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International Collaboration Schemes in Earth and Environmental Sciences: IGEC Programmes and UNESCO IHP

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Abstract

There is a lack of studies that investigate how internationalization of science can effectively contribute to the globalization of environmental knowledge. Two cases of international collaboration programmes are analyzed from a science and innovation research perspective: (1) The organizational scheme of the International Global Environmental Change (IGEC) programmes in the ICSU tradition, and (2) the International Hydrological Programme (IHP), led by UNESCO. The paper draws on two analytical distinctions: Firstly, following Turner et al. (1990), systemic global change is distinguished from local or regional environmental change that becomes global by worldwide accumulation. Secondly, collaboration programmes that belong to the social system of science are distinguished from programmes at the intersection of scientific and political spheres. Both cases are compared in terms of their (a) rationales for international collaboration, (b) their organisational structure and funding, (c) international participation and (d) linkages between problem structure and collaboration. Representative and contrasting examples, their juxtaposition illustrates actual strategies and various constraints faced by scientific and intergouvernmental agencies promoting international collaboration in S&T for sustainability and capacity development. The paper reports research of my ongoing dissertation project under the working title "Internationalization in environmental research: The case of freshwater".

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Introduction

This paper compares two cases of international collaboration schemes in earth and environmental sciences in the context of the debate on "International organizations and global environmental governance" (Berlin Conference 2005). The first objective of the paper is to introduce important international scientific collaboration programmes to a social science and multi-disciplinary audience. The second objective is to enter into a discussion on the organizational design of international scientific collaboration with regard to global environmental change that is either systemic or cumulative in character.

It is generally recognized that science is an essential player in a future sustainability transition (Biermann et al. 2002; Cash et al., 2003; Clark, Dickson, 2003). Yet scientific capacity itself is very unevenly distributed. At present, there are hardly any studies that investigate *how internationalization of science can effectively contribute to the globalization of environmental knowledge.* The motivation to look more closely at the connection between the global environmental change and international scientific collaboration is given by the extent and the pace of anthropogenic environmental changes and the associated challenges for society, both in developed and developing countries.

The past decades witnessed a strong increase in international scientific collaboration. Due to the character of scientific work organization, most scientific collaboration rests on the decision of individual researchers to work together (Stichweh, 1999).[1] The bottom-up collaboration between researchers can be measured by means of co-authorships in scientific publications. Between 1988 and 2001, the share of internationally co-authored publications increased from 8% to 18% of all articles.[2] Growth in international collaboration is observed across all disciplines, but large differences persist between the levels of international co-authorship in different fields (NSB, 2004: 5-44). The role of international programmes for collaboration in earth and environmental sciences is not well understood.

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1 The foundation of international science associations is another aspect of scientific internationalism, beginning in the later half of the 19th century (Drori et al., 2003).

2 Internationally co-authored publications are defined as publications with author affiliations from at least two different countries. Database Science Citation Index (SCI) and Social Science Citation Index (SSCI).

The entities of our comparison are very different. The first case refers to a set of four *International Global Environmental Change* (IGEC) programmes: the World Climate Research Programme (WCRP), the International Geosphere-Biosphere Programme (IGBP), the international programme on biodiversity science (DIVERSITAS) and the International Programme on Human Dimensions of Global Environmental Change (IHDP). The second case is the collaboration scheme of the *International Hydrological Programme* (IHP), a long-term intergovernmental programme led by UNESCO.

It is argued that research fields on global environmental change have different problem structures and that the social organization of international collaboration needs to take these differences into account in order to be effective. The IGEC programmes were chosen because WCRP and IGBP are the largest and most important international programmes in global environmental change research. Although it is much smaller in size, IHP was chosen because it forms a sharp contrast in its approach to collaboration and organizational design. The paper explores these programme missions, decision structures and funding arrangements to arrive at conclusions on *institutional strengths and weaknesses with regard to different types of global problems.* An overview of the comparison is given in Table 3 (p. 38).

The paper draws on two major analytical distinctions. First, following Turner et al. (1990), I distinguish between *systemic global changes* and *local or regional environmental changes* that become global by worldwide accumulation. This distinction refers to differential spatial extensions of research problems that are addressed by research fields on global environmental change. Second, I differentiate between GEC collaboration programmes that belong to the *social system of science*, while other programmes are *institutionalized at the intersection between the spheres of science and politics*. It is argued that the character of global environmental change (either systemic or cumulative) implies different cognitive scientific problem structures which affect the viability and effectiveness of international collaboration schemes.

Methodologically, the study is based on desk research and interviews with scientists. Only few studies have been published so far that investigate the phenomenon of international collaboration programmes in earth and environmental sciences from the perspective of sociology or history of science. For the present report, an extensive content analysis of the published literature, grey literature and websites was performed. Twenty interviews were conducted with key participants of international programmes in the USA, Germany (IGEC programmes) and France in 2004 and 2005 and during a three month stay at IHP secretariat, Paris in autumn 2005. The study is confined to institutional aspects and does not entail any judgement or evaluation of the scientific output of any of the international programmes.

Section (1) introduces the distinction between systemic and cumulative global change and related differences in the cognitive problem structure of earth and environmental science fields. Section (2) presents the IGEC programme type, followed by the intergovernmental IHP in section (3). Each of the two collaboration schemes are discussed in terms of (a) their main rationales for international collaboration, (b) their formal organizational structure, (c) the scope of international participation in the programme, and (d) the question of their cognitive problem structure. Section (4) discusses the results and offers preliminary conclusions.

1. Systemic and Cumulative Global Change and International Collaboration

Sociologists of science have studied the relationship between the *cognitive structure* of research fields and their respective *forms of social organisation* (Whitley, 2000; Knorr-Cetina, 1999). This perspective will be applied here to the relationship between the global extension of environmental problems (as an important dimension of the cognitive structure) and international collaboration (as an important dimension of the social organisation) in earth and environmental sciences. With respect to the cognitive structure, I follow Turner et al. who distinguish systemic and cumulative global change:

> "In the first or systemic meaning, *'global' refers to the spatial scale of operation or functioning of a system*. A physical system is global in this sense if its attributes at any local can affect its attributes anywhere else, or even alter the global state of the system. (…) Globally systemic changes need not be caused by global scale activity, only the physical impacts of the activity need to be global in scale, manifested through the systemic adjustments that follow. (…) In the second – the cumulative – sense, *'global' refers to the area or substantive accumulation of localized change*. A change is global in this sense if it occurs on a worldwide scale, or represents a significant fraction of the total environmental phenomenon or global resource. (…) If cumulative changes reach a global scale, it is typically as the consequence of worldwide or wide-spread human activity that may not be directly registered on the major geosphere-biosphere systems" (Turner et al., 1990: 15f.; cf. Kasperson/ Kasperson, 2001: 2).

The prime example of a global system is *the climate system*. According to the IPCC,

> "the climate system is an interactive system consisting of five major components: the atmosphere, the hydrosphere, the cryosphere, the land surface and the biosphere, forced or influenced by various external forcing mechanisms, the most important of which is the sun. Also the direct effect of human activities on the climate system is considered an external forcing. (…) Although the components of the climate system are very different in their composition, physical and chemical properties, structure and behaviour, they are all linked by fluxes of mass, heat and momentum: all subsystems are open and interrelated" (IPCC 2001, Vol.I, Ch. 1.1.2).

The global systems perspective has been extended to the concept of a total *Earth System* which emphasizes the coupling of the physical with the biological aspects. "In the context of global change, the Earth System has come to mean the suite of interacting physical, chemical and biological global-scale cycles (often called biogeochemical cycles) and energy fluxes that provide the conditions necessary for life on the planet. (…)" (Steffen et al., 2004: 10). An important challenge for an earth system science consists in the integration of human society:

"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, chaotic elements, and unresolvable uncertainties. Understanding the components of the Earth system is critically important, but is unsufficient on its own to understand the functioning of the Earth system as a whole. Humans are now a significant force in the Earth system, altering key process rates and absorbing the impacts of global environmental changes. The environmental significance of human activities is now so profound that the current geological era can be called the 'Anthropocene'." (IPCC 2001, Vol. I: 784).[3]

It is argued in this paper that differential spatial problem structures should affect the organization of a scientific field. *The major difference is that systemic global research depends on a global perspective, whereas research in cumulative global problems can be conducted independently at many places.* While observations and experiments in are undertaken on a broad range of spatial scales and may include the sun and other planets, they are carried out to inform theoretical frameworks of systemic functioning on a global scale. In turn, improved understanding of the global systems is seen as the essential prerequisite for predicting regional and local impacts of systemic change. Today, numerical models are at the core of such global frameworks. Their advancement requires large scientific and technical investments.

The reliance on global frameworks and the size of the required scientific and technical investments result in a *high degree of "mutual task dependence" among researchers in systemic fields.* Mutual task dependence is a concept introduced by Richard Whitley for the analysis of scientific fields as a particular form of work organization (Whitley, 2000). According to Whitley, "modern sciences essentially are systems of jointly controlled novelty production in which researchers have to make new contributions to knowledge in order to acquire reputations from particular groups of colleagues." The author emphasizes that coordination in scientific work "is not just a technical matter of integrating specialist contributions to common goals, but involves the organisation of programmes and projects in terms of particular priorities and interests" (ibid: 85; 89). Scientific fields differ in the degree of mutual dependence between scientists in making competent and significant contributions to the jointly controlled knowledge production.[4]

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3 In 1988 a NASA committee on Earth System Sciences under Francis Bretherton published a conceptual world model of the operation of the whole Earth as a system. This "so-called 'Bretherton wiring diagram' was very influential in establishing the concept of an Earth System Science" (Mooney, 1998: 40; cf. Schellnhuber, 1999).

4 "The degree of mutual dependence has two analytically distinct aspects. The first is the extent to which researchers have to use the specific results, ideas, and procedures of fel-

A high degree of task dependence tends to reduce the diversity of approaches used in parallel within one field. It implies that researchers at different places share a comparatively small number of global frameworks. For example, only a limited number of research centres worldwide are capable of developing and running the most advanced climate models that couple processes of the atmosphere, land surface, ocean and sea ice, aerosols and the carbon cycle.[5] A higher degree of mutual task dependence also correlates with a high appreciation for standardized methods of data collection and data management. For example, world data centres are a central element of international collaboration in systemic fields, which serve the collection, storing and processing of data, ensuring open access to scientific information (Greenaway, 1996: 160-163, 175; WMO, 2005: 10). Furthermore, stronger task dependence is likely to result in a comparatively higher level of stratification among scientists and among research institutions (elite-periphery structures).

