German National Committee On Global Change Research

# Global Change Research in Germany 2008

NKGCF

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**Editorial Note**
The selection of introduced projects and programmes represent and exemplify German research activities on Global Change. Please note that several more projects and programmes in Germany address Global Change research.

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# Global Change Research in Germany 2008

edited by Bettina Höll and Wolfram Mauser
on behalf of the German National Committee on Global Change Research (NKGCF)

Munich, 2008

# Abbreviations and Acronyms

| | |
|---|---|
| ACACIA | Arid Climate and Cultural Innovation in Africa |
| ACSYS | Arctic Climate System Study |
| AIMES | Analysis, Interpretation and Modelling of the Earth System |
| ARGO | Array for Real-Time Geostrophic Oceanography |
| ATEAM | Advanced Terrestrial Ecosystem Analysis and Modelling |
| AVEC | Assessment of Vulnerable Ecosystems under Global Change |
| AWI | Alfred-Wegener-Institut für Polar- und Meeresforschung / Alfred Wegener Institute for Polar and Marine Research |
| BIOLOG | Biodiversity and Global Change |
| BMBF | Bundesministerium für Bildung und Forschung / German Federal Ministry of Education and Research |
| BOD | Burden of Disease |
| BSH | Bundesamt für Seeschifffahrt und Hydrographie / Federal Maritime and Hydrographic Agency |
| CARIBIC | Civil Aircraft for the Regular Investigation of the Atmosphere Based on an Instrument Container |
| cCASHh | Climate Change and Adaption Strategies for Human Health |
| CITES | Convention on International Trade in Endangered Species |
| CLiC | Climate and Cryosphere |
| CLIVAR | Climate Variability and Predictability |
| COCE | Conservation and Use of Wild Populations of Coffea arabica in the Montane Rainforests of Ethiopia |
| COSMOS | Community Earth System Model |
| DALY | Disease-Adjusted Live Year |
| DEKLIM | Deutsches Klimaforschungsprogramm / German Climate Research Programme |
| DFG | Deutsche Forschungsgemeinschaft / German Research Foundation |
| DKRZ | Deutsches Klimarechenzentrum / German Climate Research Centre |
| DLR | Deutsches Zentrum für Luft- und Raumfahrt / German Aerospace Centre |
| DWD | Deutscher Wetterdienst / Germany's National Meteorology Service |
| ECO-LOGIC | Institut für Internationale und Europäische Umweltpolitik / Institute for International and European Environmental policy |
| EEA | European Environment Agency |
| EOS | Earth Observation System |
| ESF | European Science Foundation |
| ESSP | Earth System Science Partnership |
| EU | European Union |
| FEU | Forschungsstelle für Europäisches Umweltrecht / Research Centre for European Environmental Law |
| FFU | Forschungsstelle für Umweltpolitik / Environmental Policy Research Centre |
| FhG | Fraunhofer Gesellschaft / Fraunhofer Association |
| fona | Forschung für Nachhaltigkeit / Research for Sustainability |
| FZJ | Forschungszentrum Jülich / Research Centre Jülich |
| FZK | Forschungszentrum Karlsruhe / Research Centre Karlsruhe |
| GAIM | Global Analysis, Integration and Modelling |
| GBF | Gesellschaft für Biotechnologische Forschung / German Research Centre for Biotechnology |
| GCP | Global Carbon Project |
| GDP | Gross Domestic Product |
| GECAFS | Global Environmental Change and Food Systems |
| GECHS | Global Environmental Change and Human Security |
| GEOSS | Global Earth Observation System of Systems |
| GEWEX | Global Energy and Water Cycle Experiment |
| GFZ | GeoForschungsZentrum Potsdam |
| GHG | Greenhouse Gas |
| GKSS | Forschungszentrum Geesthacht / Research Centre Geesthacht |
| GLOBEC | Global Ocean Ecosystem Dynamics |
| GLOWA | Global Change in the Hydrological Cycle |
| GLP | Global Land Project |
| GNI | Gross National Income |
| GPS | Global Positioning System |
| GSF | Forschungszentrum für Umwelt und Gesundheit / National Research Centre for Environment and Health |
| GWSP | Global Water System Project |
| HALO | High Altitude and Long Range Research Aircraft |
| HLRE | Höchstleistungsrechnersystem / High Performance Computing System |
| ICBM | Institut für Chemie und Biologie des Meeres / Institute for Chemistry and Biology of the Marine Environment |
| ICSU | International Council for Science |
| IDGEC | Institutional Dimensions of Global Environment Change |
| IEA | International Engery Agency |
| IFM-GEOMAR | Leibnitz- Institut für Meereswissenschaften / Leibnitz Institute of Marine Sciences |
| IGBP | International Geosphere-Biosphere Programme |
| IHDP | International Human Dimensions Programme |
| IMBER | Integrated Marine Biogeochemistry and Ecosystem Research |
| IMPRS | International Max Planck Research School |
| IOW | Institut für Ostseeforschung Warnemünde / Baltic Sea Research Institute, Warnemünde |
| IPCC | Intergovernmental Panel on Climate Change |
| ISSC | International Social Science Council |
| IT | Industrial Transformation |
| ITCZ | Intertropical Convergence Zone |
| KDM | Konsortium Deutsche Meeresforschung |
| LOICZ | Land-Ocean Interactions in the Coastal Zone |
| LUCC | Land-Use Cover Change |
| MA | Millennium Ecosystem Assessment |
| MARCOPOLI | Marine, Coastal and Polar Systems |
| MARUM | Zentrum für Marine Umweltwissenschaften / Centre for Marine Environmental Sciences |
| MICE | Modelling the Impact of Climate Extremes |
| MPG | Max-Planck-Gesellschaft / Max Planck Society |
| MPI | Max-Planck-Institut / Max Planck Institute |
| NADW | North Atlantic Deep Water |
| NEP | Net Ecosystem Production |
| NKGCF | Nationales Komitee für Global Change Forschung / German National Comittee on Global Change Research |
| PAGES | Past Global Changes |
| PDF | Probability Density Function |
| PIK | Potsdam-Institut für Klimafolgenforschung / Potsdam Institute for Climate Impact Research |
| REM | Regional Environmental Model |
| RSV | Research and Supply Vessel |
| SAR | Synthetic Aperture Radar |
| SARS | Severe Acute Respiratory Syndrome |
| SFB | Sonderforschungsbereich / Collaborative Research Centre |
| SOLAS | Surface Ocean-Lower Atmosphere Study |
| SPARC | Stratospheric Processes and their Role in Climate |
| SPP | Schwerpunktprogramm / Priority Programme |
| STORMA | Stability of Tropical Rainforest Margins in Indonesia |
| UBA | Umweltbundesamt / Federal Environmental Agency |
| UFZ | Umweltforschungszentrum / Centre for Environmental Research |
| UN | United Nations |
| UNCBD | United Nations Convention on Biological Diversity |
| UNCCD | United Nations Convention to Combat Desertification |
| UNEP | United Nations Environment Programme |
| UNFCCC | United Nations Framework Convention on Climate Change |
| USP | Unit Stream Power-Based Model |
| VAS-CLIMO | Variability Analysis of Surface Climate Observations |
| WBGU | Wissenschaftlicher Beirat Globaler Umweltveränderungen / German Advisory Council on Global Change |
| WCRP | World Climate Research Programme |
| WDCC | World Data Centre for Climate |
| WGCM | Working Group on Coupled Modelling |
| WHO | World Health Organisation |
| WMO | World Meteorological Organisation |
| WTO | World Trade Organisation |
| YLL | Years of Life Lost |
| ZEF | Zentrum für Entwicklungsforschung / Centre for Development Research |
| ZMAW | Zentrum für Marine und Atmosphärische Wissenschaften / Centre for Marine and Atmospheric Sciences |
| ZMT | Zentrum für Marine Tropenökologie / Centre for Tropical Marine Ecology |

# Table of Contents

# Global Change Research – Science for a Sustainable Future

Global Change summarises the effects of humankind's growing interference with the Earth System. This interference, both on the global and regional scale, has greatly increased during the last century.

***Human Beings and the Environment***

Global Change is triggered by the increase in human population and exacerbated by a rapid development of technologies that utilise natural resources. Human beings basically developed the ability to satisfy the major needs of a still growing population, commanding tools and developing technologies for the production of a large variety of industrial goods, as well as mechanisms to create extraordinary wealth in certain regions of the world. Given the vigorous force and mostly uncoordinated fashion these per se positive developments have taken place, it is not surprising that adverse phenomena are beginning to show. Human interaction with the Earth System is affecting the climate of the planet, altering its water cycle, causing the disappearance of non-renewable resources and starting to stress the life-support system of the planet (Figure 1).

There are no signs of a deceleration or reversal of this development. Therefore, coping with the adverse phenomena of Global Change becomes a major challenge for human societies. Since human activities cause, are affected by and alter change simultaneously, it is not just changes in the global climate system that have to be analysed, but the Earth System with its physical, biogeochemical and socio-economical processes has to be considered as a whole.

There is no alternative to sustainable development as a long-term strategy to cope with the consequences of Global Change. In a widely accepted common understanding, sustainable development is based on the balanced fulfilment of current needs without impairing the opportunities and interests of future generations. In the context of sustainable development, the Earth's ability to further support life and deliver natural goods and services to human societies is as important as economic growth and social development.

## Global Change

Over the past few decades, evidence has been growing that planetary-scale changes are occurring very rapidly. These are, in turn, changing the patterns of forcings and feedbacks that characterize the internal dynamics of the Earth System. Key indicators, such as the concentration of $CO_2$ in the atmosphere, are changing dramatically, and in many cases the linkages of these changes to human activities are strong. It is increasingly clear that the Earth System is being subjected to a wide range of new planetary-scale forces that originate from human activities, ranging from the artificial fixation of nitrogen and the emission of greenhouse gases to the conversion and fragmentation of natural vegetation and the loss of biological species. It is these activities and others like them that give rise to the phenomenon of Global Change.

Source: Steffen, W., Sanderson, A., Jäger, J., Tyson, P.D., Moore III, B., Matson, P.A., Richardson, K., Oldfield, F., SchellnhuberI, H.-J., Turner II, B.L., Wasson, R.J., 2004, Global Change and the Earth System. A Planet Under Pressure.

***The Earth System: Challenges and Strategies***

Enormous progress has been made over the last decades in understanding the parts and processes making up our natural environment, including the atmosphere, oceans, land surface and biosphere. Considerable contributions have been made by an international research community under the umbrella of the International Council for Sciences (ICSU) and the International Social Science Council's (ISSC) four international Global Change research programmes (World Climate Research Programme, WCRP, International Geosphere-Biosphere Programme, IGBP, DIVERSITAS and International Human Dimensions Programme, IHDP). The outcomes have led to a deeper and more detailed understanding of the past and present functioning of the Earth as a system as well as of the nature and dynamics of the interaction between humans and nature. Despite this progress, the intellectual complexity related to the questions about pathways of sustainable development and how they can be identified and implemented has been largely underestimated.

Global Change research analyses the natural variability of the Earth System and the causes, mechanisms and effects of the complex interactions between its components and the human population. It is particularly concentrated on the understanding of the evolution and the impact of the processes that trigger and drive change and on finding possible alternatives for dealing with change in a constructive way. Global Change research develops procedures that make the distinction between natural variability and real changes as well as provide prognostic abilities to foresee changes and their consequences, to identify options for counteraction and to balance adaptation to change and mitigation of causes. In this respect, scientific progress can only be achieved through interdisciplinary approaches. Global Change research relies on sophisticated observation systems to identify changes and optimise decision alternatives at the earliest possible stage.

***Questions of Scale***

Both global and regional strategies have to be developed in order to balance the interaction between humans and the Earth System and at the same time to ensure a sustainable development of human societies. It is on the regional/national level where decisions that promote sustainable development are most likely to be implemented and where action occurs. The focus on regions and common efforts to bridge

the gap between global perspectives on change as well as the analysis of regional impacts and the development of regional sustainable management options must therefore be intensified.

***Prospects***

The success of Global Change research will be judged by its ability to operationalise the term "sustainable development" and by the quantity of implementable knowledge and advice. Research from German scientists has contributed to the advances in Global Change research in the past. The German National Committee on Global Change Research (NKGCF) has compiled the following overview of German Global Change research. NKGCF with its close ties to the international Global Change research community has also identified priority areas and key questions where German scientists with their specific qualifications can best contribute to the international efforts to bring the very challenging practical questions of Global Change research closer to a solution.

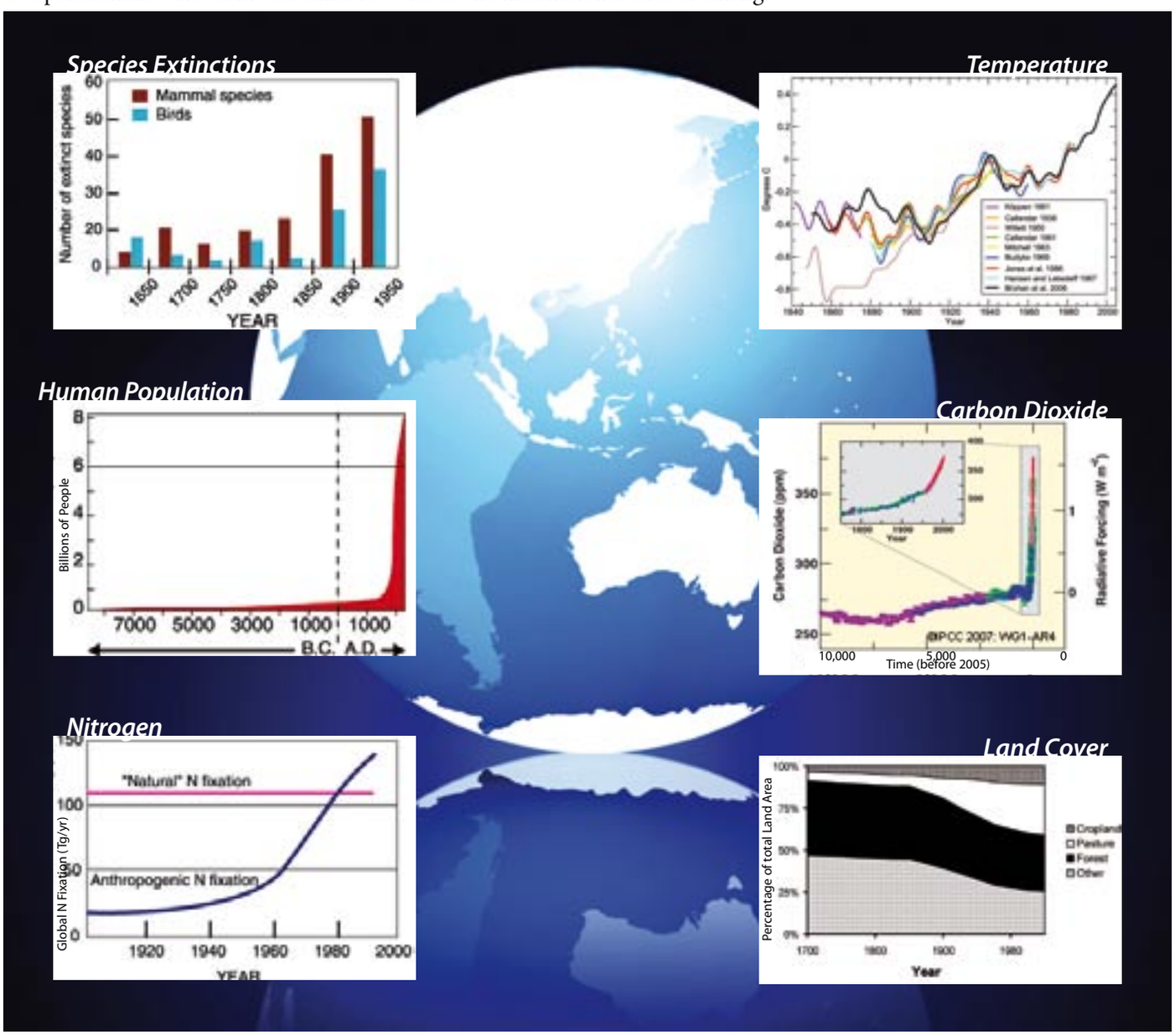



Figure 1: Selected aspects of Global Change: Changes of atmospheric composition, temperature, biodiversity, nitrogen fixation, population, land cover. Sources: | Nitrogen: Vitousek, 1994, Beyond global warming: Ecology and Global Change, Ecology 75: 1861-1876 | Species Extinction: Reid and Miller, 1989, The scientific basis for the conservation of biodiversity, World Resources Institute, Washington DC | $CO_2$*: Atmospheric concentrations of carbon dioxide over the last 10,000 years (large panels) and since 1750 (inset panels). Measurements are shown from ice cores (symbols with different colours for different studies) and atmospheric samples (red lines). The corresponding radiative forcings are shown on the right hand axes of the large panels (IPCC, 2007: WG1-AR4) | Human Population: International Database, U.S. Bureau of the Census | Land Cover: Rik Leemans, Kees Klein Goldewijk, Bilthoven & Frank Oldfield, Developing a fast-track global database of land-cover history, LUCC Newsletter No. 5, 2000 | Temperature*: Published records of surface temperature change over large regions. Brohan et al. (2006) time series are anomalies from the 1961 to 1990 mean (°C). More detailed information in IPCC 2007: WG 1-AR4 Figure 1.3. | Information has been compiled by IGBP and *IPCC.

» www.ipcc.ch«
» www.igbp.kva.se «

# Water Cycle and Water Availability

Water, and in particular an adequate supply of clean freshwater, is one of the keys to the future development of human beings on the planet. Clean drinking water is the most important factor for human health and therefore vital for the survival of societies. At present, one third of the human population relies on low quality drinking water. Despite strong international efforts in recent years, it has not been possible to reduce this fraction of the population reliant on low quality drinking water. Freshwater is also needed in considerable quantities and defined quality for industry and energy production. By far the largest consumer of freshwater is agriculture. Agriculture translates water consumption by crops directly into yield and food.

Clean freshwater for agricultural, industrial and household use is supplied by the Earth's life support system, namely physical, biogeochemical and biological cycles on the land surface, in surface or groundwater and in the oceans. These contain the most powerful and cost efficient water treatment and supply process known to man, outperforming all other known manmade water treatment technologies. Nevertheless, water technologies play an important, yet expensive role in supporting nature to maintain its productivity.

In order to run smoothly, the Earth's life support system itself is critically reliant on sufficient water, space and diversity. Global Change is putting increasing stress on this system as more and more land and water resources are put into increasingly intensive production. As a result, the conflict between the demand for water to sustain a growing population, the demand for water to grow renewable energy resources and nature's demand for water to sustain the natural water cycle is escalating sharply. In almost all populated parts of the earth, the current use of water resources is more or less unsustainable, resulting in diminished natural reserves for the water cycle. This, in the long run, will most likely damage the productivity of both managed and natural ecosystems. In the most affected regions, water shortages have already ignited severe political and cultural conflicts, e.g. in the Middle East, between the US and Mexico, and in several parts of Africa and Asia.

In an attempt to capture some of the complexity of competing water demands, changing water availability and disappearing aquatic habitat, researchers have built models of the global water system. The German research community is taking a leading role in this exciting task, for instance, as part of the EU-funded international consortium WATCH (Water and Climate Change, www.waterandclimate.org) and through various BMBF and DFG projects. Model-based research at these institutions has provided many new insights into the global water system, including the location of critical areas of increasing water abstraction, the relative impact of climate change on water resources in different regions around the world, and the future agents of change in the system (Figure 1). Global models developed at these institutions have shown that an increase in water withdrawals related to economic growth is likely to put more pressure on world water resources over the next few decades than climate change. Nevertheless, model calculations have also indicated that climate change will become an increasingly important actor as the century proceeds.

In order to develop management skills to adapt to the upcoming climatic and societal development and to manage adaptation to change on the regional level, the GLOWA research initiative (see box) as well as the Integrated Water Resources Management Initiative (IWRM) was launched by the German Federal Ministry of Education and Research (BMBF).

GLOWA contributes to the creation of the regional knowledge necessary to form a global knowledge base on water. It also prepares the necessary tools to facilitate an integrated and sustainable management of regional water resources taking into account the natural and cultural specialities of the regions under consideration. GLOWA feeds into a more global perspective, where issues like the trade of virtual water, which is consumed or transformed through agricultural and industrial production, have to be taken into account, as well as the effects of changing patterns of global atmospheric circulation on the distribution of rainfall. To approach this broader perspective, the four international Global Change research programmes (WCRP, IGBP, IHDP and DIVERSITAS) have agreed to establish the Global Water System Project (GWSP). GLOWA is a German contribution to the GWSP (see chapter German Contribution to International GC-Programmes and ESSP, page 37). It will provide important parts of a scientific picture of the global water cycle, eventually serving as a base for sustainable management strategies of global water resources.


Figure 1: Agents of change in the global water system. Shaded areas indicate where water withdrawals are computed to increase between 2000 and 2055 under the IPCC A2 scenario (WaterGAP model calculations). Different shadings indicate the water use sector that contributes most to local increases in withdrawals.

Source: Alcamo, J., Floerke, M. Maerker, M. 2007b. Future long-term changes in global water resources driven by socio-economic and climatic changes Hydrological Sciences. 52(2): 247-275.

## GLOWA (Global Change in the Hydrological Cycle)

Programme Duration: 2000 – 2010
Funding: BMBF

The GLOWA initiative was launched as a 9-year research programme and aims at developing integrated water resources management tools, which enable the study of both natural and human impacts on the water cycle at the regional level of large watersheds. Simulation models are developed and used within GLOWA to treat complex scenarios of how determining factors in the water cycle will change in the future. By quantifying the simultaneous impacts of future changes (e.g. rainfall, temperature and population structure), as well as considering developmental, cultural and political differences between regions, it aims at giving regional decision-makers the tools to ensure a sustainable use of their water resources. GLOWA works in different regions of the globe.

First results from climate change impact studies on water resources (e.g. within GLOWA Danube) using complex scenarios show that regions under current water stress will not be the only ones to be affected. The Figure below shows the severe impact of the IPCC-A1B climate change scenario on snow storage in the alpine region of the Upper Danube. Aquifer recharge from melting snow water in summer will be reduced, which together with reduced rainfall and increased evapotranspiration will lead to droughts in an area, where today no water stress symptoms are discernable. This may force farmers into irrigation, which accelerates the depletion of the aquifers. This may considerably affect river flow and water availability downstream in the river Danube in Austria, Hungary, Romania and Bulgaria, which calls for an integrated management of both agricultural and industrial water use in the Danube river basin.

### GLOWA Danube
Integrative Techniques, Scenarios and Strategies for the Sustainable Water Management in the Upper Danube
Coordination: University of Munich (LMU)

### IMPETUS
An Integrated Approach to the Efficient Management of Scarce Water Resources in West Africa
Coordination: Cologne University

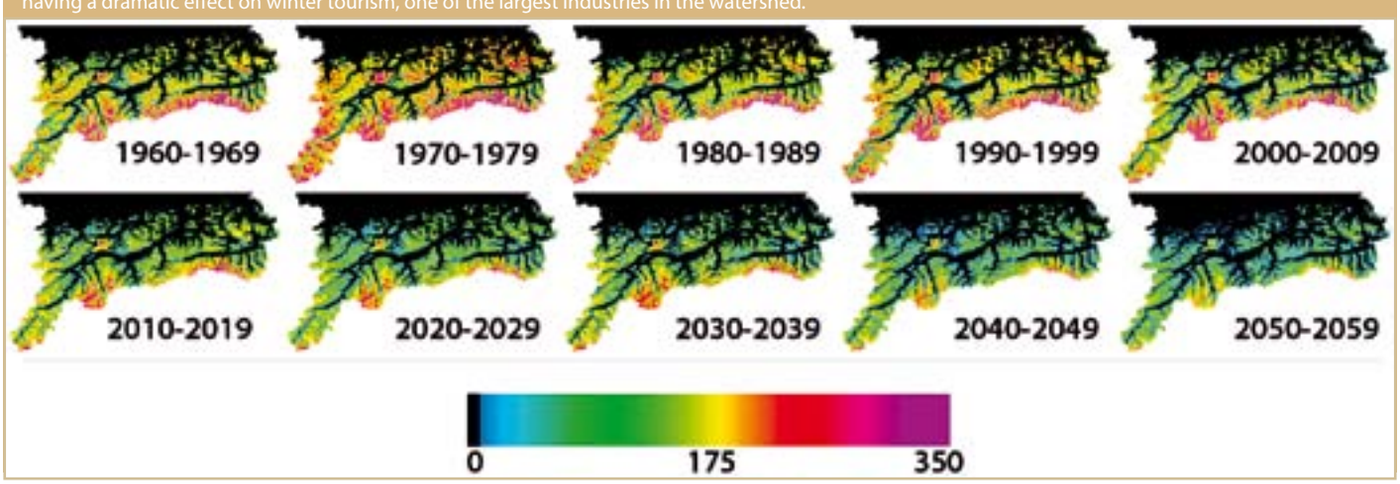
### GLOWA Volta
Sustainable Water Use, Changing Land Use, Rainfall Reliability and Water Demands in the Volta
Coordination: Bonn University (ZEF)

### GLOWA Jordan
Global Change and Integrative Water Resources Management in Arid Regions
Coordination: University of Tübingen

### GLOWA Elbe
Global Change Impact on Environment and Society in the Elbe Region
Coordination: PIK Potsdam

» www.glowa.org «

**Number of days with more than 50 mm of snow water storage**
Scenario simulations of the average annual snow cover in the German and Austrian Alps of the Upper Danube basin. The simulations show the decadal change in the number of days with a snow storage of more than 50 mm over the course of one century from 1961 to 2060. The IPCC A1B scenario was used for determining the course of the $CO_2$-emissions and temperature development. A severe and spatially heterogeneous decrease in snow storage can clearly be identified from the year 2019. This will drastically affect energy production through reduced river flows especially during summer as well as having a dramatic effect on winter tourism, one of the largest industries in the watershed.




