Conclusions

Understanding plant migration and its exact consequences for ecosystem functioning and biodiversity still seems far from reach. Paradoxically, our understanding of local dispersal processes has, during the five years that separated the two workshops, benefited from theoretical and empirical advances motivated by long-distance dispersal issues. Recent findings suggest that landscape structure, rather than dispersal potential, might be the key to understanding past and future migrations.

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Challenges of a changing Earth

Josep Canadell and Ian Noble

The Challenges of a Changing Earth: Global Change Open Science Conference was held in Amsterdam, The Netherlands, from 10 to 13 July 2001.

Earth has entered an era that has no precedent. Human-driven changes are modifying the global environment at a speed that rivals and often surpasses the geological forcing that drives changes of climate, biogeochemical cycles and biodiversity. These changes are cumulative and interactive, with multiple feedbacks and teleconnections that result in highly nonlinear system behaviour. Abrupt changes and thresholds within periods relevant to the span of a single human generation that are found in paleo-records provide insights into such planetary dynamics. The current rapid global environmental change could take the Earth into a different state, with implications for its habitability.

Earth system science faces the challenge of integrating the physical, chemical, biological and human systems to form a new understanding of the Earth's dynamics in ways that we could not even imagine just a few years ago. In recognition of the need for an urgent scientific effort to take on this challenge, and to build towards a global sustainability agenda in light of increasing human perturbation, the three major global environmental change projects, the International Geosphere–Biosphere Program (IGBP), the International Human Dimensions Program (IHDP) and the World Climate Research Program (WCRP) jointly sponsored the Challenges of a Changing Earth, their first collaborative open science conference. With scientists from 100 countries, including more than 400 scientists from developing countries, this was the biggest and most internationally attended event in global change science that has taken place.

The conference encompassed a large range of topics dealing with the carbon cycle, water cycle, food production, biodiversity, land-use change and its feedbacks on climate change and variability. Areas considered worthy of special attention over the next decade of research include:

- Carbon sinks: can we rely on them? Many of the Earth's 'sinks' for CO_2 are vulnerable to human actions and only buy time to make fundamental changes in our use of fossil resources. Where do we go from here?
- Greenhouse gases and the climate system: for the past 420 000 years, the Earth system has operated so that CO_2 levels remain within tight bounds. In the past century, we have pushed CO_2 levels well beyond these bounds. What does the future hold?
- Can technology spare the planet? It is tempting to believe that our technological ingenuity will save us from environmental hazards, but how much can we rely on technology to save us?
- Air quality in the 21st century: the 21st century will see changes in the chemistry of the atmosphere as a result of human activities. What can be done to ensure that we have clean air to breathe?
- Mega-cities and global change: mega-cities (those with more than one million inhabitants) are growing in both extent and number. What impacts will they have and how vulnerable are they to global change?
- Our changing land: nearly 50% of the land surface has been significantly transformed by our actions and only ~5% remains pristine. What do such massive changes mean for the functioning of the planet?
- El Niño Southern Oscillation: some of the most important effects of climate change will come from its influence on El Niño. Will El Niño events become more frequent in the future?

Box 1. The Amsterdam Declaration on Global Change

The scientific communities of four international global change research programmes [the International Geosphere-Biosphere Programme (IGBP), the International Human Dimensions Programme on Global Environmental Change (IHDP), the World Climate Research Programme (WCRP) and the international biodiversity programme DIVERSITAS] recognize that, in addition to the threat of significant climate change, there is growing concern over the ever-increasing human modification of other aspects of the global environment and the consequent implications for human well-being. Basic goods and services supplied by Earth, such as food, water, clean air and an environment conducive to human health, are being affected increasingly by global change.

Research carried out over the past decade under the auspices of the four programmes to address these concerns has shown that:

- The Earth system behaves as a single, self-regulating system comprising physical, chemical, biological and human components. The interactions and feedbacks between these components are complex and exhibit multi-scale temporal and spatial variability. Our understanding of the natural dynamics of the Earth system has advanced greatly in recent years and provides a sound basis for evaluating the effects and consequences of human-driven change.
- Human activities are significantly influencing Earth's environment in many ways in addition to greenhouse gas emissions and climate change. Anthropogenic changes to the land surface, oceans, coasts, atmosphere, biological diversity, the water cycle and biogeochemical cycles are clearly identifiable beyond natural variability. They are equal to some of the great forces of nature in their extent and impact. Global change is real and is happening now.
- Global change cannot be understood in terms of a simple cause–effect paradigm. Human-driven changes cause multiple effects that cascade through the Earth system in complex ways. These effects interact with each other and with local- and regional-scale changes in multidimensional patterns that are difficult to understand and even more difficult to predict.
- Earth system dynamics are characterized by critical thresholds and abrupt changes. Human activities could inadvertently trigger such changes with severe consequences for Earth's environment and inhabitants. The Earth system has operated in different states over the past 500 000 years, with abrupt transitions (a decade or less) sometimes occurring between them. Human activities have the potential to switch the Earth system to alternative modes of operation that might prove irreversible and less hospitable to humans and other life. The probability of a human-driven abrupt change in Earth's environment has yet to be quantified but is not negligible.
- In terms of some key environmental parameters, the Earth system has moved well outside the range of the natural variability exhibited over the past 500 000 years at least. The nature, magnitudes and rates of changes now occurring simultaneously in the Earth system are unprecedented. The Earth is currently operating in a no-analogue state.