Ecology, soil science and regional hydrology are examples of fields that typically focus their investigations on certain conditions in particular places. Almost by definition, the spatial resolution required to understand local and regional change is much finer than in global systems research. A finer spatial resolution is also often linked with a stronger adaptation of research approaches to specific local conditions. Certainly, theories and methods of "place-based" fields contain generalizations which make them applicable in different contexts and allow the accumulation and progress of knowledge across sites. Still, the mutual dependence of scientists at different sites remains weak, relative to systemic fields. *The combination of higher spatial resolution, greater attention to local specifics and lower task dependence between scientists or research sites favours a greater diversity of approaches.* It reduces the pressure for a standardization of methods and can also result in various standards applied in different regions.

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low specialists in order to construct knowledge claims which are regarded as competent and useful contributions. This can be called *the degree of functional dependence* between members of a field and refers to the need to co-ordinate task outcomes and demonstrate adherence to common competence standards. (…) The second aspect of mutual dependence refers to the extent to which researchers have to persuade colleagues of the significance and importance of their problem and approach to obtain a high reputation from them. This can be called the *degree of strategic dependence* for it covers the necessity of co-ordinating research strategies and convincing colleagues of the centrality of particular concerns to collective goals." (Whitley, 2000: 88; italics in original). Although these aspects are analytically distinct, they are rather difficult to separate in empirical investigations of scientific fields (Hohn, 1998). For simplification, it is assumed here that both aspects of task dependence are higher in systemic fields than in place-based fields of earth and environmental sciences.

5 On development stages of coupled modelling cf. Carson (2005).

A good *illustration of this place-based character of research* can be found in Stephen Bocking's study of "ecologists and environmental politics" (1997). Bocking presents four different research sites, all of which contributed in important, yet different, ways to the history of ecology. The four cases are the origins and early research of nature conservancy in Great Britain; the development of ecology at the Oak Ridge National Laboratory in Tennessee; the work of the Hubbard Brook ecosystem study in New Hampshire; research in fisheries ecology at the University of Toronto and the Ontario provincial government in Canada. Bocking demonstrates how inventions and new directions, that became influential in the discipline as a whole, evolved through scientists' skillful exploitation of the challenges, obligations and opportunity structures that presented themselves in the natural object and in the institutional environment at each particular place.

Research in the human dimensions of global environmental change is equally place-based. Although social processes cause systemic changes on the global scale, there are few if any examples of systemic global social drivers. Globally systemic conditions are not to be confused with universal anthropological conditions. Rather, there is a great variety of local and regional change and an increasing dynamic of interconnections by means of communication, travel and trade, as signified by the term "globalization". While there is worldwide diffusion of ideas, technologies and institutions, any strategy to manage anthropogenic fluxes still requires a deeper understanding of the local conditions and the meaningful differences among various places, regions and nations. *Consequently, the degree of mutual task dependence is low in the social sciences and there is considerable diversity of research approaches and traditions within and among the different disciplines*.

International collaboration is an important aspect of the social organisation of scientific fields. Of course, there are *general explanations for increasing collaboration* that are independent of the geography of the research object. Encounters and exchange among specialists are useful to extend their knowledge and abilities, and sometimes produce unexpected and creative outcomes. The access to international networks is part of scientists' competition for reputation within their fields. Barriers were lowered with decreasing costs for distant travel and communication. Also, as a consequence of the heightened publication pressure, co-authorships are increasingly used to acknowledge merely technical or institutional contributions, so that increases in institutional co-authorship may overestimate real changes in collaboration. Yet such general observations do not explain the prevailing differences in the level of internationalization among various environmental fields.

Because of the higher degree of mutual task dependence, it can be assumed that the *scientific interest to collaborate in large-scale, internationally coordinated schemes is stronger in systemic fields than in place-based fields* of research (all other things being equal). In systemic fields, "megascience" collaborations are built to advance global frameworks, connecting scientific capabilities and financial investments from many countries.[6] At the same time, the perceived transaction costs of large multi-national coordination are likely to be lower in systemic fields, because some research priorities can be derived from shared global frameworks and because methods and approaches are more standardized.

In place-based fields, the following specific motivations can be assumed. Place-based research is more often application-oriented, as for example in agronomy, forestry, water management or nature preservation, developing *methods and technologies* for the monitoring, management and preservation of natural resources and ecosystems. To varying degrees, these methods and techniques have to be modified and adapted to specific local conditions. Thus, a specific motivation for collaboration consists in the *exchange of experiences among particular sites*. Yet exchange per se does not imply a global perspective. *A global perspective comes into play with global assessments and capacity development.*

G*lobal assessments of cumulative changes* are in growing demand, partly to raise awareness of urgency among decision-makers and the public. However, a truly global perspective in place-based research requires a broad range of participating countries: since place-specific conditions are more important, investigations must be conducted in depth at a large number of places. Models and satellite remote-sensing can substitute for in-situ data to a lesser extent. For this reason, global assessments are often compilations of existing knowledge and include only some original research (e.g. Millenium Ecosystem Assessment, UNEP Global International Waters Assessment).[7]

From a normative point of view, *knowledge transfer and capacity development in emerging, transition and developing countries* is an essential issue. But we do not know to what extent capacity development actually motivates international scientific collaboration and how this collaboration can be most effectively enhanced. Since the management of environmental resources and capacity development are themselves place-based affairs, the paper draws particular attention to the question:

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6 OECD global science forum, formerly Megascience Forum, www.oecd.org; last accessed 14. 11. 2005.

7 www.millenniumassessment.org/en/index.aspx; www.giwa.net

What kinds of international collaboration programmes are effective in organizing scientific collaboration in place-based problems?

Section 2 and 3 analyze IGEC and IHP programmes in terms of (a) their main rationales for international collaboration, (b) their formal organizational structure, (c) the scope of international participation in the programme, and (d) the relation between cognitive problem structure and collaboration.

2. The IGEC Scheme

The World Climate Research Programme (WCRP), the International Geosphere-Biosphere Programme (IGBP), the biodiversity research programme DIVERSITAS and the International Programme on Human Dimensions of Global Environmental Change (IHDP) are a group of major international scientific collaboration programmes, sponsored by the International Council for Science. In organizing scientific collaboration, all programmes of the IGEC group share *common elements of design*. In terms of the number of scientists and the financial resources, WCRP and IGBP are much larger than IHDP and DIVERSITAS. As an abbreviation, the whole group is referred to in the following as the International Global Environmental Change (IGEC) programmes.[8]

The *International Council for Science (ICSU)* is a non-governmental organization with membership of international associations of natural science disciplines, such as the International Union of Geodesy and Geophysics (IUGG), and national scientific members. National scientific members are "institutions representing scientifically separate geographic areas", in many cases national scientific academies (Greenaway, 1996: 239). ICSU acts as a sponsor for all four IGEC programmes, in cooperation with other non-governmental and intergovernmental organizations.[9] The sponsoring role chiefly consists in enablement and support of contacts into the scientific communities and organization of meetings (cf. Andresen, Agrawala, 2002: 43). It also involves certain amounts of financial resources, mainly as seed money for the development of new programmes and projects, and for international meetings and workshops.

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8 Since the aim of the paper is to compare two types of organisational design and to discuss their comparative strengths, the description of the IGEC scheme aims at an ideal type and may not correspond equally well to every sub-programme and research area within IGEC.

9 WCRP is sponsored by WMO, UNESCO IOC and ICSU; IGBP by ICSU; DIVERSITAS by IUBS; ICSU-SCOPE, UNESCO, ICSU, and IUMS; IHDP by ISSC and ICSU.

In terms of sociological systems theory, the IGEC programmes belong to the functional system of science (Luhmann, 1992).[10] They are science-driven, committed to basic research and avoid direct engagement in national and international arenas of environmental politics. Nor is their structure centred on collaboration between governments. *The IGEC programmes are best described as institutionalized networks of scientists.* They build connections among scientists and funding sources from many different countries and in this sense may be called "international" or "transnational" interchangeably.

2.1 Rationales for International Collaboration

The basic idea of the IGEC programme type is that *a large number of scientists, of many national and institutional affiliations, coordinate their work according to one grand master plan to achieve shared scientific goals*. The scale of ambition is illustrated by the objectives of WCRP:

"to develop the fundamental scientific understanding of the physical climate system and climate processes needed to determine to what extent climate can be predicted and the extent of human influence on climate. The programme encompasses studies of the global atmosphere, oceans, sea and land ice, and the land surface which together constitute the Earth's physical climate system (…)".

A recurrent motive for grand strategy collaboration is to achieve *spatial coverage in research either on a global scale, in large transnational regions, or sometimes in very remote places* which may not fall under the jurisdiction of any one single nation, e.g. the polar regions or the open oceans. Global programmes are a means to coordinate simultaneous efforts at many sites around the world, including data collection, experiments and methods of data analysis and interpretation.

The first time in history that research was conducted in (nearly) all parts of the world in an internationally coordinated effort was the *International Geophysical Year (1957-58).*[11] The IGY included research in 14 different disciplinary areas under the umbrella

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10 The notion of science as a functional social system takes account of the fact that scientific communication and practice are intrinsically oriented toward the production of new knowledge. Sociological systems theory describes this basic rationale of scientific communication as the "functional code" of the science system. It maintains that the functional codes of different social systems, such as science, economics, politics, law, religion etc. are deeply distinct, in the sense that they cannot be reduced to one common denominator. Thus, the scientific orientation toward the production of new knowledge is held to be irreducible to other means of social coordination, such as monetary exchanges or power relations. The analytical notion of functional systems does not preclude the intermingling of spheres on the level of organisations and individuals' social roles where systems are often "coupled".

11 Mainland China withdrew from IGY just before the programme started (Hamblin, 2005: 90).

of geophysics. The most important criterion in selecting research topics for special attention during the IGY was that problems require "concurrent synoptic observation at many points involving cooperative observations by many nations". The IGY became famous for its scientific success and the inspiration it provided to subsequent international cooperation. It involved 60,000 scientists and technicians from 66 nations. It is generally held to mark the historical beginning of the ICSU tradition of international global change research.[12]

Another important rationale for large-scale international collaboration is to assemble the *critical scientific mass for new fields of enquiry*. Generally speaking, international collaboration has often been useful in developing and promoting new scientific themes because it builds connections among a group of people whose interest and expertise in the topic are as yet infrequent. In the history of earth sciences, international collaboration more than once had a catalysing effect, as for example in the case of numerical weather prediction, climate sciences, biogeochemistry or global terrestrial ecology (Harper, 2003; Miller, 2001; Weart, 2004; Malone, 1986; Mooney, 1998).