## IWRM Mongolia (Integrated water resources management in Central Asia exemplified for a model region in Mongolia)

Programme Duration: 2006 – 2009
Funding: BMBF

Mongolia is proposed as a model region for the development, solution and implementation of integrated water resources management (IWRM) in Central Asia. The basic concept of this proposal is the integrated consideration of uses and protection of freshwater resources including the development of measures and their implementation using a transdisciplinary management approach. Furthermore, it is proposed to implement IWRM on three scales: (1) a specific river catchment (river Kharaa/Darkhan) with a representative range of water problems (impact of global climate change, overexploitation of water resources, diffuse pollution, mining, water supply and wastewater treatment in rural and urban areas, protection of ecological functions and nature conservation) and that can be addressed in a meaningful way, (2) the scale of other river catchments in Mongolia, (3) the scale of other catchments in Central Asia.

» www.IWRM-momo.de «

# Biodiversity

Biodiversity is an essential resource for the maintenance of our global life support system. Within the Earth System, biological processes "play a much stronger role than previously believed in keeping the Earth's environment within habitable limits" (IGBP). Living organisms generated the oxygen atmosphere. Evolution and adaptation of organisms have turned most of the globe into productive ecosystems, controlling fluxes of water, carbon, nitrogen and providing goods and services necessary for human life. Therefore, the dramatic decline of biodiversity on all levels (ecosystems, species richness, genetic diversity) is threatening not only the potential use of the areas that are thus degraded, but it might also entail many cascading effects and negative long-term consequences for ecosystem functions and adaptation potential within the Earth System. In view of the rapid decrease in biological diversity, research is needed that can generate positive influences on such developments. The main goals of biodiversity research have been formulated within the science plan of the DIVERSITAS programme (www.diversitas-international.org) integrating biodiversity science for human well-being. It consists of four core projects that are implemented as part of German research activities.

**bioGENESIS:**
**Documenting biodiversity, its diversification and the effects of human-induced changes**
This new core project will focus on significantly expanding our baseline data on species identities, distributions and phylogenetic relationships, as well as increasing our knowledge of the relevant underlying evolutionary processes. For this purpose, new strategies and tools for discovering and documenting biodiversity need to be developed. The dynamics of diversification will be analysed from an evolutionary viewpoint, and there will be a follow-up of the evolutionary biology of human-induced environmental changes.

**bioDISCOVERY:**
**Assessing current levels of biodiversity; developing the scientific basis for monitoring and observing, understanding, and predicting change**
bioDISCOVERY focuses on developing tools and infrastructures for assessing the spatial dimension of current biodiversity, monitoring change, understanding the processes of change and predicting future biodiversity changes. German activities within bioDISCOVERY focus on the development and establishment of standardised biodiversity observation sites on a local, regional and global scale (see BIOTA AFRICA and Observation Systems).

## European Networking – The ALARM Project

The ALARM (Assessing LArge Scale Risks for Biodiversity with Tested Methods) project is the only integrated project on terrestrial and freshwater biodiversity within the 6th Framework of the EU that is coordinated in Germany. The consortium combines the expertise of 68 partners from 35 countries.
Based on the search for a better understanding of terrestrial and freshwater biodiversity and ecosystem functioning, ALARM develops and tests methods and protocols for the assessmentoflarge-scaleenvironmental risks in order to minimise negative direct and indirect human impacts.
» www.alarmproject.net/alarm «

## Networking – Diversitas Germany

Diversitas Germany is a scientific network that identifies problems relating to the safeguarding of biodiversity and the sustainable use of its goods and services. Diversitas Germany supports the implementation of the aims of DIVERSITAS International and the UN Convention on Biological Diversity (UNCBD) through the German National Committee on Global Change Research (NKGCF). The national network strengthens links with international research partners for innovative and interdisciplinary research.
» www.diversitas-deutschland.de «

## Mata Atlântica

Programme Duration: 2002 – 2009
Funding: BMBF

The programme Mata Atlântica aims to develop strategies and action plans for the conservation, sustainable management and use of endangered remnants of the Brazilian Atlantic forest. These strategies will be based on interdisciplinary research and provide a long-term vision.
The application of scientific results should improve the efficiency of measures to protect the biodiversity of the Mata Atlântica, and thereby provide an ecological basis for regional landscape planning, in order to promote the persistence and regeneration of the typical biodiversity within this region.
» www.pt-uf.pt-dlr.de/en/160.php «

## Jena Experiment

The Role of Biodiversity for Element Cycling and Trophic Interactions: An Experimental Approach in a Grassland Community

Project Duration: 2002 – 2008
Funding: DFG

The long-term experiment in Jena studies the interactions between plant diversity and ecosystem processes, focussing on element cycling and trophic interactions.
60 plant species, native and common to the Central European Arrhenatherum grasslands, serve as species pool.
The species assemblages serve as a basis to study interactions not only among plant individuals and plant species, but also between the different trophic levels. In addition, special attention is paid to the ecosystem carbon balance and the turnover and loss of nutrients.

Aerial view of the field site

J. Baade

**ecoSERVICES:**
**Expanding scientific research into biodiversity and ecosystem functioning onto a larger scale and over a greater breadth of the biological hierarchy; linking changes in ecosystem structure and functioning to changes in ecosystem services; assessing human response to changes in ecosystem services**
Biodiversity plays a crucial role for ecosystem functioning, and thus for the provision of ecosystem services (e.g. climate regulation, carrier functions for agriculture, carbon sequestration, or ground water recharge). On a global scale, but often even locally, ecosystem functioning constitutes critical natural capital that can hardly be substituted by human-made capital. In Germany, ecoSERVICES' research projects focus, for example, on the risks arising from climate change, environmental chemicals, biological invasions and pollinator loss in the context of current and future European land use patterns, the role of functional diversity on ecosystem functions, and on the connection between ecosystem services, their use and economic valuation (see Jena Experiment, DFG Exploratories, ALARM and Mata Atlântica).

**bioSUSTAINABILITY:**
**Developing new knowledge to guide policy and decision-making that support the sustainable use of biodiversity; evaluating the effectiveness of current conservation measures; studying the social, political and economic drivers of biodiversity loss, as well as social choice and decision-making**
However, there is not enough scientific knowledge to guarantee the swift and efficient protection of our planet's biota. A central field of Germany's contributions to bioSUSTAINABILITY is research into the protection of biodiversity in cultural landscapes (see BioTeam, BfN-projects).

## BIOLOG (Biodiversity and Global Change)

The objective of BIOLOG, initiated by the German Federal Ministry of Education and Research (BMBF) in 1999, is to arrive at a better understanding of the role of biological diversity in ecosystems and develop strategies for a sustainable use of biological diversity in cooperation with international partners. BIOLOG consists of

- BIOLOG Europe, exploring the effects of increasing changes on biological diversity in the European landscape,
- BIOTA Africa, with contributions from and in Benin, Burkina Faso, Cote d'Ivoire, Dem. Rep. Congo, Germany, Kenya, Maroc, Namibia, South Africa and Uganda, aims at a holistic scientific contribution towards sustainable use and conservation of the biodiversity of the African continent.

» www.pt-uf.pt-dlr.de/en/158.php «

BIOTA AFRICA
Project Duration: 2000 – 2010
Funding: BMBF, DS&T and other African contributions

BIOTA AFRICA forms an Africa-wide scientific network which develops scientific support for sustainable use and conservation of African biodiversity. The network integrates the activities of more than 80 institutions with 395 co-workers from 13 countries. Core topics are (a) the measurement of change of biodiversity as related to drivers and pressures, with specific foci on land use and climate change, (b) the analysis of processes and mechanisms of change, (c) the production of user-friendly tools for decision-makers supporting sustainable land-use management, the transformation of scientific results based on decision support modules, capacity development and learning partnerships.

» www.biota-africa.org «

## DFG Exploratories

Recently, the DFG has established three exemplary large-scale and long-term research sites called biodiversity exploratories that address critical questions about how different types of land use affect biodiversity and how biodiversity change impacts ecosystem processes. The exploratories are situated at the Schorfheide-Chorin Biosphere Reserve (NE Germany), at the Hainich National Park and surrounding area (centre of Germany), and in the upcoming Schwäbische Alb Biosphere Reserve (SW Germany), focussing on grassland and forest ecosystems.

» www.biodiversity-exploratories.de «

## BioTeam

Programme Duration: individual
Funding: BMBF

The BioTeam research initiative "BIOsphere Research – InTEgrative and Application-Oriented Model Projects" is tackling three core issues:
1. Can a price be put on biological diversity?
2. How can the benefits deriving from the use of biological diversity be fairly distributed?
3. Is biological diversity in Germany also under threat?
Several projects investigate the potential of the UNCBD Ecosystem Approach and the Access and Benefit Sharing mechanism. For example, one project focuses on the threat to the last populations of wild coffee by land use change (Conservation and Use of Wild Populations of Coffea arabica in the Montane Rainforests of Ethiopia, CoCE, another on process-oriented development of a model for a fair benefit-sharing for the use of biological resources in the Amazon lowland of Ecuador (ProBenefit).

» www.coffee.uni-bonn.de «
» www.probenefit.de «
» www.pt-uf.pt-dlr.de/en/157.php «

## Risks for Protected Areas under Climate Change

Project Duration: 2006-2009
Funding: German Federal Agency for Nature Conservation (BfN)

Risk assessment of nature conservation goods facing climate change, differentiated for species, habitat types and regions as well as the development of recommendations on a management as well as political scale.

# Global Change in the Ocean

The ocean is the Earth's largest reservoir of heat and climatically active gases, which it stores and exchanges with the atmosphere. Therefore, the ocean has a decisive influence on our climate. The North Atlantic is one of the sensitive spots in ocean dynamics, with prime importance for our climate. The North Atlantic thermohaline circulation is responsible for heat transport far north on the eastern side of the Atlantic, supporting a relatively mild climate in northern Europe as well as the formation of deep water that sequesters significant amounts of anthropogenic $CO_2$ in the interior of the ocean.

A great deal of effort has been directed towards understanding the variability of the current system in the northern North Atlantic. Hydrographic observations show that water properties and the deep wintertime mixing in the Labrador Sea have experienced strong changes (Figure 1). The intensity of the wintertime deep-water formation is determined by the competition between the heat loss associated with cold westerly winds and the input of low-salinity water from the Arctic. Future climatic change and increasing ice melt will have the potential to significantly decrease the intensity of deep-water formation in the North Atlantic, with consequences for the uptake of anthropogenic $CO_2$ and heat transport to northern Europe.

Unlike on land, there are very few possibilities to observe changes in the ocean. Usually, each cruise by a research ship can only provide snapshots of observation in space and time. Therefore, it is important to develop automatic observation systems capable of measuring and relaying to shore relevant information in real time. Satellite observation of the ocean surface is of course a major tool in this respect. However, the deeper ocean layers are much more difficult to observe, and present efforts are directed towards the development of observation technology to trace critical changes in physical, chemical and biological processes. As an intermediate step between ship-based and autonomous observation systems, moored instruments provide time series of crucial circulation parameters, such as the strength of the thermohaline circulation in the Atlantic at 26.5°N (Figure 2).

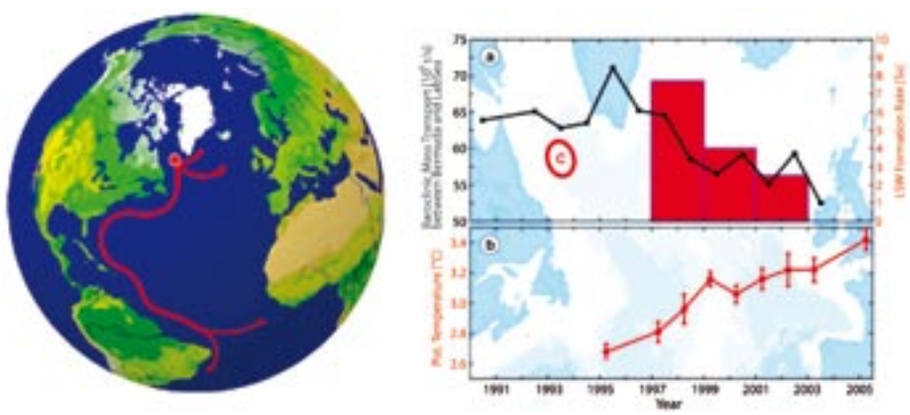



Figure 1: Flow of Labrador Sea Water (LSW) from the source (red dot) into the Atlantic. (a) The black line shows the eastward mass transport [in megatons per second] between the central Labrador Sea and Bermuda, in the depth range: 0–2000 metres. The red bars show LSW formation rates (Sv, 1 Sv corresponds to 1 megaton per second). (c) Temperature time series of LSW source water.

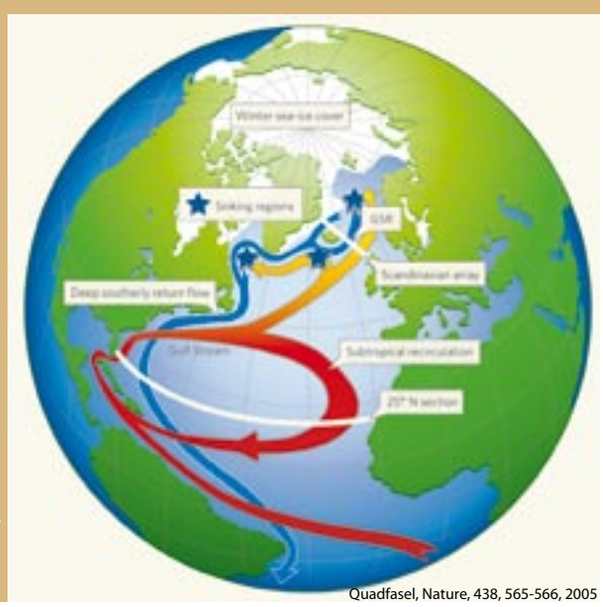
Source: Institute for Environmental Physics, University of Bremen; Kieke et al., Geophysical Research Letters, 34, L06605, doi:10.1029/2006GL028959, 2007

## The North Atlantic as Part of the Earth System: From System Comprehension to Analysis of Regional Impacts

Programme Duration: 2006-2009
Funding: BMBF (Cooperative Project)

The overall objective of the project is to specify an observational and diagnostics system capable of determining the impact of large-scale variability on regions of the North Atlantic, its adjacent seas and the European continent itself. The intention is to improve the qualitative and quantitative prediction capabilities of application-relevant models. The cooperative project uses measurements in the Atlantic to describe its current state, as well as links to other measurement campaigns. In addition, there is a status description as a function of time via models, and an assessment of large-scale variability effects on regional social and economic conditions in Europe.

» www.zmaw.de/index.php?id=105 «




Schematic of the North Atlantic circulation.

Quadfasel, Nature, 438, 565-566, 2005

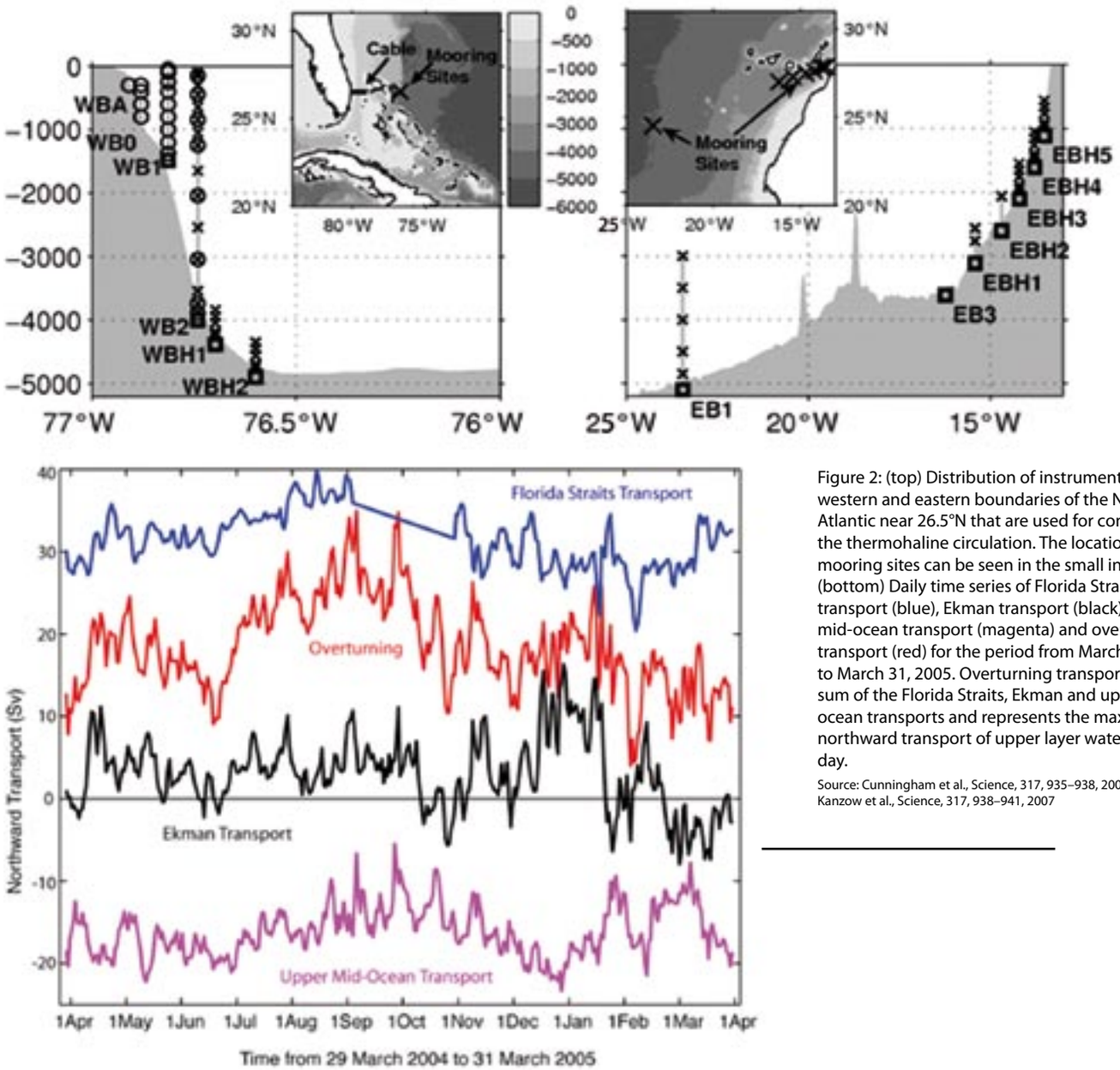



Figure 2: (top) Distribution of instruments at the western and eastern boundaries of the North Atlantic near 26.5°N that are used for computing the thermohaline circulation. The location of the mooring sites can be seen in the small insets. (bottom) Daily time series of Florida Straits transport (blue), Ekman transport (black), upper mid-ocean transport (magenta) and overturning transport (red) for the period from March 29, 2004 to March 31, 2005. Overturning transport is the sum of the Florida Straits, Ekman and upper mid-ocean transports and represents the maximum northward transport of upper layer waters on each day.

Source: Cunningham et al., Science, 317, 935–938, 2007, and Kanzow et al., Science, 317, 938–941, 2007

## Excellence Cluster "The Future Ocean"

Programme Duration: 2006-2011
Funding: DFG (Excellence Initiative)

THE TASK

The ocean is extensively used and altered by mankind. Fishing and the combustion of fossil fuels cause a multitude of changes that can already be observed and that will have consequences yet unforeseen in both the near and distant future. This is another reason why a global management of the oceans and their resources leading to a new symbiosis between man and the sea is urgently needed.

THE IMPLEMENTATION

The work of the scientists in the Kiel Cluster of Excellence "Future Ocean" is aimed at examining the changes in the oceans and re-assessing the risks and opportunities that will arise from the ocean for the future. The long history of marine science research in Kiel is the perfect background for broadening scientific horizons and taking an interdisciplinary approach to the pressing research at hand. A large group of scientists from the most diverse disciplines has joined forces in this Cluster to explore the future ocean together. The Cluster encompasses not only marine researchers, but also geologists, medical scientists, economists, mathematicians, chemists, legal experts and social scientists. A total of five faculties and 26 institutes at Kiel University, the Leibniz Institute of Marine Sciences at the University of Kiel (IFM-GEOMAR) and the Kiel Institute for World Economics (IfW) as well as the Muthesius Academy of Fine Arts are participating in this Cluster. It will establish the marine research focus at Kiel University and thus raise the university's profile as a leading centre for marine research.

» www.future-ocean.de «

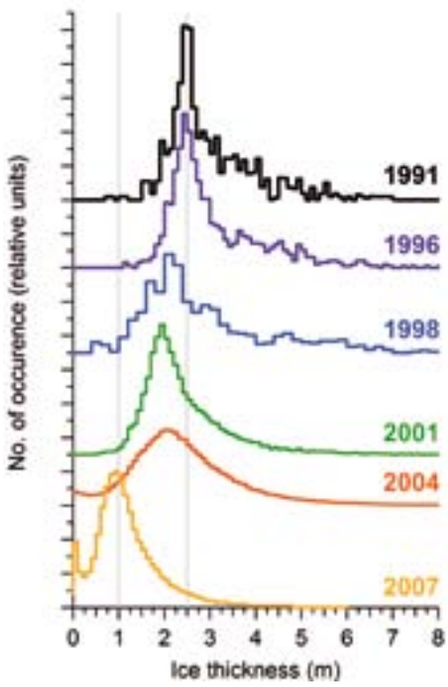
Earth System variability and change is mainly a result of weak external forcing and strong internal feedbacks within the Earth System. Predominant areas in this regard are polar regions which play a special role within the Earth System. They are characterised by very low temperatures, marked seasonality, huge continental ice shields, large oceanic areas permanently or seasonally covered by sea ice, and massive and deep-reaching permafrost layers. The polar regions react sensitively to climate change on the one hand, but on the other they govern global climate evolution on a broad range of timescales as well as having a direct influence on global sea level change, hence impacting coastal regions. Due to extremely long recovery cycles, polar ecosystems are highly susceptible to perturbation.

The particular significance of polar regions is highlighted by the fact that about 90% of the volume of the world's oceans, comprising the deep cold waters, is connected to only 10% of their surface area, and most of these ventilation windows lie in the polar regions. Very specific physical and chemical processes shape the high latitudes, which influence the global environment and its changes through atmospheric and oceanic teleconnections. Examples are the formation of cold air above the white, highly reflective snow and ice surfaces and the production of cold, dense water masses which drive global atmospheric and oceanic circulation; the seasonal cycles of sea ice extent and thickness with resulting changes in ocean-atmosphere coupling; and the specific conditions for chemical reactions in the stratosphere during polar winters.

The Antarctic Circumpolar Current system effectively isolates the Southern Ocean, whereas continents surround the Arctic Ocean with only one deep-water passage. Continental ice sheets are a further special characteristic, acting as integral parts of the climate system by responding, on the one hand, to changes in external forcing and on the other hand driving changes, e. g. by altering global albedo while growing or shrinking. They also act as palaeoclimate archives. Polar ice cores are unique because, of all palaeo-records, they are the most directly linked to the atmosphere and they contain information for many forcing factors of climate. Polar marine ecosystems and organisms are special in that they survive under conditions of permanent cold, extreme seasonality and food shortage.

