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Sustaining Earth's life support systems – the challenge for the next decade and beyond

by Berrien Moore III, Chair, IGBP

Integration, interdisciplinarity, and a systems approach mark the emerging ethos in IGBP as the Programme evolves rapidly into its second decade of international global change research.

In late February in Cuernavaca, Mexico, the Scientific Committee of the IGBP held a landmark meeting in which it was decided that the strength and maturity of the Programme would allow an increased emphasis on the systemic challenges of Global Environmental Change. The strength has been made particularly apparent in the developing Core Project syntheses.

This strength and capability of the IGBP at this point in time is extraordinarily valuable since the SC-IGBP also recognised that the challenges of Global Environmental Change demand a treatment of the full Earth System. It is simply a reality that a scientific understanding of the Earth System *is required* to help human societies develop in ways that sustain the global life support system.

The core of the IGBP Programme for the next decade will be built around three interlocking and complementary structures:

- Core projects that focus on key processes will continue to be the foundation for the IGBP;
- A formal integrated study of the Earth System as a whole, in its full functional and geographical complexity over time, and

- A focus on three cross-cutting issues where advances in our scientific understanding are required to help human societies develop in ways that sustain the global life support system.

The research will be undertaken in the context of an expanding and strengthening collaboration with the International Human Dimensions Programme on Global Environmental Change (IHDP) and the World Climate Research Programme (WCRP). The new challenge is to build, on our collective scientific foundation, an international programme of Earth System Science. This effort will be driven by a common mission and common questions, employing visionary and creative scientific approaches, and based on an ever-closer collaboration across disciplines, research themes, programmes, nations, and regions.

Driving the new structures and approaches are two critical messages that have become ever clearer through the past decade plus of global change research.

First, the Earth functions as a system, with properties and behaviour that are characteristic of the system as a whole. These include critical thresholds, 'switch' or 'control' points, strong nonlinearities, teleconnections, and unresolvable uncertainties. Understanding components of the Earth System is critically important, but is insufficient on its own to understand the functioning of the Earth System as a whole.

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The “Anthropocene”

by Paul J. Crutzen and Eugene F. Stoermer

The name Holocene (“Recent Whole”) for the post-glacial geological epoch of the past ten to twelve thousand years seems to have been proposed for the first time by Sir Charles Lyell in 1833, and adopted by the International Geological Congress in Bologna in 1885 (1). During the Holocene mankind’s activities gradually grew into a significant geological, morphological force, as recognised early on by a number of scientists. Thus, G.P. Marsh already in 1864 published a book with the title “Man and Nature”, more recently reprinted as “The Earth as Modified by Human Action” (2). Stoppani in 1873 rated mankind’s activities as a “new telluric force which in power and universality may be compared to the greater forces of earth” [quoted from Clark (3)]. Stoppani already spoke of the anthropozoic era. Mankind has now inhabited or visited almost all places on Earth; he has even set foot on the moon.

The great Russian geologist V.I. Vernadsky (4) in 1926 recognized the increasing power of mankind as part of the biosphere with the following excerpt “... the direction in which the processes of evolution must proceed, namely towards increasing consciousness and thought, and forms having greater and greater influence on their surroundings”. He, the French Jesuit P. Teilhard de Chardin and E. Le Roy in 1924 coined the term “noosphere”, the world of thought, to mark the growing role played by mankind’s brainpower and technological talents in shaping its own future and environment.

The expansion of mankind, both in numbers and per capita exploitation of Earth’s resources has been astounding (5). To give a few examples: During the past 3 centuries human population increased tenfold to 6000 million, accom-

panied e.g. by a growth in cattle population to 1400 million (6) (about one cow per average size family). Urbanisation has even increased tenfold in the past century. In a few generations mankind is exhausting the fossil fuels that were generated over several hundred million years. The release of SO₂ globally about 160 Tg/year to the atmosphere by coal and oil burning, is at least two times larger than the sum of all natural emissions, occurring mainly as marine dimethyl-sulfide from the oceans (7); from Vitousek et al. (8) we learn that 30-50% of the land surface has been transformed by human action; more nitrogen is now fixed synthetically and applied as fertilizers in agriculture than fixed naturally in all terrestrial ecosystems; the escape into the atmosphere of NO from fossil fuel and biomass combustion likewise is larger than the natural inputs, giving rise to photochemical ozone (“smog”) formation in extensive regions of the world; more than half of all accessible fresh water is used by mankind; human activity has increased the species extinction rate by thousand to ten thousand fold in the tropical rain forests (9) and several climatically important “greenhouse” gases have substantially increased in the atmosphere: CO₂ by more than 30% and CH₄ by even more than 100%. Furthermore, mankind releases many toxic substances in the environment and even some, the chlorofluorocarbon gases, which are not toxic at all, but which nevertheless have led to the Antarctic “ozone hole” and which would have destroyed much of the ozone layer if no international regulatory measures to end their production had been taken. Coastal wetlands are also affected by humans, having resulted in the loss of 50% of the world’s man-

groves. Finally, mechanized human predation (“fisheries”) removes more than 25% of the primary production of the oceans in the upwelling regions and 35% in the temperate continental shelf regions (10). Anthropogenic effects are also well illustrated by the history of biotic communities that leave remains in lake sediments. The effects documented include modification of the geochemical cycle in large freshwater systems and occur in systems remote from primary sources (11-13).