The IGBP is interesting in this regard, because it was explicitly designed to address global problems that required *interdisciplinary collaboration* of an 'unprecedented degree' (Rapley: 1999: 115). Large scientific problems which were never systematically addressed before almost by implication fall in between the lines of the already established specialities. Consequently, at the beginning they may depend on strong interdisciplinary efforts to arrive at promising approaches. In the case of IGBP, the new challenge was to link research on physical, chemical and biological processes in the earth system.[13] The IGBP (phase I) did not include research on the human dimensions of global environmental change.

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12 Figures from Doel, 2003: 647. According to Greenaway's history of ICSU, the "IGY was the beginning of the new view of the earth that characterised scientific cooperation in the second half of [the 20th] century" (Greenaway, 1996: 156). Malone states that "IGY marked the beginning of a new era of science of the human habitat" (1986: 8). During the same year, the first earth satellite, Sputnik I, was launched as part of the USSR IGY programme.

13 The objective of IGBP: "To describe and understand the interactive physical, chemical and biological processes that regulate the total Earth system, the unique environment it provides for life, the changes that are occurring in that system, and the manner by which these changes are influenced by human action"; cited after Malone, 1986: 8; Mooney, 1998: 38).

2.2 Organisational Structure and Funding

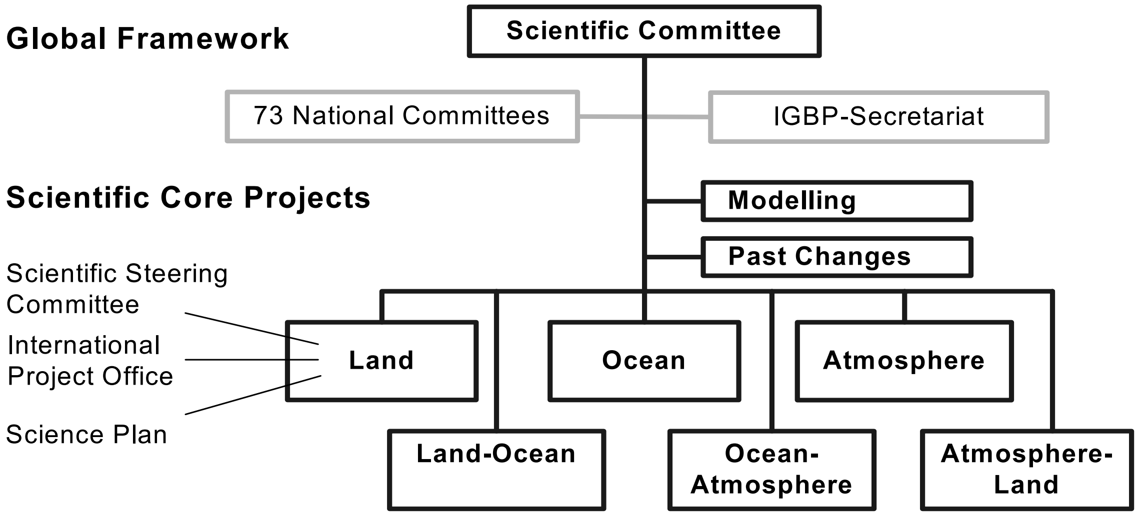
The central organizational challenge of the IGEC programme type is to align scientists and funding sources from many different national origins for large-scale, coordinated research. To this end, each of the four major programmes assembles a set of research projects or sub-programmes. These so-called *"scientific core projects" are the basic organizational units* for international collaboration. The project-based structure of the IGEC type represents an important contrast to the intergovernmental programme described in section 3. Each of the four programmes has *two levels of scientific leadership*: on the level of the scientific core project, research is led by an international group of scientists (scientific steering committee). On top of this, there is a scientific committee for overall programme coordination and integration (more detailed descriptions of these elements are given in Table 1).

Thematically, the scientific core projects are designed as complementary building blocks within the overall programme framework. As illustrated by the example of IGBP, *the IGEC type emphasizes the cognitive integration of the parts over the integration through hierarchical decision-making.* Figure 1 shows a simplified structure of IGBP (phase II). IGBP scientific core projects investigate the major compartments of the earth (land, ocean, the atmosphere) or the interfaces between them. Cross-cutting themes are the modelling of global systems and the paleohistoric investigation of past global changes.

Table 1 Components of the IGEC scheme

Major IGEC Programme • *Scientific committee*: distinguished scientists appointed by the sponsoring organizations. Its task is to provide overall scientific guidance for the research, to develop the overall scientific plans, to oversee their implementation and to help disseminate the results. • *Programme secretariat*: coordinates the central activities of the programme under the leadership of an executive director and with a small number of scientific and administrative staff.
Scientific Core Project • *Scientific steering committee:* undertakes the detailed planning and implementation of the scientific core project. It is composed of 10-20 scientists from different countries with three-year terms of appointment, once renewable. • *International project office:* supports the steering committee, the implementation of the project, the publication of results with staff on a full-time basis. • *Science Plan:* describes a core project's research objectives, concepts and methodological frameworks, for ca. a decade.

Figure 1 IGBP Structure (simplified)



Source: own drawing based on description of programme structure, footnote 9.

The most significant capital of the IGEC programme type is the allegiance and support by scientists from the respective scientific communities. Input and feedback from a larger scientific community by means of consultations, scientific workshops and conferences are sought especially during the planning phase of new scientific core projects, and for the review of achievements and the integration of results at the end of a programme phase. Chris Rapley, executive director of IGBP 1994-97 conveys the enthusiasm of one of these scientific meetings:

"In my opinion, the greatest success of the IGBP has been its demonstrated capacity to assemble such international, interdisciplinary groups. It has attracted nearly two hundred of the world's top ranking scientists to carry out the on-going planning and oversight of the programme, which now involves some ten thousand researchers and technical support staff from over one hundred nations (…). Last year, we brought all the Scientific Steering Committee members together for the first time, after nearly ten years; (…) We had Nobel Prize winners and Tyler Prize winners present, and the consensus view was that it was one of the most intellectually vibrant events that any of them had participated in, largely because the attendance list was like a "Who's who" of the bio- and geochemistry elements of Earth system science." (Rapley, 1999).[14]

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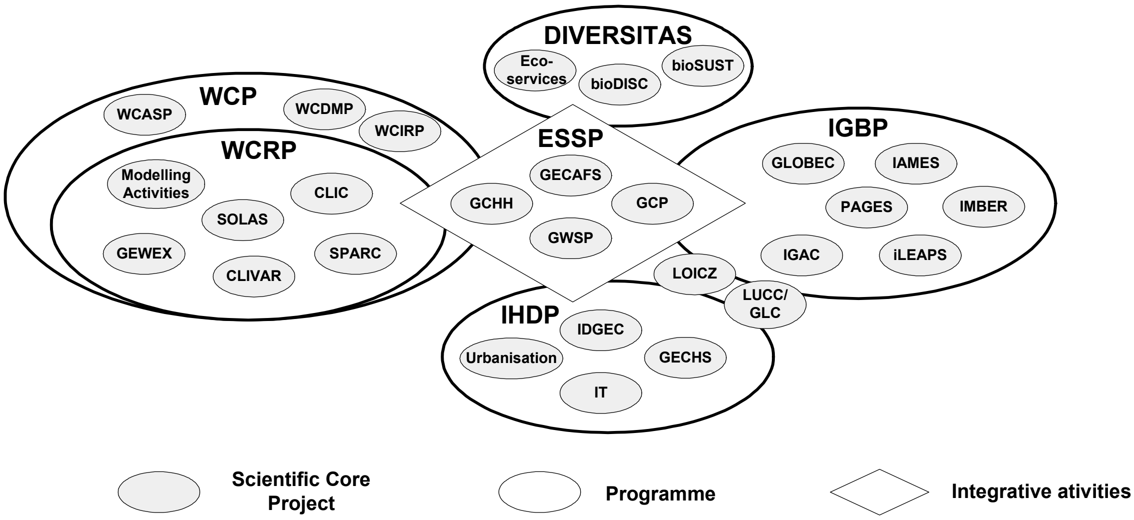
14 "In 1967 a Global Atmosphere Research Programme GARP was instituted jointly by ICSU and WMO. It was said of GARP's relation to ICSU and WMO that the two organisations not only represented non-governmental and governmental scientific structures, but *between them could claim to command allegiance of the whole of the atmospheric science community*. As described in a later chapter, GARP continued until it was eventually absorbed into the WCRP (1984)"; (Greenaway: 147; italics added).

Figure 2: Distributed Structure of the IGEC Programmes



Source: Adapted from WBGU (1996), updated for 2005. Acronyms refer to scientific core projects. Size differences of core projects and programmes not represented.

The network of the international project offices and the programme secretariat form the basic infrastructure that supports the research activities.[15] Since each core project has its own scientific leadership and supporting project office, the IGEC scheme is decentralized and has been referred to as "distributed megascience". The distributed structure facilitates programme growth, since new scientific core projects can be added within the global framework (Figure 2).

An important part of the challenge within the IGEC programme type is to achieve consistency and coherence in programme content while enlisting funding from national R&D funding agencies, which often target diverging research priorities. In practice, many IGEC scientific core projects do not have an overall budget at their disposal to implement their science plan. Rather, individual scientists and research groups approach their national funding agencies with research proposals that are approved by the core project's scientific steering committee. Another possibility which is increasingly sought is funding of European consortia by the European Union. In turn, the affiliation with a prestigious IGEC programme can improve a scientist's eligibility for national or EU research funding and thus is an incentive for participation. International project offices are mostly financed by the respective host country, and in some cases through systems of national contributions (interviews conducted by the author).

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15 Description of programme: www.igbp.kva.se/cgi-bin/php/frameset.php.