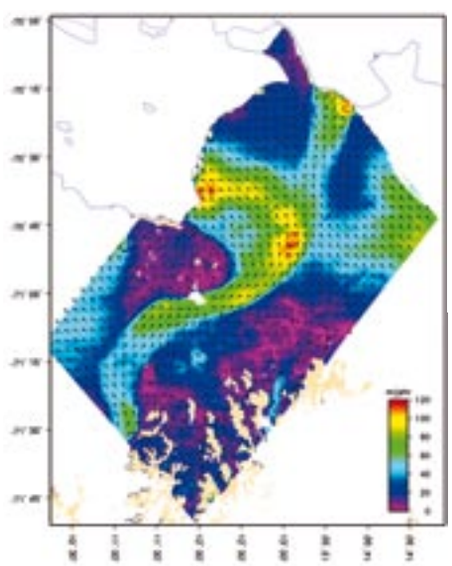
Changes in the sea ice cover, as part of the surface freshwater flux, also play an important role within the system. The physics of sea ice is also influenced by the fact that it is a habitat for many species of marine flora and fauna. Sea ice is an effective channel of primary productivity of small algae to stocks of large animals despite harsh environmental conditions. Excellent global satellite observations of the extent of sea ice are available for the past three decades and they indicate a significant retreat, especially in summer. Large-scale measurements of sea ice thickness, on the other hand, are still hugely challenging. An electromagnetic technique to measure the thickness of sea ice floes has been developed which is now also used from helicopters, thus covering larger distances than previously possible. During six expeditions with the research icebreaker Polarstern, an extensive dataset has been collected which indicates a thinning of the sea ice cover between Spitsbergen and the North Pole from 2.5 m in 1991 to 2.0 m in 2004 and to 1.0 m in 2007 (Figure 1).

Ice sheets store a significant amount of fresh water. Accordingly, their variations have a big impact on the height of sea level with major consequences for coastal regions. A special focus is now put on the outlet glaciers and ice streams of the polar ice sheets, since there are recent indications that, in some cases, the ice discharge is increasing. With the help of radar interferometry, horizontal ice velocities are determined (Figure 2), which are then converted to mass flux data.




C. Haas, AWI

Figure 1: Thickness distribution of extensive sea ice thickness measurements in the Arctic (PDF: Probability Density Function).



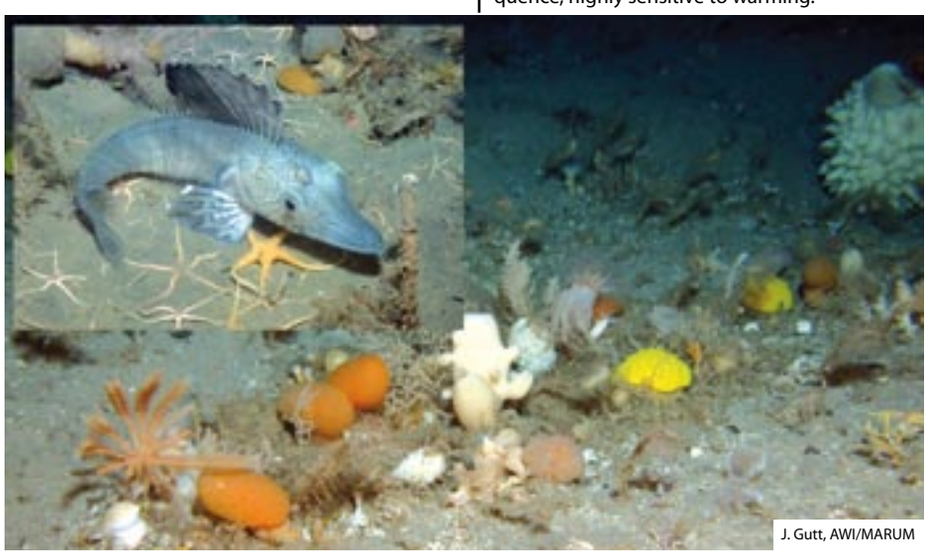
R. Dietrich, Technical University of Dresden

Figure 2: Interferomeric SAR (Synthetic Aperture Radar) analysis gives a detailed picture on horizontal ice velocities (region of Schirmacher Oasis, central Dronning Maud Land, Antartica).

Of special importance is the understanding of the interaction between atmosphere, ice, ocean and land surfaces, their variability, and their impact on the marine and terrestrial ecosystem. Important research questions are the effects of environmental variability on the stress tolerance and resilience of polar organisms and ecosystems. High-latitude organisms and ecosystems (Figure 3) are

highly adapted to polar climate regimes as well as prevailing ice conditions. This makes them particularly sensitive to ongoing warming and acidification of the oceans, which additionally occur at faster rates at polar latitudes than at lower latitudes. Previous research at the molecular, physiological and ecological levels of biological organisation has established the concept of oxygen- and capacity-limited thermal tolerance in marine animals. This concept allows the quantification of the first signs of warming stress felt by individual specimens. It also links performance characters of the organism to the functional properties of the ecosystem, and contributes to explaining the role each species plays in the complex interaction web that makes up an ecosystem. Building on this principal insight, current research elaborates the climate-dependent evolution of polar marine ecosystems, from foraminifera to mammals, through the functional characters of their organisms. Organisms can modify the mechanisms involved in shaping tolerance to ambient extremes by acclimation (of the individual) and adaptation processes (between generations). The capacity and limits of acclimation and adaptation differ between species and climatic regions. For a cause and effect understanding of climate impact, further efforts need to work on elaborating the mechanistic background of, and the reasons for, such differences. This will also support reliable forecasting of future developments in the species composition and functional properties of ecosystems during climatic change.

Figure 3: Antarctic invertebrate assemblage, colonising the sea floor at a water depth of 230m. The inset shows an Antarctic icefish (photographs by J. Gutt). The assemblage includes pioneer species such as sea squirts, horny corals and worms, which recruit and grow soon after disturbance events, as well as young and slow growing adult glass sponges. Icefish (inset) occur predominantly in high latitude Antarctic habitats since they are adapted to low temperatures and, as a consequence, highly sensitive to warming.



J. Gutt, AWI/MARUM

## Research Infrastructure

German polar research relies on a sophisticated infrastructure for operations in Polar Regions including research vessels, aircraft and research stations both in the Arctic and Antarctic.

***Research and Supply Vessel "R/V Polarstern"***

An important tool in Germany's polar research programme is the "Polarstern". Since she was first commissioned in 1982, the "Polarstern" has completed a total of 22 expeditions to the Arctic and 24 to the Antarctic. The ship is equipped for biological, geological, geophysical, glaciological, chemical, oceanographic and meteorological research, and contains nine research laboratories. Additional laboratory containers may be stowed on and below deck. Refridgerated rooms and aquaria permit the transport of samples and living marine fauna. Research equipment and measuring instruments are positioned with the help of cranes and winches, sometimes at extreme depths. Special sounding devices with depth ranges up to 10,000 m and which can penetrate up to 150 m into the sea floor are available for scientific investigations. The computer system on board continuously captures and stores meteorological, oceanographic and other data as required.

» www.awi.de/en/infrastructure/ships/polarstern «

Photo: G. Chapelle, Source: Alfred Wegener Institute

Source: Alfred Wegener Institute

***Neumayer-Station***

The first "Georg von Neumayer" Station in the Antarctic, run by the Alfred Wegener Institute for Polar and Marine Research (AWI), was established in 1981 on the Ekströmn Ice Shelf as a research observatory for geophysical, meteorological and air chemistry measurements, as well as a logistics base for summer expeditions. Through funding from the German Federal Ministry of Education and Research (BMBF), the new polar station Neumayer III is currently being constructed in the Antarctic. The new station, which is made of environmentally compatible materials, supplies a space of 3,300 m² and will be completed in 2009.

» www.awi.de/en/infrastructure/stations/neumayer_station_iii «

"Desertification", i.e. land degradation of arid to semi-humid ecosystems, "resulting from various factors, including climatic variations and human activities" (UNCCD), poses one of the most challenging threats to the continued development of society.

Drylands make up 41% of the world's land surface, and a third of the human population (figures from 2000) lives in these drought- and desertification-prone areas (Figure 1). These ecosystems, ranging from pastoral desert margins to some key agricultural regions (including irrigated areas), are characterized by a very high sensitivity and vulnerability when exposed to declining rainfall or unsustainable land use. Making the distinction between the two causes of degradation remains a serious scientific challenge. The Millennium Ecosystem Assessment (2005) estimates with medium certainty that approximately 10-20% of the drylands – between 6 million and 12 million km² – are already degraded, other reports claim a "greening of the Sahel" since the drought of the early 1980ies Desertification leads to a degradation of the function and productivity of the ecosystem. The cost of agricultural losses alone due to desertification are estimated at $28 billion annually. The Earth System Science Partnership on Global Environmental Change and Human Health estimates that 250 million people are at risk of health consequences from desertification. Whereas desertification due to global climate change calls for adaptive measures, mismanagement of land resources can be prevented and calls for mitigation strategies. The cost of land restoration by far exceeds the cost of preventing human induced degradation. Thus, a key scientific challenge is to distinguish the causes of degradation.

Human induced desertification is caused by land mismanagement such as

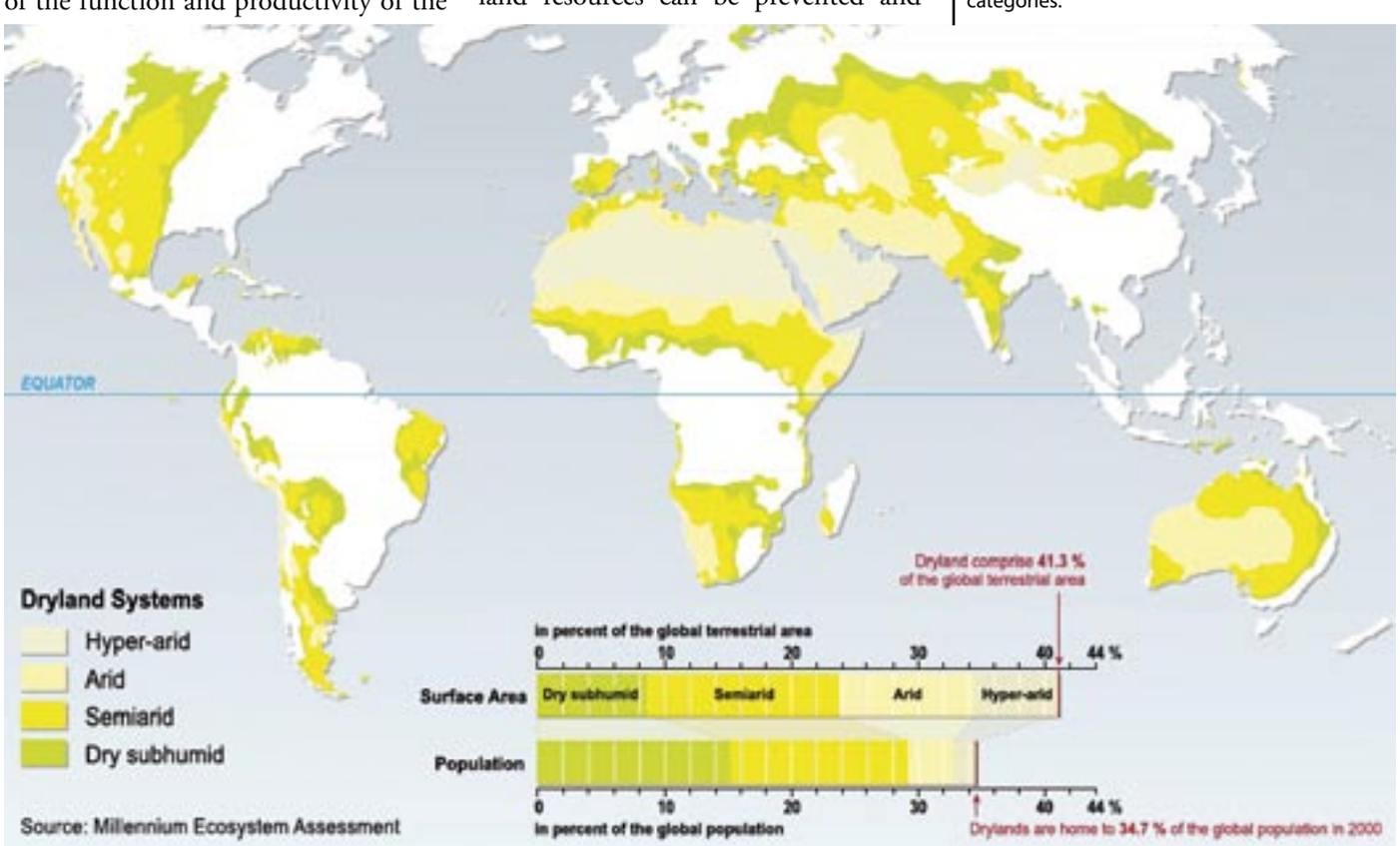
## Scientific Cooperation
## Desert*Net Germany and European DesertNet

The German Scientific Network to Combat Desertification (Desert*Net) is an association which was founded as an interdisciplinary scientific network that serves as an interface for communication and knowledge transfer to prevent and combat desertification (www.desertnet.de). The expertise of Desert*Net Germany is based on an interdisciplinary group of scientists with long-term field and laboratory experience in basic and applied research into desertification in over 40 countries. The major aims of the network are to support bilateral and multilateral activities for sustainable land use systems in degraded areas of developing or transition countries.

The network believes that the dialogue between science and policymakers should be strengthened and Desert*Net works in close cooperation with the United Nations Convention to Combat Desertification (UNCCD). In October 2006, a series of international meetings led to the foundation of European DesertNet, an international scientific network for global desertification research. The European DesertNet has strong support from the EC's DG RECH. Several European ministries have declared that this new network is important to furthering the research process in the combat against and prevention of desertification.

» www.european-desertnet.eu «

Figure 1:
Overlap of urban areas with the four dryland categories.



overgrazing, deforestation, or nutrient mining, erosion and salinisation due to cultivation. Superimposed climate change may lead to non-linear feedbacks that depend on ecosystem properties thus rendering the system complex. Desertification involves processes and mechanisms on various scales, ranging from the single field or pasture to the global biosphere. Similarly, decision-makers are found at various levels, from local farmers to global players in world trade. Combating desertification, thus, calls for integrated approaches and measures, based on knowledge derived from natural as well as socio-economic scientific disciplines.

In many developing countries desertification is emerging as a major obstacle to sustainable development and poverty reduction. It particularly impacts rural households whose economic stability relies on the quality and quantity of their natural resources. The loss in productivity of the land increases rural poverty and intensifies the competition for use and access to increasingly limited natural resources. Conflicts and migration are often the consequence of these processes. Environmental refugees cross national borders in search of new economic perspectives whilst at the same time exporting conflicts and tensions.

Important fields of research are:

- monitoring land resources by remote sensing and airborne systems,
- understanding the causes, processes and mechanisms of desertification,
- modelling and predicting future changes,
- establishing early warning systems,
- developing preventive strategies through sustainable management of natural resources,
- developing adaptive forms of land use to cope with the impact of climate change,
- developing rehabilitation techniques for degraded systems.

This research agenda requires an integrated approach, taking into account the local realities of the affected areas as well as the complex interaction with external actors. Such research should be implemented with the involvement of both local and regional stakeholders and the findings should be communicated both on a local and global scale. Research on desertification and related issues in Germany involves various institutes and universities, covering a wide range of disciplines, research regions and countries.

## Economic and Ecological Restructuring of Land- and Water Use in the Khorezm Region

Project Duration: 2002 – 2011
Funding: BMBF

Since the 1920s, irrigation for cultivation in Uzbekistan, which involves taking water from the Aral Sea, has been continuously intensified. Up until now, water has been delivered through extensive irrigation systems, which are expensive to maintain, and the monocultures have been heavily treated with fertilisers and pesticides. Nevertheless, the population is still exposed to low water availability, soil degradation and salinisation, in economically centralised structures.
The basic idea behind the project is to follow an integrated, interdisciplinary approach, taking into account natural resource management (integrating plantations, e.g. locally favoured poplars for wood production; adapting agricultural production methods, e.g. improvement of irrigation techniques, tillage methods, and the planting of hedges and windbreaks), economic aspects (investigation of economic incentives for saving water, privatising land and developing markets) and legal-administrative factors (e.g. investigation of decision structures and water allocation mechanisms).

» www.zef.de «

Irrigation equipment.

ZEF

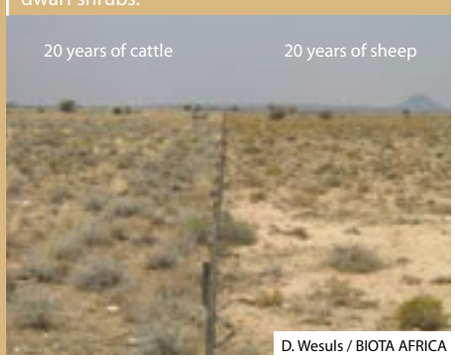
## BIOTA Southern Africa

Project Duration: 2000 – 2009
Funding: BMBF

The BIOTA South projects in Namibia and western parts of South Africa are investigating the changes in biological diversity caused by humans as well as by climate change. To this end, 25 observatories have been set up over an area of 2,000 km$^2$.
The observation zones are differentiated, on the one hand, by their different climates and vegetation and, on the other hand, by varying intensities of agricultural use. Socio-economic and ecological thresholds that characterise adverse management can thus be identified.
The BIOTA South project also shows how the surface of the land has changed over the long-term along the line of observatories. Contributory factors here include farming use, deforestation, the impact of fires and excessive grazing.

» www.biota-africa.de «

Namibia: Grazing can have a strong impact on the composition of plant cover. The photo shows the Duruchaus farm in central Namibia (right-hand side of the fence) where intensive grazing by a high number of sheep and goats caused differences in the species composition of the vegetation compared to the neighbouring farm (cattle farming): On the right-hand side, there is less cover of perennial grasses and palatable dwarf shrubs.




D. Wesuls / BIOTA AFRICA

# Coastal Zone Management

As areas of socio-ecological development and transition, coastal zones are subject to the influence of the ocean, the atmosphere and the land. They encompass drainage basins, coastal lowlands, estuaries and the adjoining shelf seas. In common with most of the world's coastline, the North and Baltic Sea coasts, which are the focus of German research activities, can hardly be regarded as natural environments. They have already undergone major modifications caused by human activities, specifically land reclamation, coastal defences and industrial developments. The latter resulted in both qualitative and quantitative changes of emissions to coastal seas. Ongoing threats to water quality originate from contamination by hazardous substances, eutrophication and oil spills. Global Change implications on the regional scale would be another, more indirect, manifestation of the anthropogenic impact on coastal zones. The prediction of the possible consequences of a changing climate for the North-German coastal regions is one area of focus of the newly formed transdisciplinary cluster of excellence 'Integrated Climate System Analysis and Prediction' (CLISAP) which involves around 120 researchers from universities and research institutions.

Assessing the effects of regional and local climate change and evaluating the necessity, feasibility and efficiency of options for adaptation is a key challenge for global change science. It requires the correct differentiation between the effects brought about by climate change and the consequences of ongoing pressure from old and new forms of human land and sea use. Hence considerable effort is being put into building a re-trospective picture of climatic evolution during the past decades using long time series and model-based analyses of climate variables and dependent para-meters. An IPCC-like assessment report for past, current and possible future climate change and its impact on terrestrial and marine ecosystems put together by approximately 80 scientists from 13 countries ('BALTEX Assessment of Climate Change for the Baltic Sea Basin (BACC)'; http://www.baltex-research.eu/BACC/) was accepted by the Helsinki Commission for the Baltic Sea as a foundation for political discussion. A similar exercise, which is expected to be concluded in 2010, has been launched for the extended metropolitan region of Hamburg. An interim synthesis of continuing studies on long-term ecological change in the German Bight is planned as part of the new Helmholtz research programme 'Polar Regions and Coasts in the Changing Earth System'. The research will be carried out from 2009 to 2013 (www.gkss.de).

Multi-decadal high-resolution re-analyses of environmental conditions from state-of-the-art numerical models play a prominent role in the reconstruction of past conditions. Model data are the only way to obtain regional information with no gaps in space and time. The coastDat portal (www.coastdat.de) is a platform that hosts homogeneous and consistent sets of high-resolution hindcasts for the coastal region. These retrospective analyses are complemented by plausible model-based coastal scenarios for the near future. To further support management decisions on a regional scale, atmospheric global change scenarios are processed for the North Sea and finally broken down into potential impact levels, for example with regard to surface waves, storm surges or transport rates of water constituents.

Besides climate forcing, different forms of human modification of the coastal environment including land- and sea-based use of natural resources (harbours, oil and gas exploitation, wind energy, minerals, fisheries, aquaculture) or their utilisation for recreational and conservational purposes inevitably provoke conflicts of interest. A sustainable use of coastal zones requires rational and integrated management balancing human activity with the requirements of ecosystem conservation. Integrative studies of interactions between different human

## ICZM-Oder/Odra

an integrated river basin – coast – sea approach in a changing world

Duration: 2004-2010
Funding: BMBF

The interdisciplinary national project on coastal management "ICZM-Oder/Odra" has one major focus on integrated water quality modeling, assessment and management. Rivers and their drainage basin control processes and water quality in the coastal zone. Climate change and ongoing transformation processes in agriculture have serious consequences on nutrient fluxes and loads in the rivers.

- How do different stakeholders perceive water quality and what are their specific demands?
- Which measures in the river basin will be necessary to reach a "good" water quality status in coastal waters (according to the Water Framework Directive) and which nutrient sources have to be tackled preferably?
- What are the costs for different water quality scenarios and how would a cost-efficient approach look like?
- How long would it take to reach a certain status and how will the status and all measures be influenced by climate and regional change?

» www.ikzm-oder.de «

Tourism is the major source of income at the Oder/Odra estuary. Increasing storm surges and beach erosion as well as water quality problems due to climate change are a serious economic threat.

Schernewski 2007

activities and the coastal ecosystem are the main focus of two ongoing project clusters (see boxes). Their affiliation with the international coastal research project 'Land-Ocean Interactions in the Coastal Zone', LOICZ (http://www.loicz.org), (operating in contribution to the International Geosphere Biosphere Programme and the International Human Dimensions Programme on Global Environmental Change) opens exchange and review with scientific peers worldwide in a global context.

Coastal zones have always been threatened by weather extremes such as storm surges, flooding and wave activity. The traditional perception of these threats within society is something effective coastal zone management must take into consideration. Stakeholders, including the media and the public at large interpret scientific statements on Global Change within a socio-cultural framework. In addition, scientific knowledge, due to vested interests, political as well as economical, frequently undergoes significant transformation before entering the public arena. Socio-cultural sciences need to explore and comprehend such transformations in the effort to put them into the context of social choice and decision-making.

In order to scientifically underpin an informed integrated management of coastal zones, fundamental research on climate, shelf sea oceanography, biogeochemical processes and cycles, ecological chemistry, as well as ecosystem and biodiversity, must be integrated with applied perspectives, including the regional impact of global change processes. Appropriate observational monitoring strategies are implemented combining efficient instrumental (in-situ and remote) measuring systems with model-assisted data analysis to document ongoing change and trends. Regional environmental models (REMs) analysing recent and historical data assist in determining the background of natural system variability and local particularities. Process knowledge serves to better understand the role of the changing coastal environment for ecosystem function and biodiversity, thus for ecosystem goods and services, and is crucial for the adequate construction of scenarios of possible future developments on decadal and longer timescales. In this context, one of the greatest challenges is the task of ascribing observed environmental trends to either climate change or direct anthropogenic pressure.

The above coastal research approaches have been adopted within the programme topic 'Coastal Dynamics and Causes of Change' of the Helmholtz programme 'Marine, Coastal and Polar Systems (MARCOPOLI)'. Through shared current and future research on projects such as LOICZ and IMBER (Integrated Marine Biogeochemistry and Ecosystem Research), there is ample opportunity for exchange between scientific peers on a global level. Thus, each individual country's research contributes directly to the implementation of the scientific projects of Earth System Science partners such as IGBP, IHDP and the Scientific Committee on Oceanic Research, SCOR.

Successful integrated management of coastal zones, however, also requires interfaces that facilitate a two-way exchange of concepts, concerns, questions and knowledge between the climate research community and the general public. Changing public perceptions and preferences have to be taken into account by researchers. To achieve this goal the 'Norddeutsches Klimabüro' (www.norddeutsches-klimabuero.de) was founded in 2006 as one node of a network of similar regional offices. The objective of the office is to identify and satisfy the information needs of a multiplicity of coastal stakeholders. The spectrum of information to be transmitted encompasses comprehensive analyses of regional climate conditions including possible trends. The office also aims to provide context and explanation of basic concepts such as natural climate variability, detection of human-induced change and attribution to causes, scenarios and uncertainty. Located at the science-practice interface it will help both to better identify practice-oriented aspects in climate research and to communicate the outcomes of such research to a wider non-scientific audience.

