail: sec@igbp.kva.se)

NewsLetter requests and change of address information should be sent to:

IGBP Secretariat
The Royal Swedish Academy of Science
Box 50005, S-104 05 Stockholm,
Sweden

Tel: (+46-8) 16 64 48

Fax: (+46-8) 16 64 05

E-mail: sec@igbp.kva.se
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