The network character and the fragmented funding sources restrict the viability of a hierarchic approach to programme integration. The achievement of coherence eventually depends to a large degree on the personal effort and time that participating scientists are able and willing to invest in exchange and integrative work. The following quote from H. Mooney, who played a central role in IGBP I, summarizes this experience:

"The reality of funding possibilities made IGBP a mix of bottom-up and top-down science. The IGBP planning process developed a community agreed-upon research agenda, based on a new research paradigm, and a structure to accomplish the required interdisciplinary research efforts. However, research funding, to a large extent had to come from the efforts of individual scientists captivated by the challenges and opportunities of a new kind of science. (…) funding for research for the IGBP is piecemeal coming mainly from national science programmes, most often not explicitly for one of the core projects. This is quite different than what happened with the IGY, or even the IBP, where funding was provided by governments specifically for these efforts. The more diffuse funding base for the IGBP has certainly been constraining but not totally limiting probably because of the dedication and conviction of the scientists involved. (…)" (Mooney, 1998: 47f.)

Furthermore, as a consequence of the scattered funding sources, it is *difficult to determine the total amount of funding for IGEC programmes*. As indicated, resources that scientists use for research under IGEC are often not explicitly earmarked for that purpose. IGFA estimated that R&D funding for *national and international* GEC research added up to a global total in the order of US $ two billion in 2001, excluding funding for satellite programmes (US $ 1,873 million from the countries represented in IGFA plus approximately 200 million from France and Japan). Resource assessments were undertaken twice so far, based on information requests to the funding agencies participating in IGFA. The assessment in 2004 has not been published (cf. IGFA, 2004). The first assessment estimated the total amount allocated to the international scientific core projects at US $ 513 million for 1995, almost entirely to WCRP and IGBP core projects.

The IGEC programmes IGBP, IHDP and DIVERSITAS set up national committees (currently in 73 countries for IGBP, 32 for IHDP and 30 for DIVERSITAS). Some countries have one common "Global Change National Committee". *The national committees serve as interfaces to GEC research at the national level and national S&T policies*: „National IGBP or Global Change Committees assist in the national coordination of relevant studies, facilitate linkages between national and international global change research, and often assist in the mobilization of funds to support the central activities of IGBP“.[16] In contrast, they are not conceived as communication channels between science and national environmental or climate policies.

16 www.diversitas-international.org/national.html#national;
www.igbp.kva.se/cgi-bin/php/ frameset.php.; last accessed 14. Nov. 2005

2.3 International Participation

Although IGEC programmes include efforts at capacity building, the prior possession of *advanced scientific and technical capabilities remains a practical prerequisite for any nation to contribute significantly to this type of large-scale scientific collaboration*. This is documented by comparing national affiliations of scientists who take a leading role in IGEC projects with output shares of the same countries in major publication databases.

While it is methodologically challenging to measure national scientific capacities in a comparable manner, publication output in peer-reviewed journals can serve as a first approximate indicator. National publication shares in the ISI databases Science Citation Index (SCI) and Social Sciences Citation Index (SSCI) show that *peer-reviewed scientific publication is heavily concentrated in a limited number of industrialized countries.*[17] In 2001, the twenty major producing countries together accounted for 88.3 % of world publication output as covered in the ISI database (SCI+SSCI); an additional 9.2 % were produced by the group of the next twenty scientifically medium-sized and small countries.[18] In 2001, the USA accounted for 30.9 % of all publications, followed by Japan with 8.8, the United Kingdom with 7.3 and Germany with 6.7 % (NSB, 2004: A5-35).[19]

An important synergistic dimension of IGEC programmes consists in the linkage of small and medium-sized countries with advanced scientific capabilities. Note that there are a number of countries with small but not insignificant output shares, as twenty-five countries in total contribute in the range of 0.5 and 5 % each. In interviews conducted by the author, scientists mentioned that the opportunities of collaboration through IGEC are especially valued by these scientifically small and medium-sized countries. Whereas scientifically large countries like the USA and Japan dispose of rather comprehensive capacities in earth observation and environmental disciplines for their own needs, even scientifically advanced countries like the Netherlands, Sweden or Switzer-

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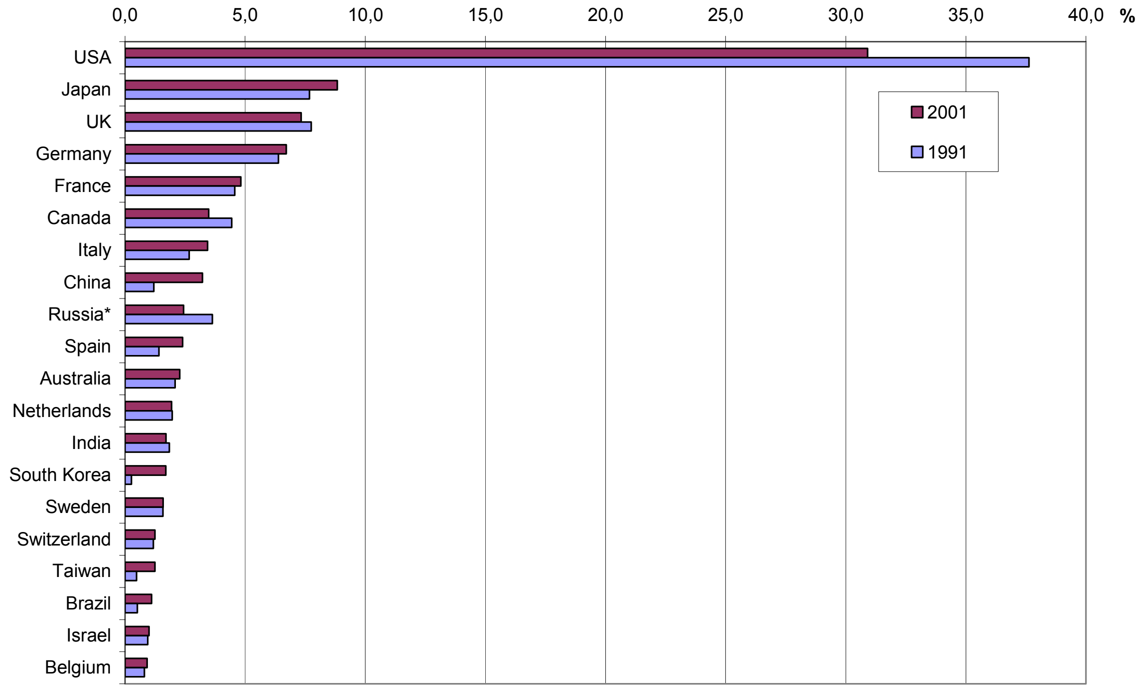
17 Since SCI covers only a selection of predominantly "international" English language scientific journals, this particular indicator may overestimate the actual concentration of scientific capacity. SCI is not just an objective indicator, but also a powerful formative channel of scientific attention (Weingart, 2005; Gibbs, 1995).

18 Shares are based on fractional assignments of publications. Total number of publications in the database: 649.795 in 2001; 466.419 in 1988 (NSB, 2004: A5-35).

19 The past two decades witnessed a slow decrease in output concentration. The relative decrease in scientific output from North America is mostly captured by countries from Asia and Western Europe. Brazil, Turkey, Mexico and Argentina are other examples of scientifically smaller countries with growing output shares. On the other hand, the output share of the whole region of sub-Saharan Africa decreased from 0,97% 1988 to 0,61% 2001 with an absolute decline in publication numbers of more than 12 %.

Figure 3: Output of 20 Major Producing Countries as Percentage of SCI + SSCI



Source: NSB (2004; 1993). Percentage based on fractional country assignment.

*1993 in place of 1991.

land, among others, would have difficulties to cover all relevant research fields. This is why they take advantage of a cooperative framework where they can contribute their own expertise and resources.

Beyond this circle of large and smaller advanced countries, the prerequisite of capacity limits the true scope of international collaboration in the IGEC programmes. As a proxy indicator for national scientific participation in IGEC, an analysis was performed of the national affiliations of scientists who were *members of the scientific steering committees* in WCRP, IGBP and IHDP scientific core projects in 2004. This gives a picture of the international composition of "IGEC scientists" in this year (Table 2).

If the 41 countries in Table 2 are compared to the list of the major scientific countries in Figure 3, two facts can be noted. Firstly, all of the twenty largest producing countries, with the exception of South Korea, have scientists steering IGEC projects, mostly several. Secondly, some Latin American, African and Asian countries (Chile, Colombia, Kenya, Ghana, Nigeria, the Phillippines, Indonesia, Malaysia, Nepal, New Caledonia, Sri Lanka and Thailand) are represented in IGEC steering committees at this point that have few publications measured in the SCI/SSCI, while some Eastern European countries (Poland, Czech Republic, Hungary and Ukraine) and Turkey are comparatively underrepresented in IGEC steering committees. *Overall, the international composition of IGEC steering committees is consistent with the distribution of national scientific output shares among the 20 largest producing countries*.

The IGEC programmes established a *capacity building programme* called "System for Analysis, Research and Training" (START). START "seeks to establish and foster regional networks of collaborating scientists and institutions in developing countries." The objectives of these regional networks are to *study regional aspects of global changes*, to assess impacts and vulnerabilities and to inform decision-makers in developing countries. Capacity building activities include training workshops, summer schools, the provision of fellowships, young scientists awards and small research grants.[20]

Table 2 International Participation in Scientific Steering Committees of IGEC Scientifc Core Projects[21]

SSC members per country	Countries	SSC members per category	Percentage	Cumulated percentage
64	USA	64	24.4	24.4
24	UK	24	9.2	33.6
10-20	Japan, Germany, Canada, Netherlands, China, Norway	78	29.8	63.4
5-9	Australia, France, Russia, Brazil, India, South Africa, Belgium, Sweden	55	21	84.4
2-4	Argentina, Chile, Kenya, New Zealand, Switzerland, Colombia, Finland, Italy, Mexico, Philippines	26	9.9	94.3
1	Austria, Denmark, Ghana, Greece, Indonesia, Israel, Malaysia, Nepal, New Caledonia, Nigeria, Portugal, RoC Taiwan, Spain, Sri Lanka, Thailand	15	5.7	100
Total	41 countries	262	100	

20 www.start.org; last accessed 14. Nov. 2005.

21 Based on membership lists on the programme websites as of September 2004. At this date there were yet no lists published for the new DIVERSITAS core projects.