## Zukunft Küste – Coastal Futures

Analysing coastal socio-ecological systems and related governance structures in times of global change

Duration: 2004-2010
Funding: BMBF

The project cluster "Zukunft Küste – Coastal Futures" works towards integrated assessment for coastal changes. Based on the notion of socio-ecological systems, the application of the Driver-Pressure-State-Impact-Response (DPSIR) approach and the concept of ecosystem services, the cluster focuses on risks and opportunities associated with offshore wind farms in the German North Sea as an example for sea use change. Key activities include:

- discussing future sea use patterns using a scenario approach,
- modelling and assessing impacts of offshore wind energy on specific ecosystem services,
- modelling and assessing economic impacts of offshore wind energy at local and regional scale,
- analysing social values, problem perceptions, institutional networks and communication,
- analysing and assessing related policies and governance structures.

» www.coastal-futures.org «

REpower Systems AG

# Carbon Cycle Research as a Challenge of the Anthropocene

Fossil organic carbon deposits in the form of oil, coal, methane gas or peat are presently being used at an ever-increasing rate as humankind's main energy supply. The $CO_2$ released by the burning of these fossil fuels is a climatically active gas influencing the Earth's heat balance. Rising surface temperatures and changes in climatic conditions are consequences of the mounting $CO_2$ concentrations in the atmosphere. This real danger has precipitated intensive research into the natural and anthropogenically influenced carbon cycle as well as its relevance to global society. Only about 50% of the emitted $CO_2$ accumulates in the atmosphere, the remainder being taken up by sinks in the ocean and terrestrial ecosystems. It is not clear whether these sinks will continue to exist in the future, particularly in the face of a changing climate. Therefore, the elucidation of oceanic and terrestrial carbon sink processes and their regional and global quantification is a priority item in carbon cycle research.

In Germany, specific research effort has been concentrated in the following areas: The investigation of the role of the North Atlantic in sequestering anthropogenic $CO_2$, the determination of the European carbon balance, an understanding of the impact of climate and land use change on terrestrial carbon fluxes and the development of alternative carbon-free technologies for energy production.

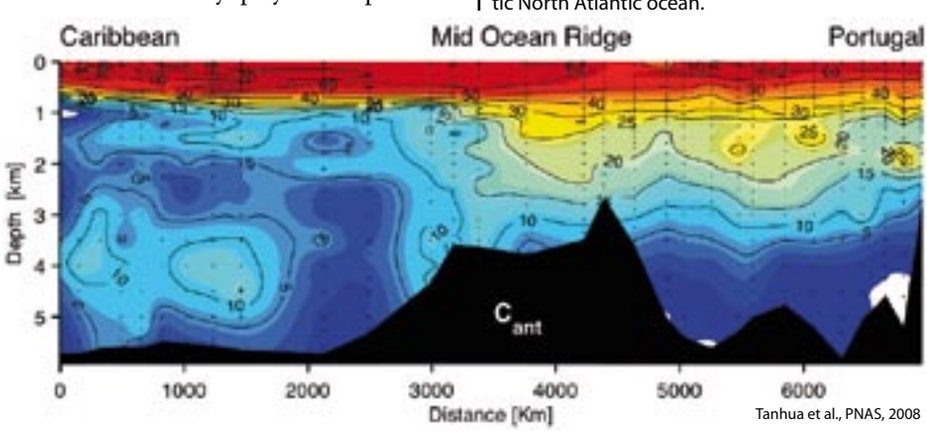
The ocean contains 50 times more carbon than the atmosphere and, hence, small changes in the flux between ocean and atmosphere have a very big impact on the atmospheric balance of $CO_2$. One of the most important regions for oceanic uptake of $CO_2$ is the North Atlantic (Figure 1). About 20% of the global oceanic uptake of $CO_2$ enters this region and is transported into the ocean's interior by physical processes of deep water formation. In addition to such physical processes, biological uptake and subsequent sinking of organic carbon to deeper waters also contribute to the global oceanic carbon balance.

High spatial resolution models that couple physical ocean processes with biological and chemical processes show that there is a strong fluctuation in the uptake of $CO_2$ from year to year, mainly caused by variations in wind stress and heat flux which affect the biological fixation of carbon. Changes in the intensity of deep-water formation, climatic fluctuations and shifts in biological production significantly alter the carbon uptake and, therefore, it cannot be assumed that the ocean is a constant sink for anthropogenic carbon.

In contrast to the ocean, terrestrial carbon sinks are much more heterogeneous in space and time, and are controlled by a multitude of processes that are still poorly understood. In Europe, the carbon balance is determined primarily by fossil fuel emissions (total of 1.2 Pg C $y^{-1}$) for which there is approximately 30% compensation by terrestrial carbon uptake in growing forests. On the other hand, croplands are losing carbon and hence reducing this terrestrial sink. In addition, climate variations strongly modify the terrestrial carbon balance. Ecosystem model simulations, covering the period from 1948-2003, showed a significant decrease in carbon uptake in Southern Europe (especially Spain and Southern France) and Eastern Europe during the drought year of 2003 (Figure 2). In the aforementioned regions, net ecosystem production (NEP) declined by more than 100% relative to the long-term mean. The model results also show that enhanced nitrogen deposition, increased $CO_2$ concentrations and moisture availability play an important role in the enhanced growth of forests, especially young forests.

An observation system for monitoring and quantifying large-scale regional changes in carbon fluxes and stocks on the European continent and the North Atlantic Ocean has been set up in recent years within the framework of the two European integrated research projects CarboEurope-IP (www.carboeurope.org) and CarboOcean-IP (www.carboocean.org). This observation system will provide (1) regional information on carbon sinks, their magnitude and spatio-temporal variability, (2) regional information on climate - carbon cycle feedback processes and (3) help to independently monitor the evolution of the European carbon balance in the context of the Kyoto protocol and its successor treaties. As part of the large-scale European research infrastructure, the Integrated Carbon Observing System (ICOS) has been established to harmonise high quality carbon observations over the next few decades.
National support for the long-term operation of ICOS constitutes a high priority and contributes considerably

Figure 1: Concentration of anthropogenic carbon (Cant) in the year 2004 on a transect across the North Atlantic at approximately 35°N (in µmol/kg, from the Caribbean to Portugal). Most of the anthropogenic $CO_2$ uptake by the ocean results in an accumulation of DIC (Dissolved Inorganic Carbon) in the uppermost 800 m of the water column. Significant accumulations are also evident in the Mediterranean outflow waters around 2 km depth in the eastern Atlantic as well as in the western Atlantic below 3 km as part of the deep water circulation sequestering excess $CO_2$ that has been taken up in the subarctic North Atlantic ocean.

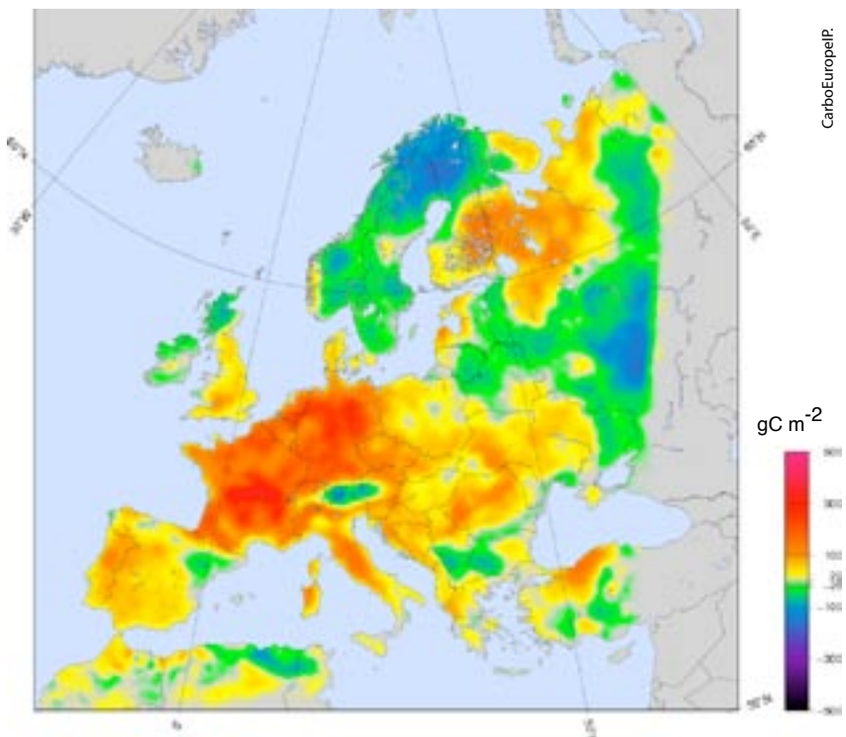



Tanhua et al., PNAS, 2008

to the implementation of the Global Earth Observation System of Systems (GEOSS).

Within the United Nations Framework Convention on Climate Change (UNFCCC), the vast majority of nations has agreed to a "stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (Art. 2). Whereas original climate policy initiatives have concentrated on the emissions of greenhouse gases – of which $CO_2$ is presently considered to be the most important – it is now apparent that carbon management will need to incorporate the complete carbon cycle and not only atmospheric emissions. Hence, different forms of carbon sinks are being looked into. The Kyoto Protocol already takes account of the terrestrial carbon sink in the form of biomass. Sequestration of carbon in the deep oceans and in geological land formations are part of the research considerations and a number of test projects already exist. However, there is still a considerable amount of research to be done before sufficient knowledge to enable full carbon management becomes available and before policy measures are developed in order to make such management feasible. The European emissions trading system for $CO_2$ is a first step in this direction.

Figure 2: Anomalies of net ecosystem production (NEP) in 2003 were calculated as the difference between May-September NEP in 2003 and May-September mean NEP for 1998-2002 and are expressed as deviation in g C $m^{-2}$. NEP was calculated with the Lund-Potsdam-Jena ecosystem model.




## CARBOOCEAN (Marine Carbon Sources and Sinks Assessment )

Project Duration: 01/2005 – 12/2009
Funding: EU

The aim of CARBOOCEAN is to describe and quantify the sources and sinks of natural and anthropogenic $CO_2$ in the ocean. The project's main questions are:
What are the exact dimensions of the Atlantic and Southern Ocean $CO_2$ sinks, i.e. how efficient is the downward transport of carbon in the deep-water production areas of the world's ocean?
What do European rivers and shelf seas contribute to the large scale $CO_2$ sources and sinks pattern of the North Atlantic Ocean in relation to uptake within Western Europe?
What are the key biogeochemical feedbacks that can affect ocean carbon up-take and how do they operate?
What is the quantitative global and regional impact of such feedbacks when forced by climatic change in the next 200 years?

» www.carboocean.org «

## CarboEurope: Assessment of the European Terrestrial Carbon Balance

Project Duration: 01/2004 – 12/2008
Funding: EU

What is the role of the European continent in the global carbon cycle? To advance our understanding in a multidisciplinary and integrated way, 61 research centres from 17 European countries have joined forces for a 5-year EU-funded research project that began in January 2004 and is coordinated by the MPI for Biogeochemistry, Jena. CarboEurope aims to understand and quantify Europe's present terrestrial carbon balance and the associated uncertainty on a local, regional and continental scale. This involves determining the European carbon balance with its spatial and temporal patterns, understanding the controlling processes and mechanisms of carbon cycling in European ecosystems and how these are affected by climate change, variability and human management, as well as developing an observation system to detect changes in atmospheric $CO_2$ concentrations and ecosystem carbon stocks related to the European commitments under the Kyoto Protocol.
In order to achieve these aims, CarboEurope addresses three major topics:

1. Determination of the carbon balance of the European continent, its geographical patterns, and changes over time. 2. Enhanced understanding of the controlling mechanisms of carbon cycling in European ecosystems, and the impact of climate change and variability, and changing land management on the European carbon balance.
3. Design and development of an observation system to detect changes of carbon stocks and carbon fluxes related to the European commitments under the Kyoto Protocol.

» www.carboeurope.org «

# Atmospheric Changes

In the past century, the composition of the atmosphere has changed dramatically, with direct consequences for air quality, the earth's energy budget, protection from ultraviolet radiation, weather events and the water cycle, all of which primary conditions for life. It is evident that the atmosphere is a central component in the climate system. In fact, the atmosphere is a major natural transport system for energy, water, nutrients and pollutants, being effective on different space and time scales.

The main research objective is to establish the predictive capability required for a timely response to atmospheric and climate change, whether it be anthropogenic or natural in origin. This requires the extension of the current generation of computer models into predictive tools, which can be adequately verified and validated through the comparison with observations. A vital aspect is therefore the expansion of the measurements of key atmospheric parameters.

Atmospheric research using aircraft has a long tradition in Germany (Figure 1). In 2009, a new research aircraft, HALO (see box), will be put into operation. Satellite sensors are also powerful tools in atmospheric research, adding the global perspective. Based on novel data retrieval techniques, German researchers pioneered comprehensive sensing of reactive tropospheric gases from space. Europe has undergone a strong expansion in its capabilities of remote sensing from space thanks to ENVISAT, the largest environmental satellite to date. ENVISAT comprises ten sensors measuring a multitude of parameters in the atmosphere and on the earth's surface, including temperature, water vapour, concentrations of trace constituents and cloud properties.

The synthesis of growing knowledge is advanced through computer modelling. German institutions have been at the forefront of modelling advancements, initially via the development of general atmospheric circulation models. In the last decade, coupled ocean-atmosphere-land models have advanced and are now able to perform transient climate simulations and seasonal climate anomaly predictions. Also emerging in the last few years are the first high-resolution regional coupled models, including interactive hydrology for detailed regional climate scenario calculations.

Computer models are used to analyse complex system feedback through sensitivity studies, and to predict possible states of the system. Atmospheric forecasting on short timescales of up to two weeks is optimised by assimilating observed data into the model. This limits the initial conditions for simulations and provides deterministic information about predicted weather conditions, as well as air quality and ultraviolet radiation levels. It was recently shown that anomalous weather conditions in the stratosphere can be forecast with a new coupled atmospheric chemistry-climate model (Figure 2). On longer timescales, the atmosphere-climate system is "chaotic" so that forecasting can only provide statistical information.

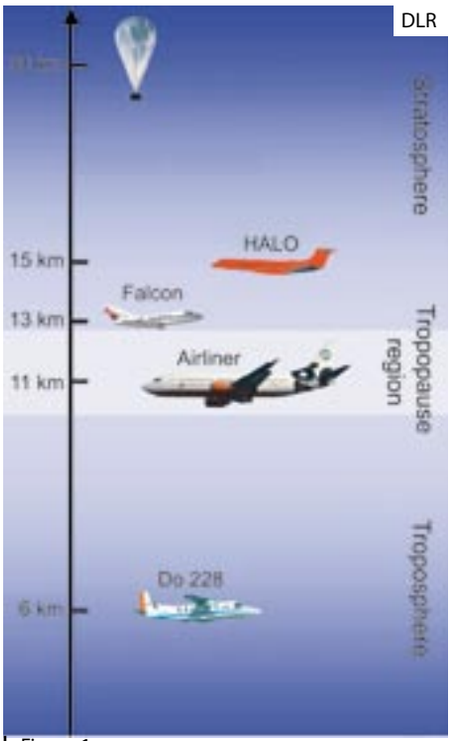
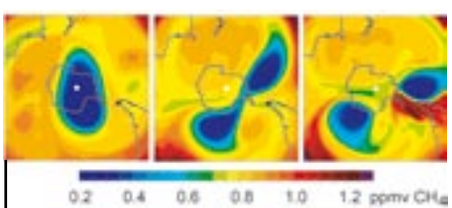



Figure 1:
Airborne research platforms used in atmospheric research, indicating the investigated altitude ranges.



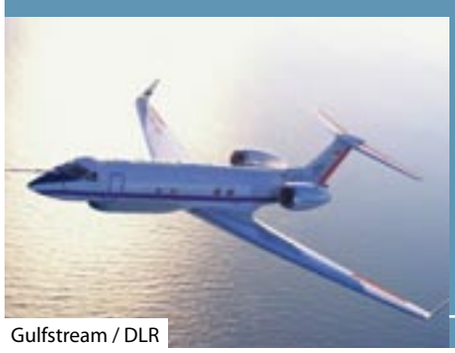

MPI for Chemistry

Figure 2:
Model calculation of the unusual vortex split in the stratosphere over Antarctica, 20-28 September, 2002 (10 hPa).

## HALO (High Altitude and Long Range Research Aircraft)

HALO is financed by the German Federal Ministry of Education and Research (BMBF), the Helmholtz Association of German Research Centres and the Max Planck Society (MPG).

It will be used for global atmospheric research in the high troposphere and lower stratosphere for its ability to facilitate operations with a suite of instruments at altitudes up to 15.5 km with a range of about 8,000 km.
HALO will open up a new quality of airborne atmospheric research for German scientists with the potential to perform multi-sensor measurements on large scales, from the tropical rain forest to the remote oceans and the polar regions.



Gulfstream / DLR

HALO (Artwork).

The atmospheric research community has identified six thematic areas for which work programmes have been developed:

- **"Atmospheric self-cleaning capacity and air quality"** addresses the hemispheric and global distributions as well as sources/sinks of short- and long-lived chemical components and the changes affecting them. There is a particular need to better understand the role of natural trace gases, the photochemistry of the tropical troposphere and processes in the tropopause region.
- **"Lower-middle atmosphere interactions and climate"** investigates stratosphere-troposphere coupling relating to the ozone layer and climate predictability and their impact on ultraviolet radiation. This area highlights the role of water vapour in the energy budget as well as the dynamics of the stratosphere, and how studies of dynamic interactions with the troposphere may improve long-term weather and climate forecasting.
- **"Biogeochemical cycles and the climate system"** studies atmosphere-biosphere, atmosphere-ocean and atmosphere-land exchange processes, in particular in the carbon cycle, and how they link to atmospheric composition and climate change. New aspects in this area are the role of reactive carbon species of natural origin and the coupling of the nitrogen and carbon cycles.
- **"Aerosols, clouds and the water cycle"** focusses on the role of aerosol particles and cloud microphysical processes, convection and the properties of cirrus clouds. The investigations encompass effects of aerosols on the surface energy budget and evaporation, and precipitation formation in convective clouds.
- **"Extreme weather events"**, is particularly concerned with the processes that lead to floods and droughts. The question is how these processes act under climate change, and how precipitation forecasts can be improved. While the overall picture is that global warming is expected to accelerate the water cycle, precipitation may become more intense in some regions and decrease in others.
- **"Seasonal to interdecadal variability and predictability"** analyses the Earth System dynamics and its representation in coupled ocean-atmosphere-land climate simulations. The present climate models will be extended into a first generation of Earth System models to be used in scenario simulations and climate forecasts. The level of detail of biogeochemical, aerosol and cloud processes in the models will be based on the thematic studies mentioned above.

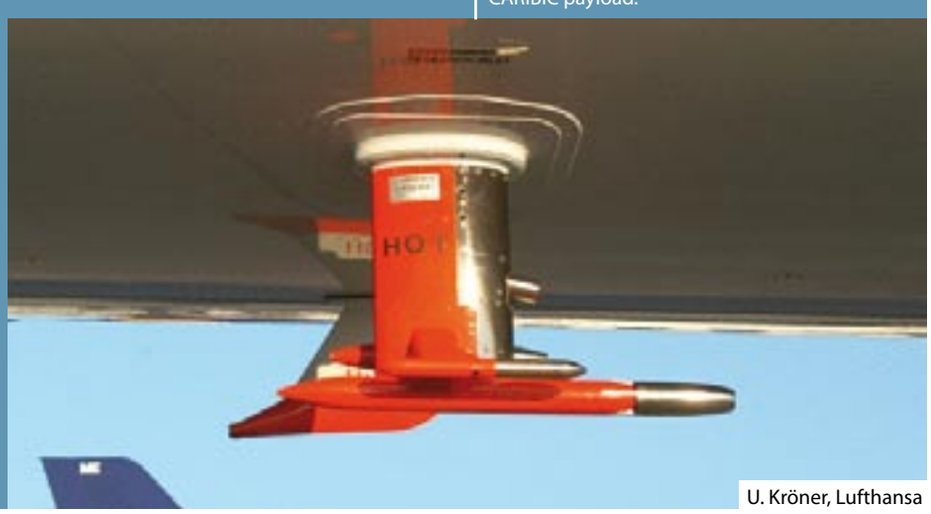
## CARIBIC (Civil Aircraft for the Regular Investigation of the Atmosphere Based on an Instrument Container)

Project Duration: 1995 – 2013
Funding: EU, BMBF

CARIBIC is a long-term project aimed at the understanding of Global Change in the upper troposphere and lower stratosphere. The heart of CARIBIC is an automated instrument container with an ever-increasing number of analyses of trace gas and aerosol parameters. This 1.5 ton payload is deployed on commercial aircraft flying on intercontinental routes, operating autonomously at altitudes of between 8 and 12 km. From 1997-2001, the CARIBIC payload was carried on a Boeing 767 of LTU between Germany and a number of destinations in the Indian Ocean, Southern Africa and the Caribbean. Since 2005, the new partner airline Lufthansa carries CARIBIC on an Airbus 340-600 to longer haul destinations such as South America and Eastern Asia. It is planned that this partnership will last at least ten years. CARIBIC yields systematic long-term intercontinental data on composition and processes in a sensitive region of the atmosphere, which is stressed by the increasing burden of commercial air traffic and by the flux of anthropogenic emissions from the earth's surface. Its current total of 1,000,000 flight kilometres corresponds to 25 circumnavigations of the globe. Highlights of the results to date are revised global budgets of trace gases, aerosol climatologies, convective transport of particles and trace gases over tropical Africa, and mixing processes between tropo- and stratosphere. The CARIBIC consortium was founded in 1993 by the MPI for Atmospheric Chemistry, Mainz, the Institute for Meteorology and Climate Research, Forschungszentrum Karlsruhe and the Leibniz Institute for Tropospheric Research, Leipzig. To date, the consortium comprises six German and five European research groups, each with their own specific experimental or modelling competence.

» *www.caribic-atmospheric.com* «

Air inlets and video camera at the lower fuselage of the Lufthansa A340-600, carrying the CARIBIC payload.



U. Kröner, Lufthansa

# Land Use Change

Change in land cover caused by conversion is the most substantial human-induced alteration of the Earth's System. Conversion for farming or another productive use serves human well-being, but also causes changes in environmental processes that are shaping the ecosystem functions and services on which mankind depends. For example, agricultural intensification as fostered by the Common Agricultural Policy (CAP) of the European Union has increased the effectiveness of agricultural production over the last 40 years but has also profoundly changed European agroecosystems. Because environmental damage is often very difficult to reverse, research on the consequences of land use change needs to be based on proactive management of land resources with a long-term perspective in order to avoid irreversible mistakes. This requires not only a sound understanding of the environmental processes affected by land use change, but also scientific tools to enable stakeholders to anticipate potential outcomes (both benefits and costs) of alternative land management options. Policy decisions on land use and management would thus be based on a proper balance between the ecosystem products and services in sustaining human livelihoods and protecting the environment. The German research community is heavily involved in the analysis of these complex processes and in the development of tools to optimise the management of these critical natural resources, both in Europe and worldwide.

Land use change is a phenomenon that emerges from the interactions between various components of the complex human-environment system, which then feeds back to influence the subsequent development of those interactions. Changes in land allocation occur at the level of households and plots of land. These short-term/localised changes are the result of multiple decisions made by individual human actors under diverse socio-ecological conditions. Temporal accumulation of short-term changes and spatial aggregations of localised changes generate emergent patterns of both socio-economic dynamics and land-use changes on the larger scale. Changes on the macro level such as infrastructural or policy interventions influence the behaviour of the individuals in a way that then produces changes on the micro level. In short, land-use change is a non-linear, dynamic and transformative process having multiple-dimensions (space, time and human).

Because of various feedback loops between society and ecological processes, land-use change studies should be integrated with studies on changes in the functionalities of land ecosystems. A major challenge is to integrate ecological and socio-economic studies on the relevant spatial scale. Changes in land use often negatively affect biodiversity on the local level while ecological functions such as biogeochemical cycles are simultaneously affected on a larger scale such as the watershed. The decisions of individual human actors are influenced by processes occurring on spatial scales ranging from international (e.g. WTO) to local level (local communities). Most models are currently insufficient and include only a limited number of components of the feedback loops or only work on specific spatial scales. For example, spatially distributed soil erosion models for Ethiopia (box below) have been successfully applied in the identification of hotspot areas of erosion, but the interactive loop between land use/management and this key ecological process was not explicitly captured. Land use/cover in such conventional models is treated as a consistent/static driver of the soil redistribution processes and the environmental feedback of such processes on the behaviour of the person using the land cannot be addressed.