On the basis of these concerns, the international global change programmes urge governments, public and private institutions and people of the world to agree that:

- An ethical framework for global stewardship and strategies for Earth system management are urgently needed. The accelerating human transformation of the Earth's environment is not sustainable. Therefore, the business-as-usual way of dealing with the Earth system is not an option. It has to be replaced – as soon as possible – by deliberate strategies of good management that sustain the Earth's environment, whilst meeting social and economic development objectives.
- A new system of global environmental science is required. This is beginning to evolve from complementary approaches of the international global change research programmes and needs strengthening and further development. It will draw strongly on the existing and expanding disciplinary base of global change science; integrate across disciplines, environment and development issues and the natural and social sciences; collaborate across national boundaries on the basis of shared and secure infrastructure; intensify efforts to enable the full involvement of developing country scientists; and employ the complementary strengths of nations and regions to build an efficient international system of global environmental science.

The global change programmes are committed to working closely with other sectors of society and across all nations and cultures to meet the challenge of a changing Earth. New partnerships are forming among university, industrial and governmental research institutions. Dialogues are increasing between the scientific community and policymakers at several levels. Action is required to formalize, consolidate and strengthen the initiatives being developed. The common goal must be to develop the essential knowledge base needed to respond effectively and quickly to the challenge of global change.

- The Kyoto Protocol: are there better options?

Conference highlights

Several hundred papers were presented that reported on a wide range of topics and components relevant to the Earth system science focus of the conference. However, most of the contributions and interest were focused on four topics, including: (1) the carbon cycle and the relevance of carbon sinks for atmospheric CO_2 stabilization; (2) food production and security under global change; (3) water availability; and (4) conservation of biodiversity and its relevance for ecosystem functioning.

The carbon cycle

Human activities have pushed the concentrations of both CO_2 and CH_4 well above limits experienced during the past half-million years and have done so at a rate many times faster than have natural rates of variability. Several speakers reported on the reliance of these atmospheric concentrations on the current global carbon sources and sinks. Robert Scholes (CSIR Division of Water, Environment and Forest Technology, Pretoria, South Africa) reported that there is increasing evidence that both the terrestrial and ocean carbon sink will

not last indefinitely. Modelling studies show that a decline in strength of the terrestrial carbon sink will occur around the year 2050, although the ocean sink will remain strong for longer but will also eventually decline.

Food production

Authors from the International Institute of Applied Systems Analysis (IIASA) from Austria released a report during the conference showing that 40 of the world's poorest countries are likely to face food production losses as high as 25% because of global warming. Guenther Fischer, one of the authors of the study, said that although more than half of developed countries are expected to benefit from climate change (including the effects of increasing atmospheric CO_2), countries such as Australia, Belgium, The Netherlands and the UK are likely to be harmed, as are many developing countries, including Brazil, Bangladesh, India and many sub-Saharan African countries.

Water availability

Today, ~2 billion people are suffering from water stress, and models predict that this will increase to >3 billion (or ~40% of the population) by the year 2025 (Charles Vörösmarty, University of New Hampshire, NH, USA). There will be winners and losers in terms of access to safe water and the world's poor nations will again be the biggest losers. Countries already suffering severe water shortages, such as Mexico, Pakistan, Northern China, Poland and countries in the Middle East and sub-Saharan Africa will be hardest hit.

Biodiversity

Extinction rates are increasing sharply in marine and terrestrial ecosystems around the world; we are now in the midst of the sixth great extinction event in Earth's history, and the first one caused by the activities of a single biological species. Mark Spalding (UNEP-World Conservation Monitoring Centre, Cambridge, UK) reported that, in the 1990s, the golden toad of Costa Rica was possibly the first victim to climate change. In 1998, such impacts were moved up to the ecosystem level, with the wholesale collapse of coral reefs in the central Indian Ocean linked to a rapid warming of the ocean surface. Land-use change, however, is still the number one cause for the rapid decline of species and its associated consequences on ecosystem stability and functioning.

The outcome

As a result of the conference, 'The Amsterdam Declaration on Global Change' (Box 1) was produced in recognition of the challenge of a more integrative Earth science system and the need to develop basic principles on global sustainability. Over 1000 scientists from around the world signed the declaration. For further information on the outcomes of the conference, visit http://www.sciconf.igbp.kva.se/fr.html.

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