2.4 Problem Structure and Collaboration

The IGEC programme type has been presented as a collaboration scheme that centres on systemic global change research. This is justified to the extent that the World Climate Research Programme and the International Geosphere-Biosphere Programme are by far the largest among the four, in terms of scientific manpower and funding. The predominance of the systemically global perspective is also expressed in the name of the joint initiative of all four programmes, which is called an "Earth System Science Partnership".[22] The very idea of an earth system science is to investigate the total of the interaction between geosphere, biosphere and society from a globally systemic point of view. *The "global master plan" approach in international research collaboration to date is intimately linked with the problem structure of systemically global change.*

The IGEC organizational scheme appears to be well adapted to organizing systemic global change research through its combination of distributed long-term scientific projects that are embedded in an integrated conceptual framework. It is not clear if the scheme is equally effective for international collaboration in place-based fields which have lower mutual task dependence. In the remainder of this section, it is asked *if the IGEC scheme has been applied with equal effectiveness in investigating cumulative place-based changes from a global perspective.* A strong conclusion cannot be drawn at this point because of a lack of comprehensive programme evaluations. The connection between problem structure and organizational structure is further explored through the presentation of the intergovernmental IHP scheme in section 3 and the comparison in section 4.

The IGEC group includes two programmes, the proper domains of which are global but not systemically global, namely the programmes in biodiversity (DIVERSITAS) and human dimensions of global environmental change (IHDP). While it has to be emphasized that no external evaluations of programme achievements are available, several indications point to *difficulties in the organizational development of both IHDP and DIVERSITAS*. One indicator is that both programmes had to be restructured and relaunched a few years after their initial start. Another indicator are the persistent difficulties to attain funding for international collaboration from national funding agencies. What is even more important, there also appear to be great differences in the allegiance and support different IGEC programmes can claim among their respective scientific fields.

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22 The "Earth System Science Partnership" consists of four new scientific core projects which are jointly sponsored by all four major IGEC programmes, focusing on the global carbon cycle, on worldwide food production, the global water system and health issues.

IHDP was first launched in 1990 as Human Dimensions Programme HDP by the International Social Science Council (ISSC). By the mid-1990s, the Scientific Council on Global Change of the German government reports that IHDP had not achieved advances comparable to IGBP (WBGU, 1996: 29). IHDP went through a major restructuring. In 1996 ICSU joined the International Social Science Council as a co-sponsor of the programme and the project secretariat was moved to Bonn. Since then, several new scientific core projects were established, while another major goal was to strengthen the links between IHDP and IGBP II through setting up collaborative core projects.[23] DIVERSITAS first started operating in 1991. From 1991 to 1998, the international secretariat of DIVERSITAS was hosted by the UNESCO programme "Man and the biosphere" (MAB). After that, the position of the executive director of the programme fell vacant due to insufficient funding. The programme was discontinued and formally re-launched in 2001-02, together with the celebration of an International Biodiversity Observation Year. Since then, two new core projects set up their International project offices in 2003-04, a third was still being negotiated in 2005. Since these are long-term projects, it is much too early to judge their success and the scale of scientific interest they evoke.[24]

The meeting reports of the International Group of Funding Agencies for Global Change Research (IGFA) regularly document the *difficult funding situation of IHDP and partly of DIVERSITAS*. In the 2004 meeting the executive director of IHDP, Barbara Goebel, deplored that "there is currently a mismatch between the increasing demand for human dimensions research and institutional involvement of IHDP and the operational limitation (work force and finance) that must be reconciled if IHDP is to function optimally". (IGFA, 2004: 28). Yet a severe deficiency in funding of IHDP was also stated in each of the preceding years since 1996, and the same applied to DIVERSITAS in the years 1998-2002 (IGFA reports 1996-2004). Thus it has to be concluded that, while both programmes are active in establishing international collaboration networks and in developing new themes of research in their respective disciplines, so far they have not been

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23 The IHDP scientific core projects investigate the topics of institutional dimensions of GEC, industrial transformation, GEC and human security, and urbanization. In recent years, three new core projects were sponsored by IHDP in collaboration with IGBP II, covering the topics of land-use and land-cover change, land, and land-ocean interactions. www.ihdp.uni-bonn.de; last accessed 14. 11. 2005.

24 Central themes of the three new core projects are the measurement and prediction of biodiversity loss, functional roles of biodiversity, conservation and the sustainable use of biodiversity and ecosystem services. The overall goal of the programme is "to promote an integrative biodiversity science linking biological, ecological and social disciplines (…) and to provide the scientific bases for the conservation and the sustainable use of biodiversity". DIVERSITAS Science Plan, (2002); www.diversitas-international.org.

able to reach scales of collaboration comparable to WCRP and IGBP in terms of research funds.

The funding problems of these particular international programmes certainly have to be viewed in a broader context, since research funding is unevenly distributed among the earth and environmental disciplines. *Traditionally, scientifically advanced nations have allocated larger investments to the understanding of the physical earth sciences than to the understanding of the biosphere and to the interactions of man and the biosphere.* This prioritization of physical earth sciences is deeply rooted in the history of the 20th century. Already during World War II and throughout much of the period of the cold war, geophysics, meteorology, oceanography and other earth science fields enjoyed more generous patronage than biological research of the environment. According to Doel,

> "the rapid rise of military funding for the earth sciences in the US after 1945 quickly elevated such fields as oceanography, atmospheric science, terrestrial magnetism, solid earth physics, and ionospheric studies, making them second only to physics in levels of support. (…) A great many other fields of science – including astronomy and most of the biological sciences (save for toxicology, physiology, and radiation ecology) – were far less affected by military patronage in the Cold War"; (Doel, 2003: 634, 639).[25]

Furthermore, it is now recognized that political and military interests in scientific collaboration played an important role in giving birth to the programme that stands at the beginning of the ICSU tradition of global change research programmes, the IGY.[26]

As a result of the sponsor organization's long tradition and experience in organising large-scale scientific collaborations and in high-level science-policy interaction, *climate research today enjoys the highest political visibility*. No other field of environmental research has an interface with intergovernmental politics that is comparable in this regard to the Intergovernmental Panel on Climate Change (IPCC) and its well-known

25 As archives of documents become declassified, historians of science have started to investigate the influence of military patronage on the development of the physical earth sciences in the US. Special Issue on the Earth Sciences and the Cold War, Social Studies of Science, 2003, Vol 33 (5).

26 "The IGY (…) was intimately connected with the national security aims of the leading nations involved in the effort. This was particularly so in the USA. (…) IGY programmes could secure earth science data from regions largely inaccessible during the cold war. (…) Geophysics, secrecy, data-collection, intelligence-gathering, and research agendas were closely interlinked because of the strategic place that the earth sciences occupied in Cold War national security policy" (Doel, 2003: 647; cf. Hamblin, 2005, chapter 3).

assessment mechanism (Agrawala, 1998; Siebenhüner, 2003).[27] Climate change is widely recognized as the driver of global change research (cf. Mooney, 1998: 120).

Yet this only brings us back to the question of the viability and the objectives of international collaboration schemes in areas of cumulative global change with a lower degree of mutual task dependence. In the case of the human dimensions programme, scientific observers point to a *lack of strong national scientific constituencies as a major obstacle.* Greenaway states with regard to the programme's first phase: "Although governments had high expectations of the social-science contribution, it proved difficult to bring HDP into operation, to some extent because ISSC had yet no tradition of major international research programmes, nor did it possess a strong constituency of national scientific members"; (Greenaway, 1996: 227). (In the case of ICSU, national scientific academies typically take the role of national scientific members). Today this view is repeated among major GEC funding agencies, concluding that among the causes for the persistent funding deficiency "you find the importance for IHDP to *build national constituencies of scientists who can channel the scientific interests of IHDP into relevant national funding bodies*"; (IGFA, 2003: 16).

In the case of biodiversity, the situation is different again, in that significant initiatives for international collaboration in ecology have also been developed outside the IGEC framework. Good examples are the International Long Term Ecological Research Networks, the Man and the Biosphere Programme and most recently the Millenium Ecosystem Assessment. *These programmes deal with the international collaboration in place-based research in different ways and thus would make interesting cases for further study.* (a) The US Long Term Ecological Research LTER programme was established by the National Science Foundation in 1980. It supports research at 26 sites in the USA that represent diverse ecosystems and research emphases. Each site "encompasses *unique ecosystems and research approaches*, investigators, students and management systems (…)".[28] Following this example, by 2004 28 countries had established formal national LTER programmes and joined the International LTER network. They collaborate in regional networks. (b) The UNESCO science programme "Man and the Biosphere" coordinates the World Network of Biosphere Reserves, including more than 440 sites in 97 countries, aiming at a reconciliation of conservation and resource

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27 "At the start of the twenty-first century the world was devoting several billion dollars a year to climate research. That sounded like a lot, yet it was less than was spent on many other scientific and technical problems. It barely sufficed for a subject where the fate of entire populations would be swayed by dozens of factors, each planetary in scope"; (Weart, 2004: 191).

28 www.lternet.edu/sites; last accessed 31.10.05; italics added.

use in the field.[29] (c) The Millenium Ecosystem Assessment was launched in 2001 to synthesize information on conditions, trends, scenarios and response options in the development of ecosystems and associated ecosystem services for decision-makers and the public. The MA includes a global assessment, completed in 2005, and "component assessments at different geographic scales".[30] In contrast to all the other examples, the MA is not a research programme, but assesses existing knowledge.

On the basis of the four IGEC programmes, it *can be concluded that both the comparatively more favourable conditions of research funding and the higher task dependence favour large-scale, coordinated collaboration efforts in systemic global change fields.* The IGEC type is an organizational structure that appears to be well adapted to organizing systemic global change research. As the examples from ecology, ILTER, MAB and MA, indicate, some place-based fields are also developing a strong scientific interest in a global perspective and they use a variety of organizational approaches to build understanding across scales (cf. Cash, 2000; Farell et al., 2003). The following section presents UNESCO's International Hydrological Programme as a scheme that deals with predominantly place-based problems. While IHP too is not comparable to WCRP and IGBP in size, the comparison of the different schemes can highlight issues and requirements that are pertinent to the organization of international collaboration in place-based fields.

3. The IHP Scheme

Among the specialized UN agencies, a great variety of programmes involve data collection and assessment of environmental conditions, but few are dedicated to scientific collaboration as their main purpose. The International Hydrological Programme (IHP) is one of these exceptions. It has been chosen for comparison because it originated from similar roots as the contemporary IGEC programmes. Invigorated by the success of the IGY and in parallel with other international science programmes reaching across the Iron Curtain, hydrologists set up an International Hydrological Decade (IHD) from 1965-1974, led by UNESCO and conducted in cooperation with other UN agencies. After the end of the hydrological decade, the IHP was founded (Batisse, 2005).