In Germany, a number of research institutions and universities have departments explicitly focussing on feedback loops between society, land use and environmental processes including biodiversity change (www.usf.uni-kassel.de/cesr/, www.pik-potsdam.de/, www.ufz.de, www. zef.de). In addition, a number of funding programmes from the main German funding agencies address the causes and consequences of land cover changes.

## Modelling Natural and Socio-Economic Dynamics

A spatially explicit multi-agent model has been developed at ZEF to simulate land use change and the interrelated socio-economic dynamics at the community-catchment scale. The natural landscape was modelled in the form of land automata, i.e., land units hosting natural processes and changing their nature in response to local conditions exerting influence on each land-unit and its immediate neighbourhood. Major ecological models, e.g. on soil erosion and biomass productivity, have been integrated into the land automata structure. The human community is represented by heterogeneous decision-making entities that integrate household, environmental and policy information into land use decisions. A multi-agent based protocol coordinates the flexible interactions among human agents and land automata, and monitors land use changes and associated socio-economic dynamics. The operational model is able to systematically generate spatio-temporally explicit land-use change and interrelated socio-economic dynamics resulting from land use policy interventions. By applying the model in an upland watershed in Central Vietnam, scenarios of land use changes under different policy options on forest protection zoning, agrochemical subsidies and agricultural extension have been generated to create a scientific basis for evaluating the consequences of such policy interventions. Efforts to fine-tune the model structure and its validation in different geographical environments are underway.

## STORMA (Stability of Tropical Rainforest Margins in Indonesia)

Programme Duration: 2000 – 2012
Funding: DFG

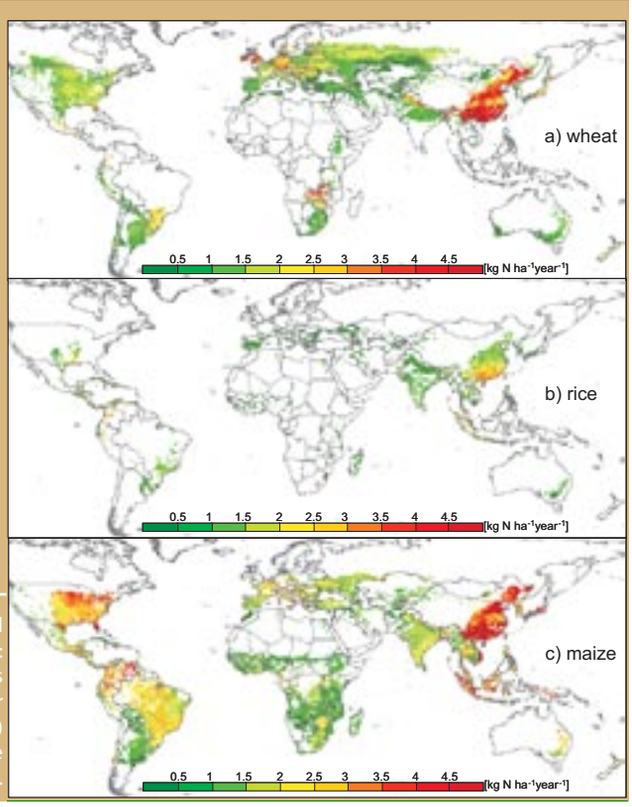
Tropical rainforests are disappearing at an alarming rate causing unprecedented losses in biodiversity and ecosystem services. Despite an increased recognition of the value of these public goods at local, national and global levels, rainforests continue to be seriously threatened by various forms of encroachments such as low-intensity harvesting of non-timber forest products by the rural poor, large-scale plantation forestry by the state or private firms, and the conversion of forested land by smallholder farmers, either temporarily through shifting cultivation or permanently through the establishment of agroforestry, cropping or grazing systems. The main objective of STORMA is to identify and analyse the many factors determining the stability of rainforest margins in a critical case study area, namely Sulawesi, Indonesia. In the course of several years of study, STORMA researchers have gained many new insights into the underlying processes of deforestation and the role of migration, land ownership and cropping patterns in these processes. Monitoring and modelling studies have provided new knowledge about the close relationship between global cash crop demands, local demographic trends, and the ecosystem services afforded by tropical forests.

» www.storma.de «

## Global Modelling of Land Use Change

Programme Duration: 2002 – 2012 (projected)
Funding: Various international and national funding organisations

The critical role that global land use change plays in the Earth System has motivated efforts to model land use change on the global scale. German research institutions are taking a leading role in this dynamic field. The Potsdam Institute for Climate Impact Research is the driving force behind the further development of the LPJ model, one of the leading tools for simulating the response of global vegetation patterns to climate and its linkage to the global carbon cycle. The Centre for Environmental System Research (CESR) at the University of Kassel has developed and applied a new global land use model LandSHIFT which combines biophysical elements (potential crop and vegetation calculations) and socio-economic elements (cellular automata) in a single integrated framework. LandSHIFT has been used to simulate changes in future patterns of urban, agricultural, grassland and forested areas. German research in global land use modelling has provided considerable new information about the coupling between global land use and the earth system, for example, about the relationship between global land use changes and the fluxes of greenhouse gases.




The relationship between land use and greenhouse gas fluxes: Simulated annual $N_2O$ emissions [kg N $ha^{-1}y^{-1}$] in the 1990s for rainfed wheat (a), wetland rice (b) and maize (c) cropping using the modified Day Cent model.

## Understanding the Feedback Loops between Society, Land Use, Biodiversity and Ecosystem Functioning

Programme Duration: 2006 – 2018 (projected)
Funding: DFG

At the end of 2006, the DFG started an ambitious project designed to address critical questions on the role of land use for biodiversity and ecosystem functioning. The novelty of this approach, termed "biodiversity exploratories" is that researchers study the diversity of a large number of taxa (from microorganisms to vertebrates) at various levels of organisation (genetic diversity, species diversity, diversity of interactions) in the same experimental plots using standardised methodology, and link the diversity to a variety of ecosystem functioning such as carbon storage, nutrient cycling or predation. The initial phase of this project focuses on grassland and forest ecosystems. In each of three areas in Germany, the Biosphere Reserve Schorfheide-Chorin (NE Germany), the Hainich area in the centre of Germany, and the upcoming Biosphere Reserve Schwäbische Alb (SW Germany), 50 grassland and 50 forest plots have been established representing a gradient of land use intensity ranging from low management (e.g. forests in national parks) to highly managed area (age-class forests). The biodiversity exploratories aim to bring the German research community together and pioneer advanced methods of storing and analysing the data generated from the projects as well as the preservation of the samples obtained.

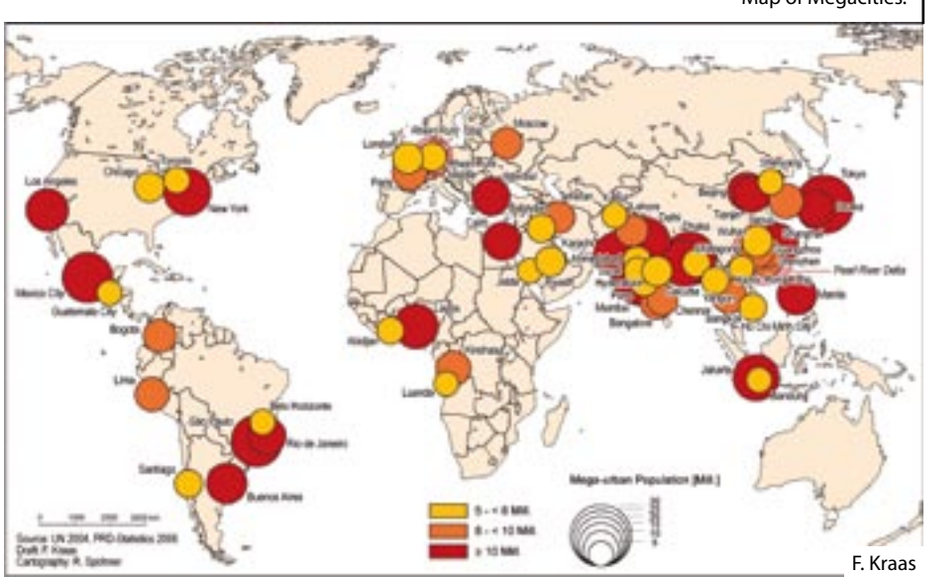
# Megacities – Urban Dynamics of Global Change

As from 2007, more than half of the world's population (3.3 billion people) lives in cities – an increase from 30% in 1950 and 47% in 2000 – and the proportion will probably reach 60% in 2030. Urbanisation is occurring at a fast pace, particularly in the developing countries of Asia and Africa. Megacities, i.e. cities with more than 5 million inhabitants, are particularly significant in this worldwide process of urbanisation. Almost 60 megacities, with total population figures of more than 600 million people, are expected to exist by 2015.

Megacities are characterised by new scales, new dynamics, new complexities, i.e. they have the largest population figures and densities and the highest development dynamics as well as intense and complex interactions of different demographic, social, political, economic and ecological processes. Moreover, highly dynamic processes take place simultaneously, thereby often reinforcing themselves. In economically booming megacities, major new opportunities coexist with strong pressure for change. In the developing world, the most dominant features are largely uncontrolled spatial expansion, high traffic volumes, often severe infrastructural deficits, high concentrations of industrial production, ecological strains and overload, unregulated and disparate land and property markets, insufficient housing provision and, in some cases, extreme socio-economic disparities and fragmentation. But one must nevertheless be wary of generalised statements, and differences in economic development, social polarisation, quality of infrastructure and governability should not be ignored.

Under the dynamics of global change – understood as global environmental change as well as global socio-economic and political change – megacities are facing an increasing number of different options: On the one hand they are prone to growing socio-economic vulnerability and risk due to pronounced poverty, socio-spatial and political fragmentations, sometimes with extreme forms of segregation, disparities and conflicts. The juxtaposition of very different ways of life (including ethnic, social and behavioural groups) and lifestyles plays a significant differentiating role. On the other hand – and this is a point that is often neglected – megacities offer positive potential for global transformation, e.g. minimisation of "space consumption", high effectiveness of resources applied, efficient disaster prevention, adequate health care – if good strategies are developed. Megacity research is therefore set to become a central element of complex global policy issues as new scales and new dynamisms make megacities both global growth and innovation areas as well as global risk areas.

Map of Megacities.




F. Kraas

F. Kraas

Crowd in Mumbai, India.

Against this background, the German National Committee on Global Change Research (NKGCF) successfully encouraged a dialogue within the scientific communities to look into options of bundling their previous research efforts focussing on the most important challenges of megacities research. At the same time the German Ministry of Education and Research (BMBF) developed its programme on "Research for the Sustainable Development of the Megacities of Tomorrow" (2005-2013). The German Research Council (DFG) granted one of its priority programmes to "Megacities – Megachallenge: Informal Dynamics of Global Change" (2006-2012). The Helmholtz Association started a project on "Risk Habitat Megacity" (2007-2013). These efforts are also in line with the recently approved new International Human Dimensions Programme (IHDP) core project on "Urbanisation and Global Environmental Change" as well as with one of the key topics "Megacities – Our Global Urban Future" of the International Year of Planet Earth (2007-2009). Most projects are based on proven international partnerships between interdisciplinary academic communities as well as major stakeholders from local governments, private enterprises, non-governmental organisations and civil societies, particularly in developing countries.

At present, all major research projects running under the three German initiatives focus on topics such as mega-

urban sustainability, comprehensive environmental and social management, mobility and transportation, climate protection and energy efficiency, water and energy supply and consumption, food supply and nutrition, waste treatment, urban health and quality of life, mega-urban planning and governance: loss of governability and steering capabilities, fragmentation and social coherence, social innovation, the dynamics of informal processes, security issues, urban vulnerability, risk assessment and disaster prevention. New methodologies have to be applied for mega-urban contexts, such as the analysis of high-resolution satellite data, decision support systems and scenario techniques.

## Megacities - Megachallenge: Informal Dynamics of Global Change

Programme Duration: 2006 – 2012
Funding: DFG

Megacities are results of globalisation processes and subject to global ecological, socio-economic, and political change. Reciprocally, they also influence these changes due to their development dynamics. Increasingly, in megacities worldwide more and more processes take place unregulated and informally, which is hardly understood and researched with respect to form, function, and interaction.
Against this background, the priority programme of the DFG is aiming at an understanding of the connection between the informal mega-urban processes and the form and effect of global change upon the spatial, social, and institutional relationships in megacities. The processes and interactions of four issues with high development dynamics and social relevance form the main focus of the programme: New governance forms and self-organisation, differentiation of urban economies, dynamics of matter and resource flows, informal settlement development. The two mega-urban areas of Pearl River Delta/China and Dhaka/Bangladesh were selected.

» www.geographie.uni-koeln.de/megacities-spp «

## Megacities of Tomorrow – Energy- and climate-efficient structures in urban growth centers

Programme Duration: 07/2005 – 03/2013
Funding: BMBF

BMBF's funding priority focuses on future megacities, i.e., rapidly growing cities, approaching the threshold to megacity status in the coming decade. These cities still have the chance to practice precaution, chart sustainable courses to their future and utilize proactively the momentum of the inevitable transformations. Urban agglomerations and, in particular, megacities in developing and newly industrialising countries also contribute to the three quarter of global energy consumption as well as approx. 85% of the global production of greenhouse gases originating in cities. Many of these future megacities not only co-drive climate change, they also receive the full brunt of its consequences, not least because about a fifth of the world's population lives less than 30 kilometers from the coast in areas with high population densities.
The funding priority aims at the development and implementation of solution-oriented and integrated planning and management concepts (best practice). Sixteen projects were set up for a pre-phase (07/2005-03/2008): Cities in Latin America, Africa and Asia are considered. As to their topics, they are dedicated towards specific practical needs, exigencies as well as innovation potentials of urban living e.g., energy supply and consumption, water supply, urban planning. For the up-coming main-phase (04/2008-03/2013) successful teams will have to prove their capacities in prioritizing their efforts on the implementation of energy- and climate-efficient structures in urban growth centers.
The funding priority contributes to the international dialogue as outlined in BMBF's "Hightech Strategy for Climate Protection". Furthermore, it is part of the "fona - Research for Sustainability" framework programme by BMBF.

» www.emerging-megacities.org «

## Risk Habitat Megacity.
## Strategies for Sustainable Development of Megacities and Urban Agglomerations

Programme Duration: 2007 – 2013
Funding: Helmholtz Iniatiative and Networking Fund

Urbanization, as a social phenomenon and physical transformation of landscapes, is one of the dramatic current global changes. Its speed, scale and global connectedness turn the urban habitat in megacities into both a space of risk and a space of opportunity. What factors drive the risks and opportunities that associate with the global trend towards mega-urbanization? What risks, or indeed opportunities, are associated with mega-urbanization? What specific strategies and policies can steer the urban system towards a more sustainable development?
These questions are the focus of the Risk Habitat Megacity research initiative in which scientists from currently five Helmholtz research centers and their partner organisations from Latin America seek to generate orientation and decision making knowledge. The research adopts governance, risk concepts and sustainable urban development as three crosscutting research themes and integrating framework.
Geographically, the initiative concentrates on megacities in Latin America, which is the by far most urbanized and most inequitable developing region in the world. Santiago de Chile is the 'anchor city' for the initiative and hosts its coordination and the dissemination of results. The metropolitan region of Santiago de Chile is also the pilot case for the first implementation phase (2007-2010). The initiative intends to transfer the interdisciplinary and integrative research framework to other Latin American megacities in a second phase (2010-2013). The initiative is strongly committed to training of young scientists in interdisciplinary and problem-oriented research.

» www.risk-habitat-megacity.org «

There has been a growing awareness of the centrality of human health in the debate on Global Change. While the effects of Global Change that have emerged in response to unprecedented human pressure on the biosphere in recent decades will have a diverse (mostly adverse) impact on economic, social and environmental conditions, the ultimate risk is to human well-being, health and survival.

It is highly unlikely that any effects on health will be new, but instead will be reflected in the gradual increase of the existing disease burden. The World Health Report 2002 estimates that in the year 2000 current climate change caused 2.4% of the cases of diarrhoea worldwide, 6% of malaria cases in some middle-income countries and 7% of dengue fever cases in industrialized nations. The WHO attributed 154,000 deaths (0.3%) and 5.5 million (0.4%) DALYs (disease-adjusted life years) to climate change.

The IPCC Synthesis Report 2007 identifies the impact on human health as one of the most important effects of the changing climate. Fundamental determinants of human well-being such as water, air and food will be affected due to the impact of climate change on the global environment. Although seemingly still few in number at this stage, it is projected that such effects will increase progressively in all countries and regions. Adaption strategies are needed in order to address the health risks and the vulnerability among the human population that is expected to occur over the coming decades.

E. Sternfeld, CESDRRC, China

Water scarcity in the Miyun water reservoir, China.

Figure 1 illustrates three generic pathways by which Global Change can affect human health. These pathways can be direct, as in the cardiovascular effects of heat stress, or ecosystem-mediated, as in the case of increased risk of vector-borne infections. Finally, health systems can collapse entirely, which has far reaching consequences. This Figure also indicates the foci of mitigation and adaptation actions, and how each of these is influenced by the results of research into climate-health relationships as well as how the level of impact on health is likely to change in future.

Environmental changes contribute to the outbreak or re-emergence of infectious diseases like SARS, West Nile virus, avian influenza virus or malaria, tuberculosis and bacterial pneumonias. Furthermore, both the long- and short-term economic impact of emerging diseases might be severe, indicated, for example, by the severe acute respiratory syndrome (SARS), slowing economic growth in some affected countries, and avian influenza, damaging the poultry industry in parts of South-East Asia.

Future research on Global Change and health should consider environmental drivers and pressures related to emerging and re-emerging infectious diseases, the exploration of linkages among environmental dynamics, disease vectors, pathogens and human susceptibility. Local action should be combined with enhanced co-operation at global and regional levels.

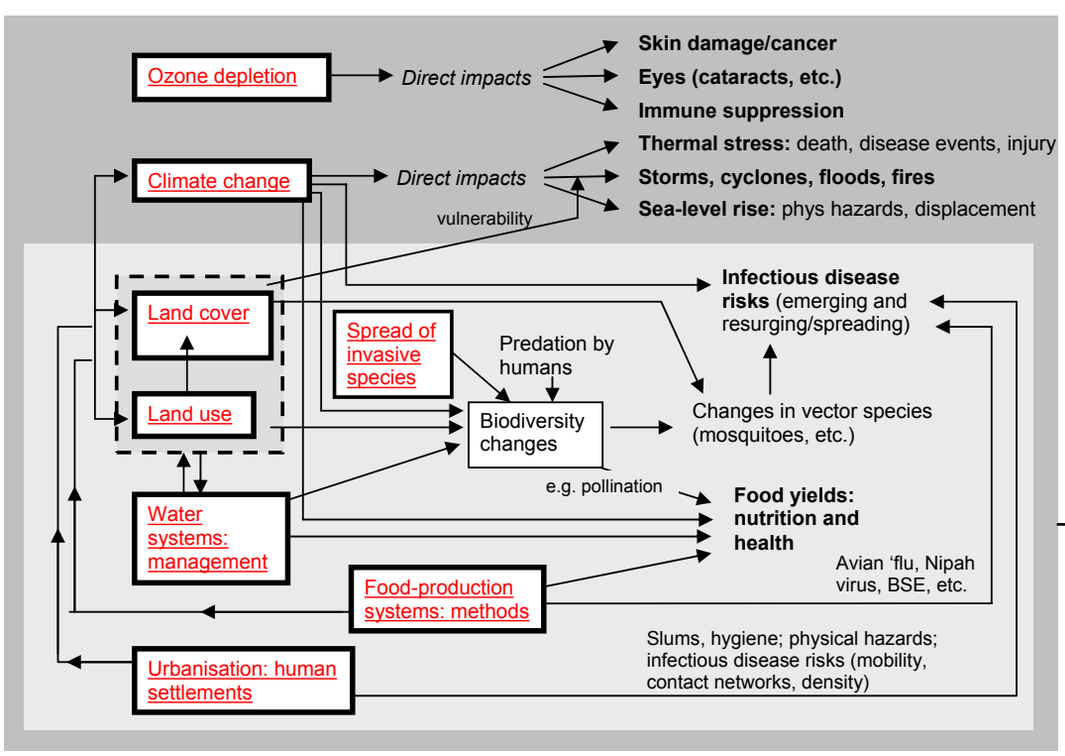


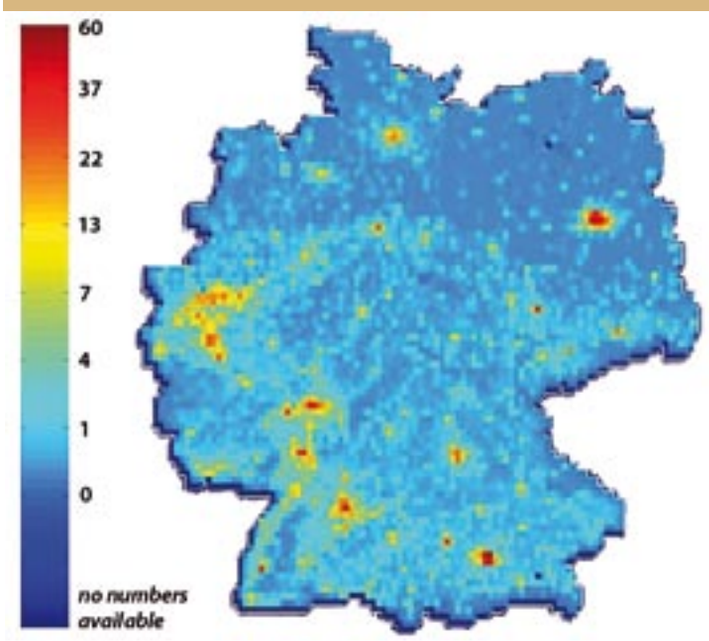

Figure 1. Schematic diagram of the main types of bio-geo-physical pathways by which Global Environmental Changes (boxed underlined text) can affect human health.

Source: ESSP Report 4. Global Environmental Change and Human Health: Science Plan and Implementation Strategy (edited by Ulisses Confalonieri and Tony McMichael).

## Direct Health Impact: The Effect of Heat Stress on Mortality

Recent scientific assessments indicate that, as global temperatures continue to increase because of climate change, the number and intensity of extreme events are likely to increase. Extreme events break new records every year somewhere around the globe, but in recent years the number of such extremes has been increasing.
The summer of 2003 was the hottest since the year 1500. Health-related mortality was investigated for the heat wave of 2003 for Baden-Württemberg, Germany. It was defined as a statistically significant deviation of mortality expectations based on previous mortality time series. In Germany, the number of deaths above the norm was estimated at around 7,000 in whole Europe it was around 35,000.
Since the 2003 events prevention and adaption measures are developed in order to reduce further avoidable mortality future events caused by heat-waves. The WHO summarizes that cities in France, Germany, Hungary, Italy, Spain, and the United Kindom have implemented heat-wave plans and warning systems. However, effective prevention and adaption requires cumulative efforts. Heat-waves need to be integrated into the health systems prepardness planning process. Adaption measures have to promote individual protective behaviour. Key issues are accurate and timely weather forecasts, a sound understanding of the effects of heat, information and advice to citizens, action aimed at vulnerable groups and urban planning.

» www.euro.who.int/Document/mediacentre/fs0307e.pdf «




Hübler and Klepper, 2007. Kosten des Klimawandels - Die Wirkung steigender Temperaturen auf Gesundheit und Leistungsfähigkeit.

Distribution of additional heat-related fatalities per year from 2071-2100 in Germany. Shown are 10x10-km² sectors (exponential extrapolation of extreme heat stress) .

» www.uni-kiel.de/ifw/prog2/wwfstudie.pdf «

## Ecosystem-mediated Health Impact (Vector-borne Disease): Incorporating Environmental Factors in Modelling Malaria Transmission in Children under Five in Rural Burkina Faso

In the Nouna health district, Burkina Faso, the contribution of malaria to the total burden of disease (BOD) is estimated at 27% and among children under five (U5s), it accounts for 1719.5 years of life lost (YLL). Since the 1980s, the country has been involved in various studies aimed at identifying locally suited methods for controlling the disease. The available malaria control and prevention methods have not been effective, largely because the mechanism of malaria transmission, especially its environment component, remains inadequately understood.
This project incorporates environmental factors aimed at broadening the understanding of malaria transmission. The hypothesis was that the incidence of malaria was associated with local transmission since differential land cover affects the microclimate and hence the microhabitat of mosquitoes and malaria parasites. The project developed and spatially validated an explicit high-resolution process-based model that can predict malaria transmission risk among U5s in a holoendemic area, and uses the model to forecast malaria outbreaks in holoendemic areas of Sub-Saharan Africa.