Considering these and many other major and still growing impacts of human activities on earth and atmosphere, and at all, including global, scales, it seems to us more than appropriate to emphasize the central role of mankind in geology and ecology by proposing to use the term “anthropocene” for the current geological epoch. The impacts of current human activities will continue over long periods. According to a study by Berger and Loutre (14), because of the anthropogenic emissions of CO₂, climate may depart significantly from natural behaviour over the next 50,000 years.

To assign a more specific date to the onset of the “anthropocene” seems somewhat arbitrary, but we propose the latter part of the 18th century, although we are aware that alternative proposals can be made (some may even want to include the entire holocene). However, we choose this date because, during the past two centuries, the global effects of human activities have become clearly noticeable. This is the period when data retrieved from glacial ice cores show the beginning of a growth in the atmospheric concentrations of several “greenhouse gases”, in particular CO₂ and CH₄ (7). Such a starting date also coincides with James Watt’s invention of the steam

engine in 1784. About at that time, biotic assemblages in most lakes began to show large changes (11-13).

Without major catastrophes like an enormous volcanic eruption, an unexpected epidemic, a large-scale nuclear war, an asteroid impact, a new ice age, or continued plundering of Earth's resources by partially still primitive technology (the last four dangers can, however, be prevented in a real functioning noösphere) mankind will remain a major geological force for many millennia, maybe millions of years, to come. To develop a world-wide accepted strategy leading to sustainability of ecosystems

against human induced stresses will be one of the great future tasks of mankind, requiring intensive research efforts and wise application of the knowledge thus acquired in the noösphere, better known as knowledge or information society. An exciting, but also difficult and daunting task lies ahead of the global research and engineering community to guide mankind towards global, sustainable, environmental management (15).

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Contribution to the regional data bundle concept: The IGBP-DIS – MEDIAS-France partnership

by Wolfgang Cramer, Chair, IGBP-DIS

There is little doubt of the importance of the regional scale for Earth System Science and the need to study systemic features of Earth System functioning at that scale. A variety of tools are required for integrated regional studies, but a crucial element in the strategy is the development and application of regional 'data bundles'.

The concept of regional data bundles was first proposed at the 1998 DIS SSC meeting in Toulouse, and has now been developed further as a major activity aimed at promoting an integrated suite of regional studies. The implementation of the regional data bundle concept will be undertaken, *inter alia*, as a partnership between IGBP-DIS, START and MEDIAS-FRANCE.

Regional data bundles consist of a consistent collection of databases, data products, in-situ measurements as well as remotely sensed data. Data bundles may include models and/or model output at regional scale. Special attention is given to the presentation of the various data sets in order to facilitate their visualization and interpretation for research purposes.

Considerable work on regional databases has already been undertaken in association with IGBP:

- The Miombo CD-ROM, coordinated by START, LUC and IGBP-DIS, is an early version of a regional data

bundle but is essentially a 'one-off'.

- LBA (the Large-scale Biosphere-Atmosphere Experiment in Amazonia) has its own data and information system, well developed and a good model for other large regional studies.
- Specific data functions have been established in some START regional secretariats, such as Nairobi (Pan-African) and Bangkok (Southeast Asia).
- The IGBP Terrestrial Transects have developed their own data sets.

However, these initiatives are largely independent of one another, making comparability across regions virtually impossible. What is needed now is coordination of these data activities to build up a coherent global picture from the various regional studies. This requires much more consistency and coherence across the various data initiatives, as well as a common framework for process studies and modelling.

MEDIAS-FRANCE is well placed to contribute to the implementation of a coordinated approach to the regional data bundle initiative. MEDIAS has acted as a regional coordinating secretariat for START, acting through projects funded by the EU's ENRICH programme and through the START Fellowship/Visiting

Scientist Programme. MEDIAS also works in close cooperation with PASS (Pan African START Secretariat), its counterpart regional structure in Africa.

In addition, MEDIAS-FRANCE is already involved with several IGBP core projects – PAGES, JGOFS, IGAC - to develop computer tools for the generation of new databases for IGBP research projects. More recently, MEDIAS-FRANCE has been asked by IGAC to develop an original tool to assist its Synthesis and Integration project. MEDIAS also maintains a "mirror" site of the global PAGES database belonging to the World Data Center-A for paleoclimatology in Boulder, USA.

Based on these existing strengths of MEDIAS, its experience in regional data development, and its knowledge of IGBP, the French space agency CNES has offered to allocate resources via MEDIAS to support a major effort over the next 2-3 years to produce a coherent set of regional data bundles. IGBP-DIS will provide guidance for the effort, and will rely on input from START, GAIM and the core projects, many of which have their own sets of regional studies.

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