In terms of its scientific objectives and its realization as a large-scale coordinated effort, the IHD was similar to the IGEC type described in section 2 and shared the same rationales for collaboration. One of IHD's principal scientific outputs was a reliable esti-

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29 www.unesco.org/mab; last acessed 7.11.05.

30 www.milleniumassessment.org/en/subglobal.workgroup.aspx; last acessed 7.11.05.

mation of the global water balance. Prior to the IHD, estimations of the total size of the world's freshwater resources had differed widely. To this end, hydrological monitoring networks had to be created in a large number of countries and instruments and methods for data collection had to be standardized (Batisse, 1964).[31] Another major objective was to advance the establishment and recognition of hydrology as a scientific discipline.[32] From the beginning, *IHD/ IHP placed a strong emphasis on education,* particularly at the postgraduate level. During the IHD, approximately 800 hydrologists were trained. An emphasis on education was facilitated by the sponsorship of UNESCO, and in this regard IHD differed from the IGEC type (interview conducted by the author).

After the end of this decade of hydrological research, international collaboration was put on a more permanent basis through the creation of the International Hydrological Programme (IHP), still led by UNESCO (Batisse, 2005). The IHP is structured in successive five-year periods and has been in continual operation for over 30 years. *IHP activities focus on scientific collaboration, capacity building and education in water related topics.* Scientific collaboration projects typically start on a regional scale and, depending on the region, there is often no clear separation of research and capacity building objectives. Recent examples are the FRIEND regional hydrology programme which focuses on the exchange of data, knowledge and techniques from experimental basins and observation networks to improve understanding of hydrological variability and similarity across different regions.[33] Another example is the ISARM programme on transboundary aquifers which aims to assess and evaluate groundwater resources and to develop transboundary management policies. ISARM is conducted in collaboration with other UN specialized and donor agencies.[34]

Since the 1960s, the development of postgraduate study programmes has been part of the IHD/ IHP activities, including the creation of UNESCO chairs in water resources at universities. In 2003 the Dutch government dedicated a former Dutch institution, *the*

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31 "The more enduring legacy of the 1st IHD is the international data collection activity that for the first time provided worldwide sharing of information." (Entekhabi et al., 1999: 2056)

32 R. L. Nace, at the time responsible for hydrogeological research at the US Geological Survey and an initiator of the IHD: "A major purpose of the International Hydrological Decade is to gain worldwide realization that a science of hydrology exists, that teaching, training and research must be expanded enormously, and that many and varied career opportunities exist for hydrologists"; (Nace, 1964: 414). This objective brought allegiance and enthusiasm from scientists and engineers of different backgrounds working on water issues (interview by the author).

33 "Flow Regimes from International Experimental and Network Data" (FRIEND); Gustard and Cole (2002).

34 "International Shared Aquifer Resource Management" (ISARM), Puri and Aureli (2005).

Institute for Water Education IHE in Delft, to become an integral part of UNESCO. This institute has been working with developing countries for almost 50 years and is now the most important means of water education within UNESCO, while the Dutch government continues to provide most of the institutional funding and fellowships (IHP/IC-XVI/6). Other recent examples include IHP's support for staff training within the Department of Water Affairs in South Africa; or IHP training courses in collaboration with regional centres (IHP/IC-XVI/Inf.11).

3.1 Rationales for International Collaboration

The principal rationales for international scientific collaboration under IHP differ from those of the IGEC programme type. Following UNESCO´s official mandate, international cooperation in itself is a central value, because *it builds peace*. UNESCO's founding declaration maintains that "the defences of peace must be constructed in the minds of people". More recently, UNESCO defined its midterm strategy in terms of contributions to "peace and human development in an era of globalization through education, science, culture and communication" (UNESCO 31C/4, 2002). This justification does not confine itself to scientific and financial considerations, but assumes that international scientific collaboration supports the political goal of peaceful international relations and can be directed towards worldwide sustainable development as defined in the Millenium Development goals.[35]

As for the IHP in particular, its main objective is to advance member states' capacities in hydrological research and water resources management. According to the mission statement, IHP "is a vehicle through which Member States can upgrade their knowledge of the water cycle and thereby increase their capacity to better manage and develop their water resources (…)".[36] This statement clearly states the hybrid nature of IHP, since the scientific and technical advances are explicitly framed as *capacities owned and employed by individual nations*. Whereas the IGEC programmes' objective is to advance fundamental scientific understanding in a universal sense with scientific communities as their primary audience, IHP's mission comprises both: universal progress of understanding and technology, but also progress in relation to the existing level of water management capacity in each country. Consequently, education, training and technology transfer are also central objectives (IHP/IC-XVI/9: pp 6).

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35 www.un.org/milleniumgoals/

36 UNESCO has currently 191 member states.

The advancement of capacity is an inclusive rationale for international collaboration, but it does not necessarily require a strong multilateral coordination of activities. In contrast to the IGEC programmes WCRP and IGBP, IHP does not focus primarily on the joining of multilateral scientific capacities to achieve large-scale projects. IHP's rationales are more in line with UNESCO's ambition to function as a "a laboratory of ideas, a standard-setter, a clearing house, a capacity builder in Member States, a catalyst for international cooperation" (UNESCO 31C/4, 2002: 6).

3.2 Organisational Structure and Funding

According to interview partners, a major strength of IHP is the *strong network of experts in developing countries* it has built over time. The intergovernmental status facilitates access to national administrations in developing countries. Countries can approach UNESCO with their specific scientific, technical and information needs in water related issues and sometimes even to help settle political issues of transboundary waters. UNESCO enjoys a reputation to work for the benefit of developing countries. The organization can convey legitimacy and credibility to scientific initiatives in these countries. Furthermore, the status as a UN agency programme facilitates cooperations with other UN and international donor agencies, such as the WMO or GEF (interviews conducted by the author).

Whereas the IGEC programmes are institutionalized networks of scientists with a science-driven agenda, the *formal structure of IHP centres on the collaboration of states.* The main structural components are IHP national committees and an international headquarter at UNESCO in Paris. The intergovernmental structure brings with it two inherent challenges for programme operation. Firstly, the programme has to ensure the continued coupling of the two spheres of scientific and intergovernmental cooperation. Secondly, the intergovernmental administration causes strong constraints for programme growth.

A continuous operational challenge for IHP is to connect the intergovernmental governance with scientific collaboration activities. Structurally, linkages between both spheres consist in a hybrid composition of IHP national committees and in a hierarchy of decision-making layers at the UNESCO headquarter, where IHP is part of the sector of natural sciences. Figure 4 represents the core elements. National committees are IHP's liaisons in the countries and are set up by the respective governments. They are IHP's formal interfaces with national governments and at the same time with national scientific and professional communities, as evident from their composition. "The composition of a National committee may vary from country to country, however, the IHP Intergovernmental Council recommends that the composition include public agencies in hydrology and water resources, private individuals, relevant university faculties and departments, research institutes, consulting agencies, professional and learned societies." [37] National committees are more important in IHP than their respective counterparts in the IGEC programmes, since they are more directly involved in the implementation of IHP. IHP maintains that „the efficiency of National Committees clearly determines the overall efficiency of the programme“ (IHP/Bur-XXXV/3: 6).

The programme headquarter is built of *hierarchical layers of decision-making*. The intergovernmental mechanism of the UNESCO General Conference is situated at the top. It convenes every two years and has to approve the strategy, programme lines and budget of the whole organization. At this level, country delegations can rarely be expected to understand the technical details of the different programme lines. At the programme level, IHP is directed by another body of intergovernmental representatives, the IHP Intergovernmental Council, which is a subsidiary organ of the General Conference. Having its own intergovernmental body provides IHP with a *high degree of autonomy* and almost the status of an international organization. Formally, the IHP Intergovernmental Council has „overall governing responsibility for planning, defining priorities and supervising the execution of the IHP“. Regional representation is an important criterion for the election, but the representatives usually have a scientific background related to hydrology.

The Intergovernmental Council convenes in plenary session biennially. In between these plenary sessions, operational work is coordinated by the Bureau of the Intergovernmental Council with support of the IHP secretariat. The IHP Secretariat has to coordinate the interests and proposals of member states and other international organizations wishing to collaborate through IHP. To facilitate contact with national committees and project implementation, IHP has a small number of staff in UNESCO regional offices and can use the infrastructure of UNESCO field offices which exist in a large number of countries.[38] In practice, professionals at the secretariat have a central role to play in defining directions of the programme. In that way, a *tension* is built into the structure *between the formal responsibility assigned to the IHP Intergovernmental Council (government representatives) and the scientific leadership at the operational level by the secretariat* (interviews conducted by the author).

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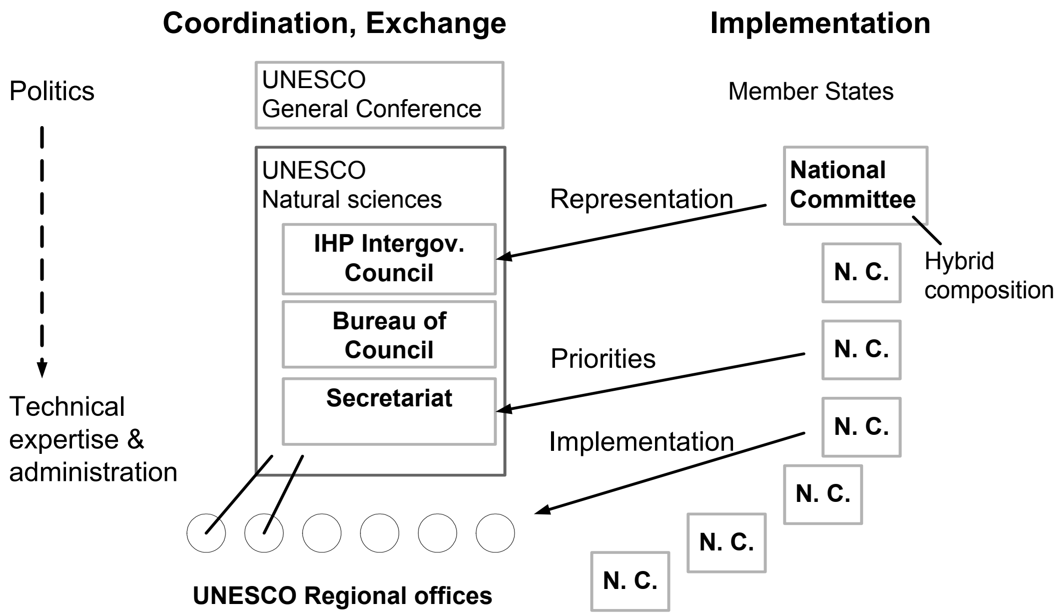
37 www.unesco.org/ihp/structure.shtml, last accessed 19. 9. 05

38 Regional hydrologists are located at UNESCO offices in Cairo, Jakarta, Montevideo, Nairobi, New Delhi and Venice.

Figure 4 IHP Structure



Source: own drawing based on description of programme structure.