» www.hyg.uni-heidelberg.de/sfb544 «

# Extreme Events

Over the last few years, Europe has been hit by a number of extreme weather events. Heavy precipitation caused major flooding in different drainage basins of European rivers, including the Oder flood in 1997 and the Elbe flooding in 2002 (Figure 1). Almost every year there was unprecedented flooding (see Table on the right). These events were often connected to weather conditions resulting from heavy precipitation.

In contrast with the precipitation and flooding events that lasted only a few days and involved relatively small regions, such as individual catchment areas, a widespread severe drought occurred in the summer of 2003. This drought, which was linked to a heat wave, was not a sudden climate event, but due to its long duration and the fact that it occurred over large areas of Europe, was termed a catastrophe.
In 2007, Greece experienced its worst year on record for forest fires (Figure 2). Extremely hot and dry weather conditions combined with strong winds led to a disastrous increase in forest fires and wildfires. In 2007, Greece requested assistance through the MIC (Monitoring and Information Centre) 4 times during June, July and August. The total area destroyed by fire in that particular year amounted to 268,834 hectares, of which 180,000 hectares were destroyed between 24th and 30th August 2007.

One of the challenging tasks for future research is to better understand and model the occurrence, evolution and role of extremes within the climate system. Moreover, better ways of predicting such events need to be explored. This requires the analysis of existing long-term measurement records. However, both heavy precipitation and gusts of wind are difficult to measure accurately due to their very limited regional extent.

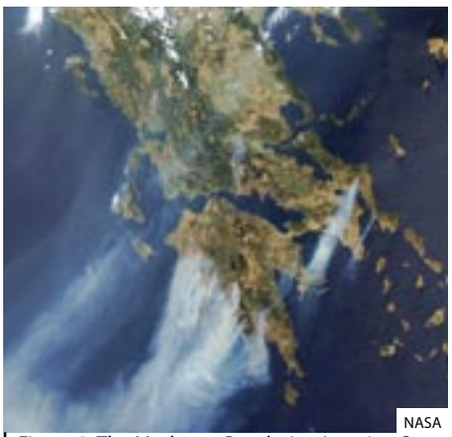
A statistical analysis of the time series of daily temperatures in Karlsruhe, carried out at Frankfurt University, shows that during the last 30 years the probability of summer heat waves like that of 2003 occurring, has increased by a factor of 20, although the probability is still very low. Investigations of climate scenarios show that the probability of low river flow will significantly increase in the future.

Possible changes in the frequency and intensity of extreme events such as hurricanes, heat waves, droughts and floods are likely to have a huge impact on society, since they can cause considerable damage. As an example, Figure 3 shows changes for the Rhine Valley up until 2050 in days affected by frost and heat calculated using a regional climate model (REMO) assuming a B2 IPCC scenario. The projected changes in extremes are coherent with the findings of Schär et al. (2004) who studied the occurrence of summer heat waves in Europe at the time and in the future. They showed that the heat wave of summer 2003 was extraordinary but could occur with greater frequency in the future.

Another strong finding is the increase of heavy precipitation events in summer, which accompanies a decrease in monthly mean summer precipitation in central Europe (Christensen and Christensen, 2004).

Spiegel No. 7, 2003

Figure 1: Flooding of the city of Dresden in 2002.

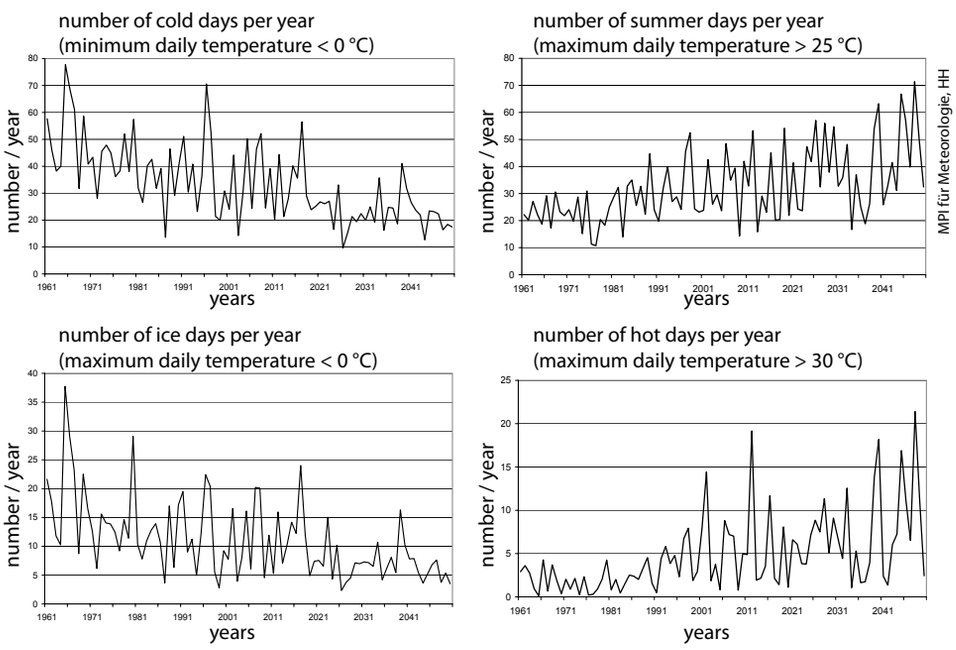


NASA

Figure 2: The Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite captured this image of Greece on Aug. 26, 2007. The red pixels that punctuate the image are areas where MODIS detected actively burning fires.

» www.nasa.gov/vision/earth/lookingatearth/greek_fires.html «

Figure 3: Daily temperature changes for the Rhine Valley up until 2050.



Such short-term, strong, convective summer precipitation events can potentially cause damage, e.g. in agricultural areas, but also in cities, where sewage systems might be flooded.

One focus of future climate change research should therefore concentrate on the development of statistical as well as dynamic methods to better understand the evolution of extreme events. This will contribute to a more reasonable prediction of expected changes in extremes.
Ongoing European projects like ENSEMBLES will contribute to this goal with global as well as regional modelling. In this context, first results from the MICE project (Modelling the Impact of Climate Extremes, with contributions from Germany as well as other European countries) have recently been published. In the warmer climate of 2070-2099 according to the IPCC SRES A2 scenario, the researchers conclude, among other findings, the following:

- heat waves will become hotter and last longer over much of Europe,
- the number of episodes with heavy rainfall (intense showers) could increase,
- fewer storms are expected, but the number of severe storms over Western Europe is expected to increase,
- floods, droughts and episodes of water pollution are likely to become more severe.

MICE communicates key messages for future research, which are also important for national research activities. They include the need to:

- focus to a greater extent on the near future i.e. 2020s instead of 2080s,
- reduce uncertainty by more reliable climate modelling,
- make research results more accessible for the layperson,
- bridge the gap between what scientists can produce and what end-users require.

## The IPCC and Extreme Weather Events

"An extreme weather event is an event that is rare within its statistical reference distribution at a particular place. Definitions of 'rare' vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile. By definition, the characteristics of what is called extreme weather may vary from place to place. An extreme climate event is an average of a number of weather events over a certain period of time, an average which itself is extreme (e.g. rainfall over a season)."

IPCC Working Group I, Climate Change 2001: The Scientific Basis, Third Assessment Report Glossary.

## Major Extreme Events in Europe 1993 – 2007

| | | |
|---|---|---|
| 1993 | December | Century flood of Rhine and Moselle |
| 1995 | January | Century flood of Rhine and Moselle |
| 1997 | July | Century floor of the Oder |
| 1999 | May | Flood of the Danube and Lake Constance |
| 2000 | Autumn | Extensive and long-lasting floods in Western Europe, in particular South England and Wales |
| 2001 | July | Flood of the Vistula |
| 2002 | August | Flood of the Danube |
| 2002 | August | Century flood of the Elbe |
| 2002 | September | Extreme precipitation and floods in Southern France |
| 2003 | January | Severe flooding in parts along German rivers |
| 2005 | Summer | Alpine Flooding |
| 2006 | October | Flood in Greece |
| 2007 | Summer | Drought and fires in Greece |

## SAFE (Sensor-Actuator-Based Early-Warning System for Hazard Protection in Extreme Weather Conditions)

Project Duration: 2006 – 2009 (projected)
Funding: BMBF

With an increase of occurrence and intensity of extreme weather events caused by climate change, the question is how society can effectively protect itself from these hazards and damages. Early-warning systems play a significant role in this, which inform the persons concerned of impending dangers in time and thus allow short-term protection measures.
The aim of the project SAFE is to implement innovative approaches in sensor technology, prognosis and information logistics in a new, high-quality extreme weather warning system for private people, communes and industrial companies. For this purpose, the previous possibilities of forecasting local extreme weather and its local impact are to be improved significantly through the application of new measuring systems and prognosis methods. Building on these more precise prognoses, the early-warning system shall also be able to activate automatic systems (e.g. in plant and building technology) apart from the targeted warning of the people concerned. Through the combination of precise prognosis and effective information distribution, SAFE is to contribute considerably to an improved hazard prevention in the case of increasing extreme weather events.

» www.klimazwei.de «
» www.safe-projekt.de «

Schär, C, Vidale PL, Lüthi D, Frei C, Häberli C, Liniger MA, Appenzeller C, 2004, The role of increasing temperature variability in European summer heat waves. Nature 427; 332-336
Christensen JH and Christensen OB, 2004, Climate modelling: severe summer flooding in Europe. Nature 421; 805-806

Fossil energy resources have been one of the main drivers of economic growth and prosperity since the 19th century. This growth in production and consumption paired with the process of globalization has triggered an ever-increasing volume of transport. In parallel our society becomes more and more mobile within a more and more globalised world. For example currently the tourism industry that relies heavily on transport services belongs to the largest economic sectors of the world economy. Mobility of people and goods is considered a major achievement of modern societies and is dominated by road traffic which is increasing world wide at the expense of rail and water transport.

The most important source of fuel for road and air transport is crude oil (Figure 1). But the use of this energy source is problematic for two reasons. On the one hand, crude oil is becoming scarcer due to limited resources, its price will therefore keep on a high and in tendency rising level and political conflicts may additionally lead to interruptions in supply and unexpected price changes. On the other hand, fossil oil used as a fuel is a major source of Greenhouse gas (GHG) emissions which are responsible for climate change.

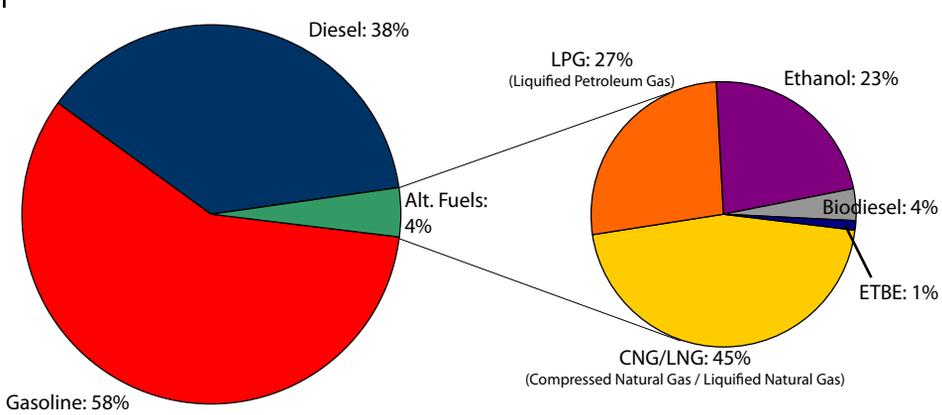
Additionally the mobility of people and goods will further increase especially in the fast growing Asian economies. According to projections, passenger car numbers might grow from some 700 million today to 2 billion by 2050. Thus transport is estimated to be the second fastest growing source of GHG emissions globally after power generation, and transport's GHG emissions are projected to grow as much as 85% between 2000 and 2030 (increase of 1990 to 2003 in EU see in Figure 2).

The share of transport in the total crude oil consumption of the industrialized world – and consequently the GHG emissions – will reach approx. 60% within the next decade. Predictions for many developing countries show a time delay but similar end points. Therefore, new strategies are needed to reduce the high dependency on crude oil within the mobility sector. Three challenges lie ahead in this respect.

**First, development of sustainable substitutes for crude oil as a fuel**. Biomass respectively biofuels are considered to be one of the most promising crude oil substitute today. Therefore the US plan to cover 20% of their fuel needs in 2020 by means of biofuels, the EU formulated a political goal to achieve a 10% biofuel share of the fuel demand in 2020. However, these plans alone do not guarantee that biofuel use will be sustainable. Overambitious political and economic incentives may accelerate the land use competition between food and energy crop production and will lead to rising food prices. Such a development may also lead to social and environmental risks in many parts of the world. Regarding the environmental implications, biofuel production, which is considered to be GHG emission neutral, can lead to net GHG emissions if vital carbon sinks like grassland, wetlands and rain forests are converted into farmland. Last but not least, the overall energy efficiency of several biofuels provision chains might be too low to become good substitutes. Therefore, it is the task of research to test the sustainability of new fuels and to develop highly efficient biofuels with low negative impacts on humans and the environment. For example EU funded projects like CROPGEN and Bio-SNG have the overall objective to develop such sustainable non-fossil oil fuel substitutes. Additionally ongoing projects are working on the development of sustainability criteria to be implemented within the world wide biofuel trade (cf. the BMBF research funding under "BioEnergy 2021 – Research for Biomass Use").

**Second, development of new drive concepts**. New drive concepts like hybrid or fuel cell motors as well as cars driven by green electricity are potential technological substitutes for the current oil-based forms of mobility. Up to now, several hybrid proto-types are at hand, but there is neither a big will in the car industry nor in politics to trigger these new car concepts. The fuel cell transport concept is rather a long term substitute and nowadays it is far from readiness to marketing. Several EU projects and the European Hydrogen and Fuel Cell Platform (HFP) are engaged in the long-term development of these new technological mobility concepts. Other projects focusing on the medium term are tackling the development of more efficient engine concepts based on mixtures between biofuels and fossil fuels. Additionally there are ongoing activities to develop concepts for cars with significantly lower energy demand.

Figure 1: Global fuel demand in 2005 (bio-fuel fraction only 1% of global fuel consumption).




Hart's World Refining and Fuel Service, 2006

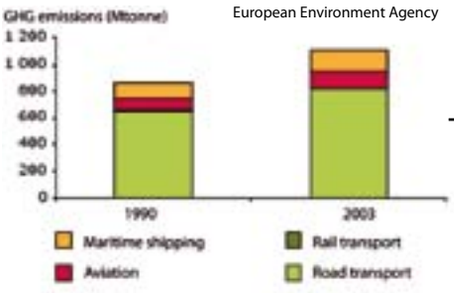



Figure 2: Comparison of EU greenhouse gas emissions of road and rail transport, maritime shipping and aviation in 1990 and 2003.

**Third, development of new social forms of mobility**. Over the last decades, in modern societies new lifestyles emerged with a high demand for new mobility options. Today, multimodal travellers frequently combine different modes for their daily travel and increasingly replace the former mono-modal traveller. The travel impacts of new household types, long-distance housing-work arrangements and new forms of mobility are explored by researchers like the European Cosmobilities Network. Other research is directed towards changing travel behaviour. For instance, the context of travel behaviour changes (e.g. key events in a life course like residential relocations) and the potential of policy interventions for redirecting these changes in a more sustainable way need to be better understood. Moreover, programmes like the EU funded "CIVITAS Initiative" aim at the design, improvement and dissemination of new mobility options and travel demand management. However, while new social forms of mobility evolve and give the opportunity for travelling with less energy consuming modes, it remains uncertain whether these opportunities will suffice to reduce future energy consumption. Therefore, improved planning of land uses and other related policy instruments like road pricing for decreased travel distances and reduced urban sprawl are needed in the future as a precondition for more sustainable travel systems.

Especially the last aspect indicates that mobility in the future might be totally different in character. However, the path of the mobility sector is important as well, because different developments in mobility may have very different impacts on society and the environment. Research projects such as the EU-funded QUANTIFY (see box) are underway which try to model several mobility scenarios and to measure the environmental impact of the transport system on a regionally disaggregated level. There is still the challenge as to how this seemingly uncontrolled process of increasing environmental pressure from increased mobility services can be reconciled with the demand for it.

In the field of energy-mobility-climate several fundamental research questions still need to be answered:

1. What are the determinants of the complex interaction of economic and social drivers of the demand for energy and mobility services with the consumption of natural and environmental resources?
2. What is the potential of current and future technologies for the provision and use of transportation fuels with respect to the sustainable use of natural resources?
3. How can the potentials of renewable sources of energy be used best for all sectors of the overall economy and what are the implications for the transport sector?
4. How should the political and regulatory framework be designed in order to support promising biofuels, technological and/or social substitutes to oil-based mobility and to prevent social and environmental externalities?
5. How can a successful transfer of new technologies in the transport sector into the fast growing regions of the developing world be achieved?
6. Which international regimes and what kinds of institutional requirements are necessary for achieving sustainable development in the area of mobility and energy supply within a globalising world?

The relevance of this research complex is also reflected in the policy paper on Global Change research, published by the German National Committee on Global Change Research (NKGCF) in June 2005, suggesting research foci for the upcoming years.

## QUANTIFY

Project Duration: 03/2005 – 02/2010
Funding: EU

QUANTIFY is an integrated project coordinated by the DLR-Institute of Atmospheric Physics, and is funded by the European Commission within the 6th Research Framework Programme. The main goal is to quantify the climate impact of global and European transport systems for the present situation and for several scenarios of future development. The climate impact of various transport modes (land surface, shipping, aviation) will be assessed, including those of long-lived greenhouse gases like $CO_2$ and $N_2O$, and in particular the effects of emissions of ozone precursors and particles, as well as of contrails and ship tracks. The project goal includes the provision of forecasts and other policy-relevant advice, which will be supplied to governments and to international assessments of climate change and ozone depletion, such as the IPCC reports (Kyoto Protocol) and WMO-UNEP ozone assessments (Montreal Protocol). To achieve the goal, several advances in our fundamental understanding of atmospheric processes will be required such as the mechanisms by which pollutants are transported from exhaust into the free atmosphere, the impact of pollutants on clouds and the role of absorbing aerosols.

In QUANTIFY, a total of 35 participants and four associated members from 16 European countries and the USA are collaborating. The research topics are organized in eight closely linked sub-projects. Accompanying measurement campaigns with research aircraft are an innovative part of QUANTIFY. Further goals are the dissemination of results through a web portal with e-learning function, a summer school, and the organisation of an international conference.

Governance is key to understanding the human impact on global environmental change and for developing mitigation and adaptation strategies. It comprises the manifold social structures and processes which shape the behaviour of individuals and societies. The issue of governance, therefore, goes far beyond the formal political and state institutions and their activities: It includes the many informal structures and actors along with economic institutions and other societal mechanisms. Consequently, in addition to law and politics, markets, economic incentives, discursive processes and moral values have to be taken into account. In addressing the challenges of Global Change, governance must focus on the global perspective, as required by the concept of "Earth System Governance". At the same time, however, the global-local interplay has to be addressed, as regional, national and local structures often play an important role in decision-making and implementation of international measures.

Thus, research on global environmental governance has to look at the ensemble of political, legal and economic institutions from a multi-level perspective. It has to take into account both the many formal and informal institutions and organisations situated at different levels – international institutions, transnational corporations, national parliaments and governments, non-governmental organisations, economic forces, other societal institutions. Research on governance and institutions has to focus in particular on the relationship between these different elements and levels of environmental governance. The goal is to identify both the potential causes of the unsustainable use of the Earth's resources and opportunities to support a more comprehensive response by humankind to the challenges of global change. Governance for global change is a demanding topic for the social sciences and its many disciplines ranging from anthropology to economics, through law to political sciences and sociology. The topic is demanding because it requires the development of a bird's eye-view to achieve a general understanding of governance issues whilst at the same time taking into account the diversity of specific environmental concerns existing at different levels, in different regions or in particular places.

**German research contributes to this research in many different ways.**

A. Künzelmann
Literature of environmental politics.

**1. Coherent Multilevel Environmental Governance**

Many organisations and institutions on a global, regional, national and local level are active in the area of global change. However, in spite of the huge number of institutions and activities, there are doubts as to the effectiveness of this kind of governance. Such doubts relate to a number of research questions, which an Institutional Dimensions of Global Environmental Change project (IDGEC) working group has coined as follows: question of scale, problem of fit and question of interplay.

(1.1) The ***question of scale*** relates to the proper assignment of responsibilities and functions to different governmental levels. The choice of an adequate scale is important to ensure that measures take into account the conditions and priorities of the area at hand. This issue is highly relevant, because it indicates that there is no easy "up-scaling" or "downsizing" of global change policies and measures. Many sustainable resource management schemes developed at local level cannot easily be transferred to the regional or national level and vice versa.

(1.2) The question of scale is closely related to the ***problem of fit*** which concerns the choice of appropriate policy instruments. Recently, the traditional command-and-control type of environmental policy measures has been supplemented and partially replaced by economic instruments. An analysis has to be made as to which instrument or instrument mix should be selected e.g. in the field of climate policy, and whether and under which circumstances these instruments are effective, efficient and legitimate.

(1.3) The ***question of interplay*** addresses the proper links between large numbers of agencies involved in global change issues at different levels. Global change must be considered as an across-the-board topic, which touches upon such diverse issues as climate policies, biodiversity, agriculture, trade, traffic and public health. These issues are often dealt with separately by different ministries or departments at national level. Moreover, at international or regional level a huge number of different organisations and institutions exist, which are in charge of matters relevant to global change. The necessary coordination between these various institutions and levels is difficult to achieve.

**2. Participation and Legitimacy**

The challenges linked to finding coherent global governance solutions contribute to the emergence of a strong and active public movement in the area of global environmental change. Non-governmental organisations play an important role in addressing global change by undertaking research, disseminating information and by taking an active part in environmental measures. More generally, these groups are part of and strengthen an international public voice. This supports insights that the ***participation*** of all relevant stakeholders in environmental decision-making at all governance levels is crucial. Moreover, for the ***legitimacy*** of institutions and decisions it is important that the people, stakeholders, local communities and non-governmental organisations affected by environmental change have a say in decision-making. A number of developments have taken place in this regard, including better access to information about the environment and access to justice. It has to be

explored how the continuation of such participation can be ensured in view of international regimes and private activities. Furthermore, the means by which consumers are able to make informed choices have to be found. Concerning legitimacy, German political science focused on the participation of the global public in international regimes. The question has been raised as to how regimes can be "constitutionalised" (ensuring that basic values and legitimacy are respected).

**3. Greening the Global Economy and Developing Economic Devices for Promoting Sustainable Development**

The impact of human societies on the environment is largely driven by economic need. The way we use natural resources and pollute the environment is importantly determined by economic and social structures, including markets and the relevant regulation. Sustainable development of human societies largely depends on there being appropriate pricing for natural resources and ecosystem services. To date, however, markets often fail to perform that function. Resource pricing often does not reflect resource scarcity and what's more, market interventions including subsidies often have a negative impact on resource use. Identifying areas of market failure, designing economic instruments for the internalisation of environmental effects are thus important tasks for governance research. This includes issues related to instrument choice, such as emission trading, environmental taxation, green labelling and other means to enable consumers to make their choice in relation to environmental preferences. Of even greater importance is that such research has to look at the ability and awareness of regulatory bodies to properly address the issue. For instance, the question has to be raised as to whether environmental concerns are properly reflected in the European Union's Common Agricultural Policy. At a global level, the intricate relationship between the World Trade Organisation (WTO) and multilateral environmental agreements are important areas of research.

**4.) Climate Change Mitigation and Adaptation – Research Priorities**

For a long time, research on climate change has focused particularly on strategies to mitigate climate change, mainly by reducing greenhouse gas emissions. Because of increasing evidence of ongoing climate change, however, recently, strategies for adaptation have become more important. This shift has important implications for further research. Research for adaptation has to deal with the specific vulnerabilities connected with climate change. These vulnerabilities are associated not only with changing global or regional climate conditions (e.g. changing precipitation rates, increasing droughts), but also with societies' capacity to cope with these changes. This differs between regions (e.g. semi-arid regions or coastal zones) and different social groups (e.g. subsistence farmers). Such capacity to cope, thus defines the way extreme events can be absorbed and how the resilience of socio-ecological systems can be maintained. Moreover, different timescales involved – some aspects of climate change may be significant in a number of years, nevertheless, action is pressing today – and uncertainties concerning precise scientific prognoses of scope and regional impact of climate change raise additional challenges for governance strategies. Questions of scale and interplay are important, too: Measures for mitigating climate change need international coordination from the word go, whereas adaptation measures have to address specific regional and local vulnerabilities, but may need national or global support. Thus, governance for adaptation represents new and additional challenges for research into strategies and measures as well as for implementation. The interplay of spatial and temporal scales has to be addressed with new and innovative concepts, the interaction of natural and societal processes in the creation of vulnerabilities must be analysed carefully, robust strategies to deal with uncertainty in decision-making while addressing urgent concerns must be developed and implemented, and, last not least, challenges for the incorporation of adaptation measures in different policy fields and for the provision of policy coherence must be addressed. Because of the pressing nature of the matter, new strategies for science policy and new interfaces between research and decision-making are necessary.