By comparison with the IGEC scheme, the programme is less decisively oriented towards the priorities of scientific disciplines. For example, IHP's strategy is not exposed to a broad peer-review at an open scientific conference. *IHP is owned by member states and has to accommodate their priorities and interests in scientific and technical topics.* The negotiation of thematic priorities is done through the preparation of a plan for an IHP phase of six years duration. The development of this plan involves an extended communication process between national committees and the secretariat. IHP phase planning commences with a technical task force that is in charge of drafting a concept note outlining a proposed approach. The task force seeks proposals, comments and revisions from the national committees in several iterations in order to take the needs and interests of member states into account. The Intergovernmental Council approves a draft and in a later session the final version of the plan. *The planning document describes a broad umbrella of themes* in water research and management, and a list of priorities under each theme. More detailed planning decisions are involved in the biennial allocation of the UNESCO IHP budget.

As with many types of hybrid organizations, *the successful coupling of spheres (in this case science and intergovernmental politics) depends on people that are capable of fulfilling multiple roles*. The IHP secretariat has to combine the role of diplomats and scientific professionals. As a result of its hybrid design, IHP strongly depends on individual gatekeepers within the UNESCO headquarters, field offices and the national committees to keep up front of scientific developments. These gatekeepers are people who have the personal capability, including the personal contact networks, to bridge science and bureaucracy. The importance of this personal capability is elevated by the low job mobility of professional staff at headquarters as a result of their status as international civil servants.[39] Furthermore, staff recruiting is required to represent different world regions. At the international level, the programme cooperates closely with the International Association of Hydrological Sciences (IAHS), the International Association of Hydrogeologists (IAH), and the International Atomic Energy Association (IAEA), among others.

Besides the coupling of science and intergovernmental relations, the other major operational challenge of the hybrid structure is programme growth. In response to the needs of member states and due to its orientation towards societal benefits of scientific achievements, IHP's thematic agenda has displayed a remarkable thematic broadening over the successive programme phases. Since the 1960s, the scope of issues was extended from the hydrologic research-driven IHD and IHP phase I, to the more practical goal of integrating science and rational management of water resources (phase II and III), to a stronger inclusion of environmental issues and ecosystem management (phase IV and V), while more recently an increased emphasis is placed on water and social issues (phase VI and VII).[40]

A broader remit allows IHP to *accommodate almost any upcoming topic or need* of member states in the area of water resources management. Yet the thematic broadening tendency has not been accompanied by a strong growth of staff or resources, as might be expected if all these thematic areas were to be covered. Sometimes thematic broadening is backed by interdisciplinary activities within UNESCO's sector of natural sciences or across sectors, as recently happened with the social science sector. *The fact that IHP's infrastructure is financed as part of the UNESCO regular budget secures organizational continuity over time, but at the same time severely restricts the programme's growth potential.*

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39 Recently, a policy of staff rotation between UNESCO headquarter and field offices was introduced as part of an organizational reform (UNESCO 32 C/32: 11).

40 "In the development of its various phases, IHP has gone through a profound transformation from a single discipline to a multi-disciplinary programme. Recently, with the increased presence of the social science component, IHP has become a truly inter-disciplinary programme, capitalizing on the recognition that the solution of the world water problems is not just a technical issue", (www.unesco.org/water/ihp/description/index.shtml; last accessed 19.9.05). Examples of social topics under IHP are ethics and water, the valuation of water, water and conflict prevention, history of water management.

UNESCO's *regular budget* covers costs for staff at headquarters and in the regional field offices and costs for activities.[41] IHP is not equipped to fund the implementation of reseach projects or capacity building in member states. Apart from limited amounts for travel, workshops, or publications, implementation has to be born by member states or other donor agencies. Member states also cover the costs of representatives to IHP governance bodies (except for the IHP Bureau). Since there is no central budget for programme implementation, accounts of the total costs of national and regional activities tied to IHP are lacking, similar to the situation of the IGEC programmes.

IHP can only increase the volume of its regular budget if UNESCO's regular budget grows as a whole or if the programme's share in this budget increases. Under the Director General K. Matsuura, *"water and associated ecosystems" have been assigned a principal priority within UNESCO* (UNESCO 31C/4: 32). After a long period of stagnation and relative decline of IHP's size, this prioritization led to an increase of the budget for IHP activities (excluding personnel) from US $ 2.76 million in the biennium 2000-01, to $ 8.91 million in 2004-05 and projected as $ 8.80 million in 2006-07 (figures from IHP/IC-XVI/Inf. 6 and UNESCO 33 C/5 Rev Annex I). IHP has currently 10 professional staff at the central headquarter and six at regional offices.

Beyond its regular budget, UNESCO administers *extrabudgetary funds* contributed by member states, other UN specialized agencies, or international donors for particular purposes. Extrabudgetary funds account for a growing portion of UNESCO's overall budget.[42] As for IHP, extrabudgetary resources amounted to $ 3.78 million in the biennium 2004-05, or 42 % of the regular budget for activities (IHP/IC-XVI/Inf.3: 1). While extra-budgetary funding is a viable option to increase the volume of programme activities, *this growth option is practically limited by the fact that regular staff is required to direct and administer the additional projects*.[43] An unusual example for the acquisition of extrabudgetary funds is the UNESCO IHE Institute for Water Education in Delft. Le-

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41 Activities include studies and research, conferences and meetings, publications, training courses, seminars and workshops, and technical and advisory services (UNESCO 32 C/5 Appendix III: 316).

42 In the biennium 2006-07, UNESCO's regular budget is projected at a volume of US $ 610 million, plus $ 395 million extrabudgetary funds (UNESCO 33 C/5 rev. Appendix I: 32).

43 "With the large increase in extra-budgetary funding in recent years, ensuring the necessary administrative support becomes more critical. The administrative load cannot be handled by the current regular programme staff of the Division of Water Sciences (whose function is not anyway to tend to this type of requirements). The capacity of the Science Sector administration also seems to be reaching its limit. New mechanisms by which the extra-budgetary funding itself can be used effectively to provide this kind of support within the administrative framework of UNESCO must be found"; (IHP/IC-XVI/Inf.11: 3).

gally, the institute forms part of UNESCO, but its main funding source is the government of the Netherlands.

By comparison with the bureaucratic intergovernmental infrastructure of IHP, the IGEC scheme can accommodate programme growth much more elegantly through the establishment of new scientific core projects with their own decentralized project office. By way of assigning temporary project leadership, IGEC programmes can rely to a large extent on the employees and infrastructure of universities and research organizations.

Another growth restraining factor for UNESCO IHP is the fragmentation of water related competencies among UN specialized agencies (see also Varady, in press). Recently, an inter-agency mechanism was initiated as a follow-up of the water-related decisions of the World Summit on Sustainable Development and the water-related Millenium Development Goals (IHP/IC-XVI/Inf.17). The simple fact that 24 UN agencies and other bodies participate in this "UN Water" inter-agency mechanism is indicative of the present degree of fragmentation of water related action and the associated potential for overlap and competition within the UN family.

3.3 International Participation

In accordance with its intergovernmental status, the national committees (NCs) are the basic venue for international participation in IHP. The IHP website lists 164 countries with an IHP NC or at least a national contact person (focal point). Sorted by world regions, 42 of these are located in African countries, 19 in Arab States, 24 in Asia and Pacific, 43 in Europe and North America and 36 in Latin America and the Caribbean. In light of the fact that in many cases IHP NCs exist in addition to UNESCO national commissions and field offices in respective countries, this represents a very sizeable network. Yet as indicators of active involvement, these numbers must be interpreted with caution. NCs in different countries differ in their composition, in terms of their connection with national water policy, management and research actors, and level of activity.

In 2002-03, an evaluation of IHP phase V was conducted by a team of external evaluators, based on a decision of the 31st General Conference. The objective of the evaluation was to give a "frank appraisal of the problems" faced in the implementation of IHP V and an "objective assessment" of the results (IHP, 2003: 2). The two main sources of information were a questionnaire survey of national committees, and expert interviews during visits to a total of fourteen countries.[44] The report also contains lists of publications and regional activities. In the survey, national committees were asked to rate the relevance, success and impact of IHP V in the national context and the efficiency of IHP organs (on five point likert scales). Questionnaire responses were received from a total of 86 countries (52 % of members). In a more qualitative manner, the country missions highlighted successful cases and problems of IHP implementation in different regions. Due to moderate ratings for IHP V impacts on national water activities and hydrological sciences, and because many iterations were necessary to achieve a satisfactory response rate from national committees, *the evaluation concludes that many national committees are ineffective* (IHP, 2003: 5, 38).

Most questions in the survey require judgements of a very general nature. The evaluation did not ask national committees to give *explicit information on their (level of) activities or their composition*, presumably because this information should be available through national reports. For the period of 2000-02, *national committees from 42 countries submitted a report on their activities under IHP.* In this particular indicator, participation diverges markedly from the list of the largest scientific producers discussed in section 2.3. Only nine reports are from the group of the 20 largest scientific producing countries listed in figure 3: the United Kingdom, Germany, Italy, Russia, Australia, the Netherlands, India, South Korea and Sweden. On the other hand, 23 countries that submitted national reports for 2000-02 are very small in terms of SCI publication shares: Azerbaijan, Costa Rica, Croatia, Cuba, Egypt, Ghana, Indonesia, Iran, Kenya, Kyrgyzstan, Latvia, Lebanon, Malaysia, Nigeria, Pakistan, Panama, Poland, Saudi Arabia, Slovakia, Sri Lanka, Thailand, Uzbekistan, Vietnam. Changes in coverage of individual countries' IHP activities from one reporting period to the other point to a weakness of national reports as an indicator, yet UNESCO does not keep any more comprehensive record of country participation in IHP.