In conclusion, it can be noted that German research has made significant contributions to the institutional dimension of Global Change. Besides ever remaining lacunae there is a more fundamental need to integrate the many different methods and problem areas.

Database (IRD), TU Darmstadt
» www.tu-darmstadt.de «

Göttingen University Institute for Intl. and Europ. Law, Dept. Intl. Economic and Environmental Law
» inteurlaw.uni-goettingen.de/inteurlaw/ «

DFG Research Training Group 765, Markets and Social Systems in Europe, Bamberg University
» web.uni- bamberg.de/sowi/mse/eng/index.html «

Environmental Policy Research Centre (FFU)
» www.fu-berlin.de/ffu «

German Development Institute
» www.die-gdi.de «

Helmholtz Centre for Environmental Research – UFZ, Working Group "Governance and Institutions"
» www.ufz.de/index.php?de=4952 «

Institute for Intercultural/International Studies (InIIS)
» www.iniis.uni-bremen.de «

Institute for Social-Ecological Research, Frankfurt/M.
» www.isoe.de «

Max Planck Institute for Comparative Public Law and International Law
» www.virtual-institute.de «

Max Planck Institute for Research on Collective Goods
» www.mpp-rdg.mpg.de «

Münchner Projektgruppe für Sozialforschung e.V.
» www.m.shuttle.de/mpsev «

Research Network GLO-GOV of Free University Berlin (FU), Potsdam Institute for Climate Impact Research (PIK), Oldenburg University and Vrije Universiteit Amsterdam.
» www.glogov.de «

Wissenschaftszentrum Berlin Transformations of the State, Bremen University
» www.wzb-berlin.de «
» www.state.uni-bremen.de «

Measurements of Earth System parameters enable an objective determination of the effects of Global Change and their spatial distribution and temporal development. They form the basis for a scientific understanding of Global Change and the relevant Earth System processes. Observing systems are the prerequisite for the development of management strategies towards sustainable development.

Over the past decades, a wide range of short- and long-term observation facilities and networks have been established. Prominent examples are the global meteorological network, which forms the basis for reliable weather forecasts; the network of high precision $CO_2$-measurement stations, which have discovered the increase of $CO_2$ in the atmosphere; the fleet of research ships and drifters (Figure 1) examining ocean processes; the diverse fleet of satellites observing the earth, which measure a variety of physical, biogeochemical and societal parameters ranging from trace gases and ice movements and chlorophyll content of vegetation to urban sprawl; a multitude of ecological research sites, studying the role of vegetation in the Earth System. Germany contributes to the global earth observing capabilities by supplying research platforms such as ships, satellites, aeroplanes, ocean drifters and balloons as well as supporting measurement activities at specific research sites, e.g. within the BIOTA, TERENO, LTER-D (see box) and GLOWA projects.

In order to monitor processes and dynamics of the Earth System, an integrated concept for an end-to-end observation process is required ranging from observations, feeding into global and regional Earth System models, creating user-related products and thereby providing a solid basis to decision-makers for a sustained management of resources. For a comprehensive effective monitoring of the Earth System's parameters, a comprehensive, integrated observation system for Global Change is required, linking observation technologies on a global level for the purpose of tracking environmental changes. The Global Earth Observation System of Systems (GEOSS) is currently being established through international cooperation. Along with new developments in monitoring, assessing and predicting environmental changes, GEOSS will enable the development of facilities to prepare for weather emergencies, predict natural hazards like floods, droughts and fires, better manage crop production, coastal areas and fisheries, monitor deforestation and land use change as well as water and air quality, support the UN's effort to help refugees in crisis regions or recognise and fight epidemic diseases, to name but a few direct benefits that affect our economic prosperity and quality of life.

The main challenge in setting up GEOSS is the integration of a wide range of existing observing systems with a long-range perspective. This includes the deployment of additional sensors to consistently deliver the full range of data on all scales and from all major fields of natural and social sciences.

Scientific achievements are needed in the following fields to establish this end-to-end process:

- development of integrated observation, data management, and information delivery systems,
- improvement of quantification of environmental processes by direct or indirect observations,
- improvement of integration of observations into coupled Earth System models,
- test of our Earth System models over varying time and spatial scales in comparison to observations,


Figure 1: ARGO, a broad-scale global array with ~3,000 free-drifting profiling floats that measure the temperature of the oceans, providing data for weather and climate prognoses and for marine sciences.

» www.ifm-geomar.de/index.php?id=3843 «
» www.argo.ucsd.edu «

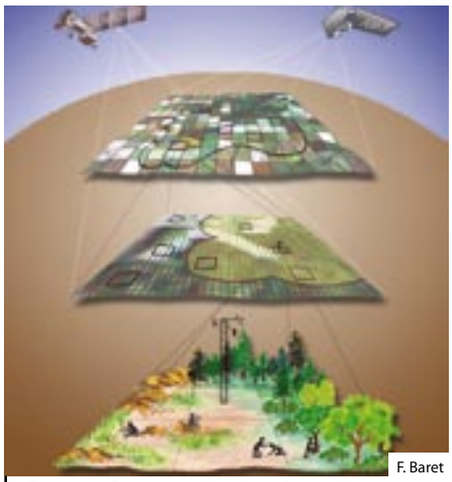

F. Baret

Figure 2: Conceptualisation of a multi-disciplinary, multi-scale approach for a future Global Change Observing System, combining local observation sites for Earth System process studies with high and medium resolution satellite observations.

- determination of climate variability and change as well as the rates of change,
- explanation of the mechanisms underlying the observed patterns,
- communication of scientific understanding to all stakeholders.

This approach implies that measurements of Earth System parameters are combined across a broad range of disciplines and scales as indicated in Figure 2 for the example of land surface state and processes observations. The backbone of the system consists of a network of standardised terrestrial observation sites. The network delivers detailed, integrated measurements of all coupled natural and socio-economic parameters. This network of observation sites is augmented by a fleet of suitable high- (second layer) and medium- (third layer) resolution satellite observation platforms, which create a steady flow of regional and global environmental and societal data to fill the gaps between the global perspective and the regional impact. Observation sites and satellites represent the inputs for regional models to enhance the understanding of the Earth System and to develop alternatives for local and regional decision-makers. The multi-scale observation approach outlined in Figure 2 can easily be transferred to other areas of Global Change like the oceans and the cryosphere.

## TERENO

Long-term observation enables the impact of climate change to be clearly distinguished from changes caused by natural fluctuations. Against this backdrop the Helmholtz Association is initiating and establishing a national network of environmental observatories for long-term observations (> 10 years) focused on the challenges of global change and the necessity of interdisciplinary research in terrestrial environmental science (Terrestrial Environmental Observatoria – TERENO). While comparable environmental research networks are typically focused on specific environmental compartments and processes (e.g. Carbon Cycle, biodiversity) the TERENO network aims at an integral view, taking into consideration the lower atmosphere, biosphere, hydrosphere, and socio-economic interactions. Currently, three observatories are planned in Germany. Each observatory will consist of different test and monitoring sites designed in a hierarchical manner to allow interdisciplinary process studies from the local to the regional scale. State-of-the-art monitoring and exploration technologies including for example remote sensing imagery as well as ground-based observation technologies allow a scale-spanning observation of the different environmental compartments. TERENO will provide a long-term series of system variables as an important input for the analysis of Global Change driven processes. Strategies for prevention, mitigation and adaptation will be developed using integrated system models.

» www.tereno.net «

## The GEO Global Biodiversity Observation Network

Members of the National Committee on Global Change Research were heavily involved in the DIVERSITAS and NASA lead initiative to develop a Global Observation System for Biodiversity. Current scientific evidence demonstrates a continued decline in the status of biodiversity. This leads to reduced benefits to people, especially in terms of genetic resources, agricultural productivity, ecosystem services, resilience to environmental disturbance, human health and well-being. Further understanding of biodiversity change is therefore critical to shift unsustainable practices towards sustainable use of biodiversity.
In response, DIVERSITAS and NASA are leading the early planning stages to implement a global biodiversity observation system that will collect, manage, share and analyse data on the status and trends of the world's biodiversity, and regularly report its findings through GEOSS.
In April 2008, a month before the COP9 of CBD opens in Bonn, Germany will also host the implementation workshop of the GEO-BON, 8-10 April 2008, in Berlin. The BIOTA-AFRICA (www.biota-africa.org) network was one of the founding members of the GEO-BON.

» www.bioOBSERVATION.net «
» www.diversitas-international.org «

## LTER-D (German Network for Long-term Ecological Research)

The components of global change operate on different spatial and temporal scales. Scientific analysis of this sphere, however, often deals with shorter time scales, due to the typical funding duration of research projects. Nevertheless, long-term observation is indispensable for the detection of long-term processes and changes, and is the foundation needed to develop sustainable strategies. LTER-D is a member of the international umbrella organisation ILTER. LTER-D insures that data are saved and documented and that they are accessible long after individual research or monitoring projects have been completed. This is in line with the long-term horizon of large-scale strategies for environmental protection, such as the EU Habitats Directive and the EU Water Framework Directive, which plans for time periods of over 20 years. LTER-D is an umbrella for other long-term research projects within Germany and works in collaboration with the German Biodiversity Exploratories and the TERENO initiative.

» www.ilter-net.edu «
» www.lter-d.ufz.de «

# Modelling the Future

Among the most challenging questions confronting Global Ghange scientists are those having to do with the future state of the global environment. The need to understand future trends of Global Change has stimulated exciting new modelling developments to which the German scientific community has made major contributions.

### *Modelling Future Climate Change*

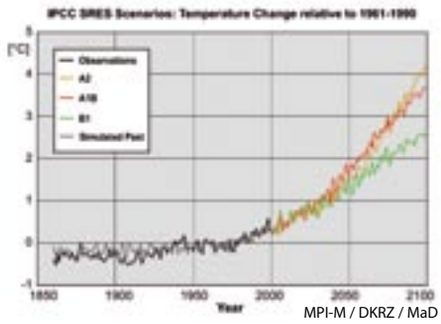
Predictions of both natural climate variability and the human impact on climate are inherently probabilistic, due to uncertainties in the initial conditions of the forecasts, in the representation of key processes within models, and in climatic forcing factors. Hence, statistically reliable estimates of climate risks can be made only through ensemble simulations. In such ensemble simulations, a model is run many times over the same time period, with different but equally likely initial conditions, and/or with different but equally likely model parameters. In this way, a multitude, or ensemble, of model results is produced, and the scatter between model results is one measure of the uncertainty of the climate simulation, albeit not the complete measure.

A multi-model ensemble of climate change simulations has recently been carried out by modelling groups across the world, in support of the fourth assessment report (AR4) by the Intergovernmental Panel on Climate Change (IPCC), which was published in 2007. In Germany, new simulations were performed showing a mean global warming of between 2.5 and 4.1 degrees Celsius until the end of this century, depending on the scenario of greenhouse gas concentrations in the atmosphere (Figure 1). One of the consequences of unabated global warming would be a decrease in sea ice – by 2080, the Arctic during late summer could become completely ice-free.

All German IPCC simulations were performed on the HLRE – the High Performance Computing System for Earth System Research (see Box). About a quarter of the total HLRE resources of one entire year were necessary to complete the simulations. The model output is stored in a relational database and is available to German scientists for analysis. The data are available from the World Data Centre for Climate (WDCC), and have fed directly into the IPCC AR4.

### *Anticipating the Future of Worldwide Ecosystem Services*

Human life support systems are vulnerable to global change in ways that are strongly mediated through the biosphere. Drivers of global change such as atmospheric $CO_2$, climate, and land use affect elements of the biosphere that are socially and economically important, such as food provisioning systems and recreation areas. A key concept for the management of the biosphere is the idea of "ecosystem goods and services",

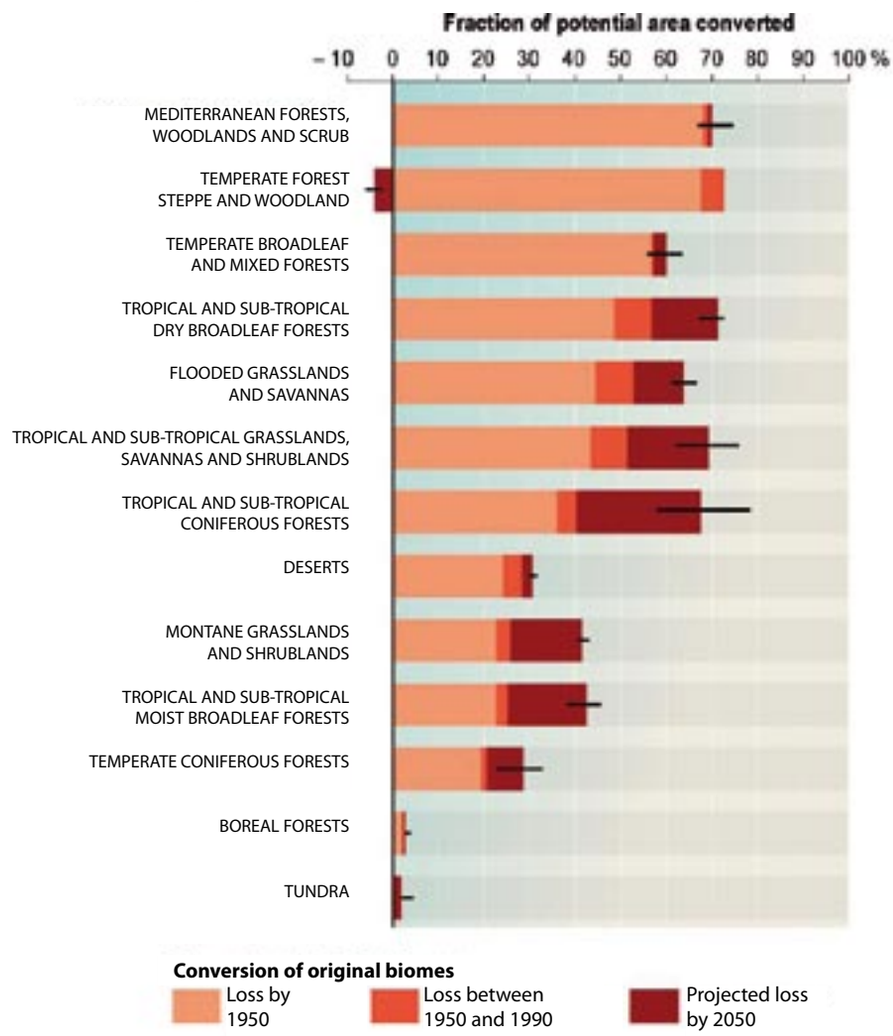



MPI-M / DKRZ / MaD

Figure 1: Simulated and observed global-mean surface temperature, relative to the time mean 1961-1990. The scenarios for concentrations of greenhouse gases and aerosols were defined in the IPCC SRES (Special Report on Emissions Scenarios). Source: Max Planck Institute for Meteorology, German Climate Computing Centre, and Model & Data Group.

Figure 2: Historical and expected land conversion for different biomes as assessed by the Millennium Ecosystem Assessment (MA). For 2050 projections, the average value of the projections under the four scenarios is plotted and the error bars (black lines) represent the range of values from the different scenarios. b According to the four MA scenarios.

» www.millenniumassessment.org «



which are the benefits that humans derive from ecosystems. Scientific support for a better management of these benefits has been provided in the "Millennium Ecosystem Assessment" (MA).
The MA has for the first time carried out a comprehensive scenario analysis of future trends in ecosystem services (Figure 2), with important contributions from German research institutions. The approach to scenario development drew on qualitative methods often referred to as the "syndrome approach". This method allows for the qualitative coupling of only partially known drivers of global change. Syndromes were also described in earlier work to support the German Advisory Council on Global Change (WBGU).
As part of the scenario development, numerical estimates were made of a wide range of global ecosystem services including agricultural production, provision of freshwater, and carbon sequestration. These estimates were derived from a global modelling exercise. The modelling exercise involved 7 global models from research groups around the world which were "soft-linked" with each other and driven with a common set of climatic and socio-economic assumptions. The scenario exercise generated a detailed picture of the prospects for worldwide ecosystem services over the coming decades and articulated the expected tradeoffs between gains and losses of services. For example, per capita water use is likely to increase in poorer countries up to 2050 (by a factor of five or more in sub-Saharan Africa) but this is likely to be accompanied by a deterioration of water quality and loss of ecosystem services provide by clean freshwater systems (genetic resources, fish production, habitat for aquatic and riparian flora and fauna.)

Indeed, one of the key findings of the MA is that historical and future changes to the biosphere lead to fundamental improvements in ecosystem service provision for human society. But most of these changes are unsustainable and will entail degradation in the coming decades. The MA also identified a significant research demand for the development of integrated solutions for resource management, particularly on a regional scale. Impacts of global change patterns, which result from an interaction of climate and land use change, urbanisation, as well as demographic and institutional change, are most pronounced on the regional scale. A broad range of modeling and simulation methodologies, together with high performance computing and visualisation, is used for assessing the impact on ecosystem goods and services, ranging from biodiversity to the provisioning and regulating of regional landscapes.

## DKRZ (German Climate Computing Centre)

DKRZ is the German national service centre for climate research and is sponsored by the German Federal Ministry of Education and Research (BMBF). According to its charter, DKRZ is responsible for the installation and operation of a high-performance computer system for basic as well as applied research in the field of climatology and related disciplines. Its basic task is the provision of computing resources for the simulation of complex processes in the climate and Earth system with sophisticated, realistic numerical models. The DKRZ also maintains facilities for the storage and management of extremely large data sets, including software tools and the required hardware. The DKRZ is a coordinating node in the national and European network of climate researchers.

» www.dkrz.de «

## CliSAP (Excellence Cluster "Integrated Climate System Analysis and Prediction")

Programme Duration: 2007-2012
Funding: DFG (Excellence Initiative)

The Cluster of Excellence CliSAP will address cutting-edge questions related to anticipated climate and climate system changes. CliSAP will analyse and predict the state of the climate system and its changes, including its physical, chemical and biological components, in response to natural and human-driven perturbations. Ongoing changes in the climate system will be analysed and compared to estimates of its past variability. CliSAP will determine predictable elements of the climate system over a wide range of space and time scales, and it will analyse uncertainties intrinsic to predictions of important climate system indices. It will investigate the feedbacks in the climate system and its interactions with social systems, including economies, in order to explore the system's critical thresholds. It will determine regional impacts of the changing climate on geohazards, terrestrial ecosystems, marine systems, and urban systems, mainly for Europe.

The most important structural goals of CliSAP are (1) to exploit the long-standing expertise of the Centre for Marine and Atmospheric Sciences (ZMAW) of the University of Hamburg and its partners, the Max Planck Institute for Meteorology and the Institute for Coastal Research (IfK) at the Research Centre Geesthacht (GKSS), to address current challenges in integrated climate system science, (2) to further intensify the cooperation between ZMAW and institutions of the University of Hamburg working on topics related to climate, such as the Department of Economics, Department of Biology, the Institute of Wood Sciences and the newly founded Carl Friedrich von Weizsäcker Centre for Science and Peace Research, (3) to offer excellent perspectives for young researchers in the field of integrated climate system science by establishing new junior research groups in key research areas proposed in this CoE, (4) to enhance graduate education at the University of Hamburg in integrated climate system and Earth system science, (5) transfer of knowledge to innovative climate and climate impact related application, and (6) to improve public perception of present and anticipated climate change through communication with the public and policy makers.

» www.clisap.de/start.151.0.html «

Despite enormous progress in climate research, climate predictions for the 21st century are still associated with huge uncertainties. The distinction between potential human influence on climate and natural climate variations poses a particular challenge for climate research. Any effort to understand this distinction is hampered by the fact that direct observation of the climate system only covers the past few decades and only enables a very limited view of the natural variability on a longer timescale. Paleoclimatic data enable the quantification of environmental variations beyond the range of instrumental records and can therefore be used to examine this important aspect of Global Change. In addition, paleoclimatic data can be used to test the response of state-of-the-art climate models to different forcings. Paleoclimatic data thus represent a significant added value for Global Change research. Accordingly, the 4th IPCC assessment report includes for the first time a chapter entirely devoted to the reconstruction and modelling of the paleoclimate. Recent findings from paleoclimatic research indicate a notably higher variability in the climate system, including during interglacials (e.g. the Holocene), than has so far been considered. Moreover, results from paleoclimaticl research made a significant contribution to a paradigm shift in climate research, according to which abrupt climate changes with partly global implications cannot be excluded in the future. Modern approaches in paleoclimatic research link all available archives containing climate information (terrestrial, marine, ice cores), in order to obtain a comprehensive analysis of global environmental variations in the past. Furthermore, by linking paleoclimatic reconstructions with results of climate models, far-reaching insights into the dynamics of climate variations can be gained, which are highly significant for future climate predictions (Figure 1).

**Marine Archives** (sediments, biogenic precipitates) contain the chronologically oldest records of natural climate variations as well as information on changes in the marine environment as a whole. Paleoclimatic reconstructions generated from marine sediment archives offer a unique opportunity to study the ocean as a key component in the climate system continuously in time over a wide range of timescales. Examination of these archives enables the quantification of the effects of climate change on the ocean and the investigation of feedbacks between the ocean and the Earth system's other components. Marine archives from shallow water are ideal for analysing and understanding variations of socio-economically relevant modes of climate variability (e.g. El Niño, North Atlantic Oscillation). Apart from providing information about the ocean, marine sedimentary archives also contain a record of the terrestrial climate. Such information offers excellent opportunities to assess land-ocean interactions in the context of climate change (Figure 2). Moreover, by employing paleoceanographic depth transects it is possible to create a 3-dimensional view of past circulation changes in the ocean.

**Lake Sediments** can also serve as climate archives. They occur throughout the world and are particularly suited for the assessment of regional aspects of terrestrial climate variability. For example, analyses can be made of climate-induced fluctuations in climatological transition zones (e.g. semi-arid regions) with enormous implications for ecosystems. Seasonally layered sediments are of particular importance, because they offer enormous potential for the study of past climate changes in a seasonal context. Moreover, annual layers enable an exact age determination and a precise assessment of the rate of past climate changes. With this high temporal resolution, changes in the frequency of climate-independent (e.g. volcanic eruptions) and climate-driven (e.g. floods) weather extremes can be detected and the probability of their occurrence can be estimated with a greater degree of confidence.

**Ice Cores** are the only paleoclimate archive that enables the measurement of past atmospheric compositions. In particular, past atmospheric greenhouse-gas concentrations can be quantified. This is of prime importance for quantifying the role of greenhouse gases as climate forcings as well as investigating the coupling between climatological and biogeochemical cycles.