National reports suggest that *participation is more diverse and less concentrated in the largest scientific producing countries.* On the other hand, *as a measure for participation national reports are much less demanding* than the criterion of steering committee members in scientific core projects used in section 2.3. Many of the activities documented in the reports of lesser developed countries relate to international conferences, workshops, publications and training courses, as well as national research activities and bi- and multilateral collaborations in thematic areas of IHP. (Another possible indicator is participation in the Intergovernmental Council; cf. IHP, 2004).

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44 Expert interviews were conducted in Brazil, Chile, the Netherlands, Germany, Ireland, Kenya, Mauritius, Japan, Jordan, United Arab Emirates, Egypt, Australia, Indonesia.

According to IHP professionals interviewed by the author, the countries that were for a long time most active in IHD/ IHP were the USA and the former USSR, Nordic European countries, both parts of Germany, the Netherlands, the Czech Republic and Hungary, Argentina, India, later on Brazil and Mexico, China and Japan. Among the African region, Nigeria, Ghana, Egypt, Tunisia and Algeria participated most actively in the past. Today the perception is that the developing and emerging countries which show strong interest either experience strong water scarcity, as with the Arab countries, or have already developed scientific capacity and "want to know more", as for example some Latin American countries.

A prevailing perception, emphasized by the evaluation of IHP V, is that IHP national committees need to be strengthened. "Although some National Committees are functioning excellently, there are many that are less active for a number of reasons, the principal being lack of basic funding and secretarial support"; (IHP/IC-XVI/10; Annex II: 4). Options for activating and enhancing national committees are a recurring topic at the sessions of the IHP Intergovernmental Council and the Intergovernmental Bureau, and discussed in connection with the issue of regionalized programme governance (see below in 3.4). This discussion also bears on the fact that UNESCO National Commissions are linked to education in many countries and have weak connections with scientific communities. Last but not least, *collaboration with a larger number of more active national committees would require programme growth in terms of personnel and activities.*

3.4 Problem Structure and Collaboration

Hydrology as a scientific discipline that deals with freshwater on earth encompasses both the systemic and the cumulative perspective on global change. The hydrological cycle is an important part of the earth system. *Yet since IHP's rational is to advance member states' capacity for water management, most of its scientific and technical problems are of a place-based nature.* Water problems are ubiquitous since water is an essential need for human life and for economic development, while water stress, pollution and freshwater habitat destruction accumulate on a global scale. The best possible management of water and water in connection with land resources is not only a very place-based affair – this holds even for adaptation under climate change – but also strongly depends on regulation and enforcement by the state.

In what ways does the organizational structure of IHP reflect a place-based problem structure? The most general answer is that IHP has to accommodate the priorities of member states, with their various natural conditions and strongly divergent levels of capacity. *The priorities of member states are themselves part of the place-based na-*

ture of the problem structure. Secondly and related to this, IHP does not push for a strong coordination and integration of scientific work, be it in terms of methodology, theory or spatial scale, in strong contrast to the IGEC scheme. The struggle for a globalization of collaboration in a place-based field of science also manifests itself in some more particular issues, for example in the question of a *regionalization of IHP* and the *strategy to develop a network of water centres*.

IHP seeks global coverage in the sense of worldwide participation of national committees. In the eyes of leading professionals at the headquarters, the vision of IHP is to *upgrade national committees "up to a level in which they have clear links with the decision-making apparatus of each country"* (interview conducted by the author). Thus ideally, national committees would provide a strong linkage with scientific communities and political decision-making on water issues worldwide and the national committees of all member states would give a strong global coverage. In practice, IHP has strong and weak national committees, depending on the scientific and political interest in collaboration through IHP in individual countries and their scientific capacity, and a number of countries do not participate at all (IHP, 2003).

The question of how to strengthen national committees led to a "strong *disagreement among Member States" over the regionalization of IHP governanc*e, including the option to establish Regional IHP Intergovernmental Councils. It is expected that a regionalization of IHP will build "a stronger commitment of Member States to the IHP activities" and facilitate the access to collaboration (IHP/IC-XVI/10 Annex II: 3). The present result of this debate is a system of regular regional meetings to foster regional cooperation without changes in the formal organizational structure. Regional cooperation is reported to have successfully strengthened IHP participation in the Arab states and South East Asia, while problems "occurred in Africa where it has not yet been possible to organize Regional Meetings due to lack of funding, and where some countries for the same reason have not been able to send representatives to Regional Meetings" (ibid.: 4).

Another organizational strategy that relates to the cumulatively global problem structure consists in the *establishment of a network of regional centres of excellence*. Regional centres are research and education institutions established and financed by national governments and affiliated with IHP through the assignment of the legal status of "centre under the auspices of UNESCO". The idea is to create a network of specialized water institutions with the Institute of Water Education in Delft at its core (IHP/IC-XVI/6: 2). The institutional network is an advanced step in the capacity development strategy, which over the last decade met a growing interest of member states.[45] From the point of view of national governments and scientists, the main attraction consists in the prestige conveyed to the respective centre and the formalized access to an international network of water professionals and scientists. It is beyond the scope of the present study to evaluate the state and progress of the different centres. Yet it can be concluded that the network strategy represents an interesting approach to capacity development under the condition of a very limited organizational budget. From the organizational point of view, a successful institutional network could constitute an indirect strategy of programme growth.

4. Conclusions

The paper presented two institutional schemes for international collaboration in earth and environmental sciences. They were compared in terms of the rationales for international collaboration, the organizational structure and funding, international participation and with regard to the global problem structure. Table 3 gives an overview of the comparison. The broad question is how international collaboration can effectively contribute to the globalization of environmental knowledge. More specifically, attention is drawn to the question: *Which organizational forms are effective in organizing international collaboration in place-based problems?*

The main findings can be summarized as follows:

1) Both more favourable funding opportunities and higher degrees of mutual task dependence favour large-scale, coordinated collaboration efforts in systemic global change fields.

2) The flexible, distributed structure of the IGEC programmes appears well adapted to large science-driven collaborations. The systemic IGEC programmes have been able to achieve high levels of scientific allegiance in their respective fields.

3) It is not known to what extent capacity development motivates international scientific collaboration in fields of place-based environmental change and how this collaboration can be most effectively enhanced.

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45 Regional and international water-related centres exist in Bejing, China; in Tehran and in Yazd, Iran; in Utrecht, Netherlands, in Belgrade, Serbia and Montenegro, in Cairo, Egypt and in Kuala Lumpur, Malaysia. New centres are being established in Tsukuba, Japon; La Serena, Chile; Lodz, Poland; Dundee, Scotland and in Columbia.

4) There are a variety of approaches to organizing multilateral collaboration in place-based research fields, examples were given from ecology and hydrology. The comparative strengths of these organizational approaches should be analyzed in more depth.

5) IHP is an example of a programme that makes a strong link between scientific collaboration, education and capacity building. In that way, IHP has been able to build a strong expert network in developing countries.

6) The legitimacy and credibility in developing countries is enhanced through the intergovernmental status of UNESCO IHP.

7) Networks of specialized regional scientific and training institutes appear to be a promising approach to capacity development that should be investigated in more depth.

8) As the example of IHP demonstrates, the intergovernmental structure also has strong disadvantages. The hybrid institution could weaken the scientific allegiance, while the centralized bureaucratic infrastructure has a restrictive effect on programme growth.

Table 3: Comparison of IGEC and IHP Organizational Schemes

IGEC Scheme	IHP Scheme
1. Rationales for International Collaboration	
Large-scale coordination for advancement of fundamental scientific understanding	Advancement of countries' capacities in hydrology and water management
Spatial coverage of global scale, large regions	Research & education
Building critical mass for new fields of research	Scientific collaboration as a means to support peace and development
2. Organizational Structure & Funding	
Institutionally anchored in science	Two institutional anchors: science and politics
Scientific projects as basic units	National committees as basic units
Rotation of scientific leadership	Civil servants as programme leaders
Planning emphasizes cognitive integration	Planning reflects diversity of countries' needs; broadening tendency
Distributed programme infrastructure	Centralized infrastructure + regional offices
Structure accommodates programme growth	Structure impedes programme growth
Institutional interface with national S&T policies but not with environmental policies	Institutional interface with national water policies intended but often weak
National funding of activities	National funding of activities
National funds contribute to international projects including international project offices	National funds contribute to UNESCO regular budget and national activities
3. International Participation	
Consistent with international distribution of scientific capacity	Participation on different levels of capacity
4. Problem Structure & Collaboration	
Systemic: global collective goods (WCRP, IGBP)	
Place-based: local, regional, national, trans-border collective goods (DIVERSITAS, IHDP)	Place-based: local, regional, national, trans-border collective goods (regional hydrology, hydrogeology)
Grand strategy design adapted to systemic global change research (?)	Network of affiliated regional centres as a solution for place-based GEC research (?)
Organizational & funding difficulties of IHDP, DIVERSITAS	Dissent on regional governance structure

Acronyms

DIVERSITAS: An international programme in biodiversity science.

FRIEND: Flow Regimes from International Experimental and Network Data Programme

GARP: Global Atmospheric Research Programme

ESSP: Earth System Science Partnership

IAEA: International Atomic Energy Agency

IAH: International Association of Hydrogeologists

IAHS: International Association of Hydrological Sciences

IC: Intergovernmental Council

ICSU: International Council for Science

ICSU-SCOPE: ICSU-Scientific Committee on Problems of the Environment

IGBP: International Geosphere-Biosphere Programme

IGEC programmes: group of four International Global Environmental Change programmes

IGFA: International Group of Funding Agencies for Global Change Research

IGY: International Geophysical Year

IHD: International Hydrological Decade

IHDP: International Human Dimensions of Global Environmental Change Programme

IHP: International Hydrological Programme

IPCC: Intergovernmental Panel on Climate Change

ISARM: International Shared Aquifer Resources Management

ISI: Thomson Scientific, formerly Thomson Institute of Scientific Information

ISSC: International Social Science Council

IUBS: International Union of Biological Sciences

IUGG: Union of Geodesy and Geophysics

LTER: Long term Ecological Research Programme

MA: Millenium Ecosystem Assessment

MAB: Man and the Biosphere Programme

NASA: National Aeronautics and Space Administration, USA

NC: National Committee

SCI: Science Citation Index

SSCI: Social Science Citation Index

START: System for Analysis, Research and Training

UNESCO: United Nations Educational, Scientific and Cultural Organisation

WCRP: World Climate Research Programme

WMO: World Meteorological Organisation

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