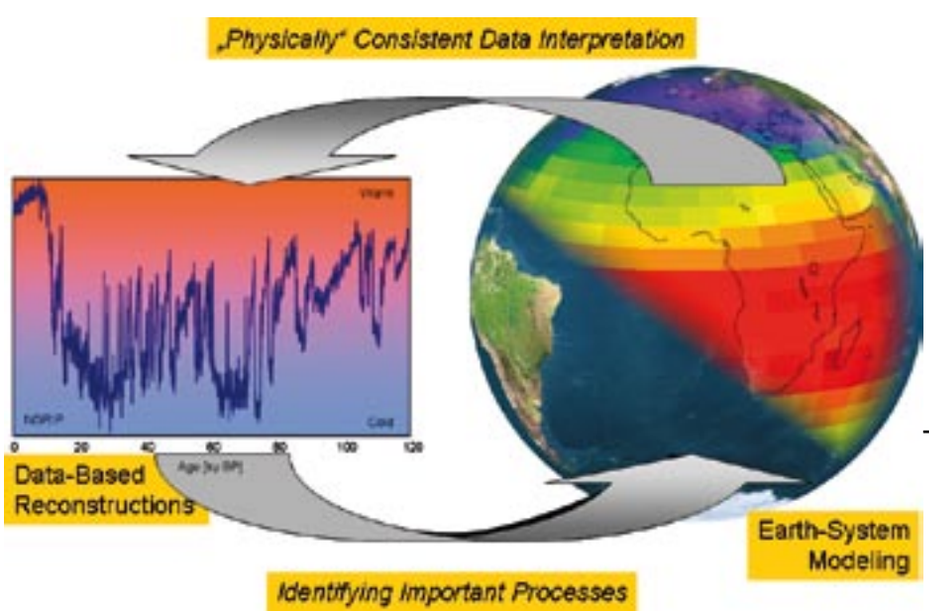
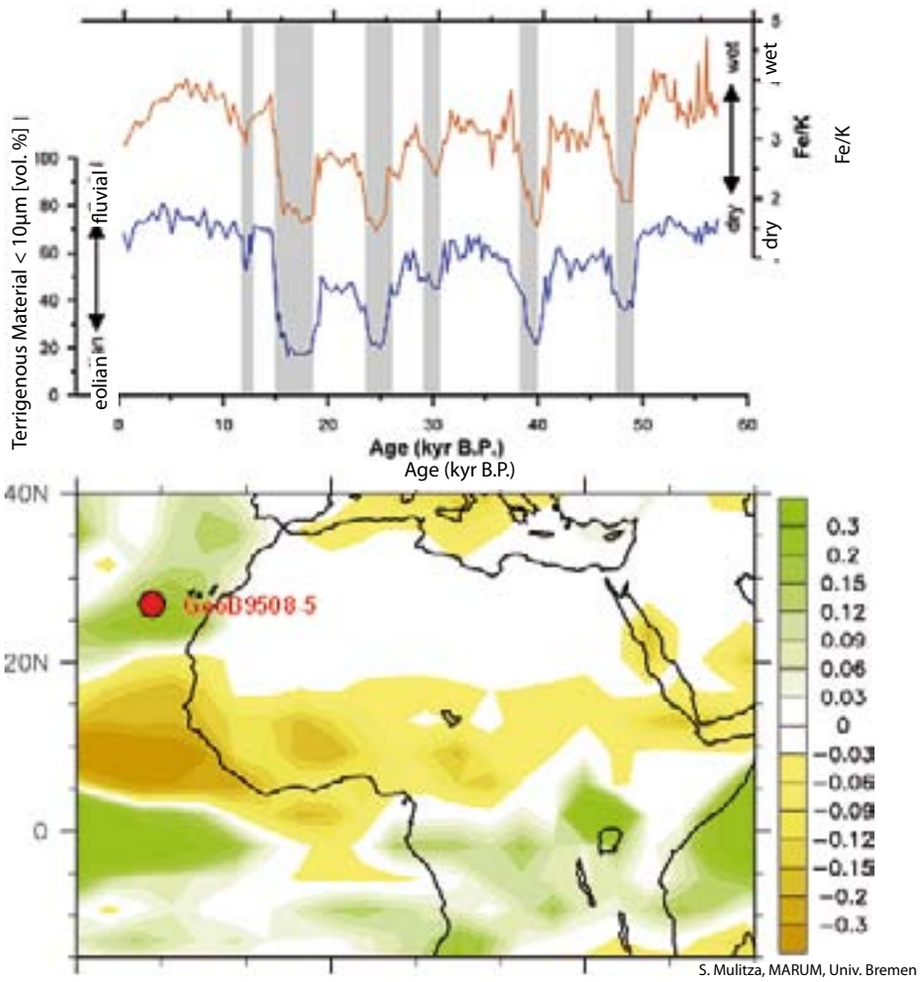



Figure 1: Combined approach of paleoclimate reconstruction and Earth-system modelling to decipher the dynamics of past environmental changes.

Data Source: North Greenland Ice Core Project members, 2004, Nature, 431, 147-151.
(Copyright M. Schulz, MARUM, Univ. Bremen).

Moreover, ice-core archives contain information on atmospheric temperature, precipitation and atmospheric aerosol load (e.g. sea salt, mineral dust, volcanic and biogenic sulphur). The climate history recorded in polar ice sheets covers several glacial cycles. In combination with reconstructions from low latitudes, polar ice cores are highly suited to the documentation of teleconnection mechanisms between low and high latitudes. Paleoclimate research based on ice cores can also be carried out on alpine glaciers that exist in the tropics and mid-latitudes. Although these archives cover shorter time periods than polar ice cores, they can contribute important insights into the variability of climate conditions at low latitudes. Because of increasing anthropogenic warming and the associated melting of alpine glaciers, these ice-core archives are increasingly under threat.




S. Mulitza, MARUM, Univ. Bremen

Figure 2: Reconstructed and modelled mega-droughts in the Sahel region. Top panel: Reconstructed changes in eolian dust and fluvial input in a marine sediment record off Senegal over the past 60,000 years. Grey bars indicate so-called Heinrich Events during which the Atlantic meridional overturning circulation was greatly reduced. Bottom panel: Summer precipitation anomaly (in metres per year) over Northern Africa due to a ~80% weakening of the Atlantic meridional overturning, simulated with a comprehensive climate model.

## INTERDYNAMIC
(Integrated analysis of interglacial climate dynamics)

Programme Duration: 2007 – 2013
Funding: DFG

This priority research programme aims to achieve a better understanding of climate dynamics using quantitative paleoclimate analyses with the idea of creating more reliable scenarios for future climate change. It is based on an integrated approach, in which climate reconstructions from all available paleoclimate archives (terrestrial and marine as well as ice cores) are combined and linked with results from Earth-system models. Key objectives are: (i) To assess natural climate variations on timescales of several years to millennia, (ii) to evaluate the potential for abrupt changes in the large-scale circulation of the Atlantic Ocean during interglacials, (iii) to disentangle which biogeochemical feedback mechanisms control the natural limits of atmospheric concentrations of greenhouse gases and aerosols, and (iv) to study potential links between climate and pre-industrial cultures.

» www.interdynamik.de «

## The Ocean in the Earth System (MARUM)

Programme Duration: 2007 - 2012
Funding: DFG (Excellence Initiative)

The Earth is a complex and dynamic system. Oceans, lithosphere, biosphere, atmosphere and cryosphere are closely connected with each other through closely linked interactions. It is the aim of "The Ocean in the Earth System" MARUM cluster of excellence to gain a better understanding of the role of the ocean in the global Earth System. The superordinate research topics are: Ocean and global change, relationship between geo- and biosphere as well as between humans and the ocean. The areas of investigation range from shelf to deep ocean regions. The MARUM cluster of excellence is based on the "Ocean margins" research centre which has been receiving funding from the DFG since 1st July 2001. The University of Bremen works in close cooperation with the following institutions: Alfred Wegener Institute for Polar and Marine Microbiology, Bremerhaven (AWI), Jacobs University Bremen (JU), Max Planck Institute for Marine Microbiology, Bremen (MPI), Senckenberg Institute by the Sea, Wilhelmshaven (SNG), and the Centre for Marine Tropical Ecology, Bremen (ZMT). The activities are closely integrated with international programmes (IGBP, PAGES, IMAGES, IODP, InterRidges, etc.). MARUM operates one of the three IODP core repositories. It is one of eight institutes worldwide to use underwater vehicles (ROVs), a sea floor rig (MeBo) and an autonomous underwater vehicle (AUV) in its research activities, which has led to MARUM becoming a centre of ocean research technology and a sought-after partner in international cooperative projects.

» www.marum.de «

# German Contributions to International Global Change Programmes and ESSP

The German National Committee on Global Change Research (NKGCF) was set up in October 1996 by Germany's major research funding agency, the German Research Foundation (DFG), in close collaboration with the German Federal Ministry of Education and Research (BMBF). As a scientific advisory committee to DFG and BMBF, the German National Committee plays a significant role in the process of identifying research priorities and in stimulating German contributions to the four international programmes on Global Change research, DIVERSITAS, International Geosphere-Biosphere Programme (IGBP), International Human Dimensions of Global Environmental Change Programme (IHDP) and World Climate Research Programme (WCRP).

The National Committee is made up of several senior scientists from different disciplines in the sciences and humanities who represent the four major international Global Change programmes; ex-officio members represent BMBF, DFG and the Federal Environment Agency (UBA), respectively. The Scientific Secretariat is also represented as the national contact point and coordinating office.

By bringing together scientists from all fields of Global Change research and the four international programmes under the umbrella of one committee, Germany has anticipated early the need for close collaboration between all the scientific disciplines that conduct Global Change research within the framework of the ESSP. This organisational structure enables the National Committee to efficiently support the ESSP and to contribute to the development of new joint projects.

In June 2005, NKGCF presented a new policy paper for a coherent German research strategy on Global Change, identifying priority research areas. A main focus is the close integration of all research activities into the four international programmes and ESSP joint projects. This policy document was followed up in 2007 with an implementation strategy for a national research programme on "Coping with Global Change – Land Use in the Area of Conflict of Resource Conservation, Food and Energy".

## Scope of NKGCF

- Acts as scientific advisory committee to the German Research Foundation and Federal Ministry of Education and Research.
- Plays a significant role in the process of identifying research priorities and in stimulating and coordinating German contributions to the four international Global Change research programmes.
- Aims to improve the internationalisation of Global Change research in Germany and at promoting the integration of German contributions into the international programmes.
- Advises the German representation to the International Council for Science (ICSU) and the European Science Foundation (ESF).

## Members NKGCF 2006 – 2008

| | |
|---|---|
| **Prof. Dr. Wolfram Mauser**<br>***Chair*** | Hydrology, Remote Sensing |
| Prof. Dr. Norbert Jürgens<br>*Co-Chair Diversitas* | Botany |
| Prof. Dr. Meinrat O. Andreae<br>*Co-Chair IGBP* | Biogeochemistry |
| Prof. Dr. Gernot Klepper<br>*Co-Chair IHDP* | Environment<br>Ressource Economics |
| Prof. Dr. Peter Lemke<br>*Co-Chair WCRP* | Climate System<br>Polar Research |
| Prof. Dr. Elisabeth Kalko | Animal Ecology |
| Prof. Dr. Peter-Tobias Stoll | Int. Business Law, Environmental Law |
| Prof. Dr. Wolfgang W. Weisser | Terrestrial Ecology |
| Prof. Dr. Joseph Alcamo | Environmental System Engeneering |
| Prof. Dr. Gerold Wefer | Marine Geology |
| Prof. Dr. Georg Teutsch | Applied Geosciences, Hydrology |
| Prof. Dr. Wilhelm Dangelmaier | Business Computing |
| Prof. Dr. Frauke Kraas | Anthropogeography, Urban Research |
| Prof. Dr. Paul L. G. Vlek | Tropical Agriculture |
| Prof. Dr. Jochem Marotzke | Meteorology, Oceanpgraphy |
| Dr. Inge Paulini | Federal Environmental Agency |
| Dr. Gisela Helbig | Federal Ministry of Education and Research |
| Dr. Bettina Höll | Scientific Secretariat |
| Dr. Johannes Karte | German Research Foundation |

*Ex Officio*

## Activities of NKGCF

- Four regular Committee Meetings per year.
- National Colloquia to discuss achievements and to redesign and refocus future needs of the global change research programmes.
- Scientific Workshops to develop new methodologies and scientific programmes, organized with financial support from DFG and BMBF, to discuss new methodological approaches and to develop new research initiatives and new programmes.
- Scientific Conferences to evaluate the progress and achievements of German contributions to Global Change research. These meetings also provide the necessary background information for future programme development. The discussions and main outcomes of these meetings are published either as books or as part of the committees' publication series.
- Ad hoc Working Groups to discuss and review new research initiatives, and to help develop new programme components.

## ESSP (Earth System Science Partnership)

The Earth System Science Partnership (ESSP) is a partnership of the four Global Change research programmes (DIVERSITAS, IGBP, IHDP and WCRP) for the integrated study of the Earth System, the changes that are occurring to the System, and the implications of these changes for global sustainability. The ESSP has five types of activities:

- joint projects on issues of global sustainability, designed to address the Global Change aspects of a small number of critical issues for human wellbeing: carbon cycle/energy systems (GCP), food systems (GECAFS), water resources (GWSP) and human health (GEC & HH),
- regional activities, including capacity building, networking and integrated regional studies,
- Earth System analysis and modelling, via collaboration among existing projects/activities of the four constituent programmes,
- global Change Open Science Conferences. ESSP recognizes the importance of broad interaction amongst the many scientists that contribute to its activities. As such, the Partnership is committed to hosting major international science meetings every five years,
- communication activities, currently under development. These include the ESSP website, a report series, a common design profile for the ESSP and features on ESSP activities in the programme newsletters.

» www.essp.org «

***DIVERSITAS***
Objectives: Addressing the complex scientific questions posed by the loss of and changes in global biodiversity.
Structure: Four interrelated areas for further development:
(1) discovering biodiversity and predicting changes – bioDISCOVERY,
(2) assessing the impact of biodiversity changes on ecosystem functioning and services – ecoSERVICES,
(3) developing the science of the conservation and sustainable use of biodiversity – bioSUSTAINABILITY,
(4) documenting biodiversity, its diversification, and the effects of human-induced changes – bioGENESIS.

» www.diversitas-international.org «

***IGBP (International Geosphere-Biosphere Programme)***
Objectives: Studying the interactions between biological, chemical and physical processes and human systems.
Structure: Four core projects are centred on the three major Earth System compartments: Oceans (IMBER and GLOBEC), land (GLP) and atmosphere (IGAC). Three projects investigate the interactions and feedbacks between them: Land/atmosphere (iLEAPS), land/ocean (LOICZ), and ocean/atmosphere (SOLAS). Two projects, PAGES and AIMES, focus on a whole system perspective.

» www.igbp.net «

***WCRP (World Climate Research Programme)***
Objectives: Developing 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.
Structure: The main core projects focus on Climate and Cryosphere (CliC), Climate Variability and Predictability (CLIVAR), Global Energy and Water Cycle Processes (GEWEX), Stratospheric Processes and their Role in Climate (SPARC), Surface Ocean-Lower Atmosphere (SOLAS). Modelling activities by different working groups lead to the development of atmospheric circulation models for climate studies, numerical weather prediction, and coupled ocean/atmosphere/land models.

»wcrp.wmo.int «

***IHDP (International Human Dimensions of Global Environmental Change Programme, Secretariat in Bonn)***
Objectives: Fostering, coordinating and conducting social science research, contributing to interdisciplinary attempts of natural and social science capacity-building of research and policy communities, working at the interface between science and policy.
Structure: Current five core core projects: Global Environmental Change and Human Security (GECHS), Industrial Transformation (IT), Urbanisation and Global Environmental Change (UGEC); co-sponsored with IGBP: Global Land Project (GLP), Land-Ocean Interactions in the Coastal Zone (LOICZ).

» www.ihdp.org «

## Joint Projects on Global Sustainability

***GWSP (Global Water System Project)***
Objectives: Developing and promoting the global and interdisciplinary dimensions of water research.
Activities: A wide range of activities focusing on developing new knowledge (international comparison of estimates of world water balance; development of internationally-comparable environmental flows; elaboration of concepts of global governance of water; development of new integrated indicators of the global water system); capacity building (international summer school on water and climate); networking and information exchange (digital world water atlas; global catchment initiative; endorsed international projects on: the water cycle in Brazil, regional-scale green water fluxes, global change in the Danube basin).

» www.gwsp.org «

# German Federal Ministry of Education and Research (BMBF)

» www.bmbf.de «

The main contributors to the financing of Global Change research in Germany are the German Federal Ministry of Education and Research (BMBF) and the German Research Foundation (DFG).

The German Federal Ministry of Education and Research (BMBF) has several funding mechanisms designed to implement scientific objectives in Global Change research. The project oriented funding serves to solve specific scientific questions on Global Change within the scope of short-term programmes. Additionally, scientific institutions through-out Germany receive institutional funding from the BMBF and also from their respective federal states. These budgets are managed independently and are self-administered. Also, significant amounts are mobilised for the scientific infrastructure. The major beneficiaries of institutional BMBF funding are four large scientific organisations: Helmholtz Association, Leibniz Association, Max Planck Society (MPG) and Fraunhofer Association (FhG). Their research facilities have a special significance in Global Change research because they operate instruments and systems. Research on Global Change relies on complex equipment (e.g. aircrafts, high-performance processors, ships and observatories). Additionally, Helmholtz and Leibniz Associations address questions of Global Change within research networks ("Earth System Science" and "Environmental Research").

## BIOTA AFRICA – An African-German Research Project for the Sustainable Use and Conservation of Biodiversity in Africa


The Biodiversity Monitoring Transects of BIOTA AFRICA.


BIOTA AFRICA cooperates closely with land users in Africa (The photo shows a land user and a member of the BIOTA AFRICA para-ecologist training programme).

The consequences of changes in and losses to biodiversity in Africa, due to climate change and the over-exploitation by humans are already visible. The situation is alarming as natural resources such as vegetation and soil still provide the economic backbone for many rural households in Africa. It is a major aim of the international BIOTA AFRICA research project to develop scientifically sound and policy-relevant pathways for the sustainable utilisation and restoration of biodiversity in Africa. In order to support a pan-African communication and data exchange network for sustainable development and biodiversity conservation, the scientists from Africa and Germany have developed multidisciplinary standards to measure and analyse changes in biodiversity so that detailed and continuously updated information on the status and ongoing changes in biodiversity (species, genes and ecosystems) is available from the local to the continental level. A standardised Biodiversity Observation system has already been established in Benin, Burkina Faso, Cote d'Ivoire, Democratic Republic of Congo, Ghana, Kenya, Morocco, Namibia, South Africa and Uganda, along Biodiversity Monitoring Transects. The first Biodiversity Observatories were set up in 2001. Currently, more than 70 Biodiversity Observatories exist in East, West, North and southern Africa. They provide multi-disciplinary data series and information on the complex causes and effects of changes in biodiversity. The inventory of the BIOTA AFRICA Project notably includes regions and groups of organisms which to date are insufficiently documented ("filling the gaps"). The long-term, interdisciplinary research at the observatories is conducted by over 300 scientists from Africa and Germany. The project has developed a data and information management system called BIOTABase to further improve software for storage, administration and analyses of ecological data and to enable regional and continental comparability. The data is openly accessible for scientific and management purposes (www.biota-africa.org). Interdisciplinary models have been developed which outline major changes and trends as well as their ecological, social and economic impacts. Capacity development is one of the project's major ambitions. BIOTA AFRICA has developed academic and non-academic training programmes for students and land users in order to make sure that its scientific recommendations for sustainable development and climate change-driven adaptation options are based on the social, economic and cultural realities of the target regions.

# German Research Foundation (DFG)

» www.dfg.de «

The German Research Foundation (DFG) is the central funding organisation for universities in Germany. DFG has been involved in funding Global Change research for a long time. As an organisation responsible for the funding of all disciplines, DFG is in charge of research related to all of the international Global Change programmes (WCRP, IGBP, IHDP, DIVERSITAS) and the Earth System Science Partnership (ESSP). Funding is through a number of individual projects and larger coordinated programmes (Collaborative Research Centres, Priority Programmes, Research Units, Research Training Groups, see overview) which are initiated through a bottom-up process. The overall annual funding dedicated to Global Change research is around 50 million EUR.

## Overview on DFG-funded Projects and Programmes related to Global Change Research

**Collaborative Research Centres (Sonderforschungsbereiche, SFB)**

299 Land Use Options for Peripheral Regions
512 Cyclones and Climate System of the North Atlantic
552 Stability of Rainforest Margins in Indonesia (STORMA)
564 Sustainable Land Use and Rural Development in Mountainous Regions of South-east Asia
574 Volatiles and Fluids in Subduction Zones: Climate Feedback and the Causes of Natural Disaster
641 The Tropospheric Ice Phase (TROPICE)
754 Climate – Biogeochemistry Interactions in the Tropical Oceans

**Transregional Collaborative Research Centres (Transregio, TR)**

32 Patterns in Soil-Vegetation-Atmosphere Systems: Monitoring, Modelling and Data Assimilation

**Priority Programmes (Schwerpunktprogramme, SPP)**

527 (Integrated) Ocean Drilling Programme (IODP/ODP)
1144 From Mantle to Ocean: Energy, Material and Life Cycles on Spreading Axes
1158 Antarctic Research with Comparable Investigations in Arctic Sea Ice Areas
1162 The Impact of Climate Variability on Aquatic Ecosystems (AQUASHIFT)
1167 Quantitative Precipitation Forecast PQP (Praecipitationis Quantitati vae Praedictio)
1176 Climate and Weather of the Sun-Earth-System
1233 Megacities: Informal Dynamics of Global Change
1257 Mass Transport and Mass Distribution in the Earth System
1266 Integrated Analysis of Interglacial Climate Dynamics (Interdynamics)
1276 Multiple-Scale Modelling in Fluid Mechanics and Meteorology
1294 Atmospheric and Earth System Research with the "High Altitude and Long Range Research Aircraft" (HALO)
1315 Biogeochemical Interfaces in Soil
1374 Biodiversity Exploratories

**Research Units (Forschergruppen)**

456 The Role of Biodiversity for Element Cycling and Trophic Interactions: An Experimental Approach in a Grassland Community
510 Ecological and Cultural Changes in West and Central Africa
536 Matter Fluxes in Grasslands of Inner Mongolia as Influenced by Stocking Rate (MAGIM)
539 Saharan Mineral Dust Experiment SAMUM
584 Earth Rotation and Global Dynamic Processes
816 Biodiversity and Sustainable Management of a Mega-diverse Mountain Ecosystems in Southern Ecuador

**Research Training Groups (Graduiertenkollegs)**

717 Proxies in Earth History
1070 Modelling Material Flows and Production Systems for Sustainable Resource Use in Intensified Crop Production in the North China Plain
1086 The Role of Biodiversity for Biogeochemical Cycles and Biotic Interactions in Temperate Deciduous Forests
1364 Interactions Between Tectonics, Climate and Biosphere in the African-Asian Monsoonal Region

**Graduate Schools (Graduiertenschulen)**

119 Global Change in the Marine Realm
208 Graduate School for Integrated Studies of Human Development in Landscapes

**Cluster of Excellence (Exzellenzcluster)**

80 The Future Ocean
177 Integrated Climate System Analysis and Prediction (CliSAP)
309 The Ocean in the Earth System

## STORMA (Stability of Rainforest Margins in Indonesia)

Project Duration: 2000-2012
Funding: DFG and several public donors in Indonesia

The stability of rainforest margin areas has been identified as a critical factor in the protection of tropical forests. Stability has an ecological, social and economic dimension. Understanding the ecological and socio-economic determinants of land use change in tropical rainforest margins on different spatial scales is the key to identify more suitable development objectives and programmes that better combine nature conservation, poverty reduction and economic development of rural areas.
The main objective of the STORMA as a multidisciplinary research programme is to analyse processes that may contribute to the stability of rainforest margins and to the development of integrated concepts of sustainable land use. Research foci in the third period (2006 - 2009) of STORMA are:

- integrated modelling of land use in a highly dynamic tropical landscape: socio-economic and environmental effects of different strategies of resource use,
- ecological and socio-economic assessment of agroforestry management: upscaling from the plot and household level to villages and landscapes,
- the Sulawesi Throughfall Displacement Experiment - Ecosystem and economic responses to ENSO droughts in rainforest and agro-forest.

» www.uni-goettingen.de/de/44103.html «

O. von Straaten

# Max Planck Society (MPG)

» www.mpg.de «

The Max Planck Society carries out independent and non-profit research in its own institutes and facilities, which benefit from total autonomy in their choice of research foci, covering humanities, social sciences, life sciences, natural sciences and engineering sciences and working in close cooperation with other research institutions and universities. At the present time, there are 77 institutes and research facilities all over Germany and in some partner countries.

**Earth Science and Climate Research**
Max Planck Institutes in Mainz, Hamburg, Jena and other partnering institutions have joined to form the Earth System Research Partnership. Its goal is an integrated approach to Earth System Science, focussing on the interactions between human activities, land-based ecosystems, oceans and atmosphere, and applying aircraft and ground-based measurements, remote sensing and modelling. The understanding of the Earth System and its interactions are a basic prerequisite for the definition of economic and political strategies for an ideal and sustainable use of the planet's resources.

Approaches involved are threefold: measurements and in-situ experiments are required to examine processes within the components. To support such measurements, the Max Planck Society operates long-term measurement stations and is a key partner in the acquisition and use of the HALO research aircraft. Secondly, the earth has to be analysed on large time and space scales in order to understand regional, global and long-term processes and alterations. For a survey of global or continental phenomena, the use and analysis of satellite data is irreplaceable. The third main pillar is modelling. Numeric models, for example, are theoretical tools for investigating interrelations in the Earth System.

The research focuses on the following questions:

- Which feedbacks and long distance relations of the Earth System are especially important?
- What regions and components have a particularly sensitive reaction to Global Change?
- Are there critical thresholds that lead to abrupt changes in the Earth System?
- Are there options to manage or control the Earth System in the long term?

These activities are of international relevance and are hence closely coupled internationally with large research programmes, notably the International Geosphere-Biosphere Programme (IGBP).

Other topics related to Global Change are: Fundamentals of sustainable energy supply (e.g. hydrogen) and changes in biodiversity, both with numerous institutes involved.

## IMPRS (International Max Planck Research Schools)

**IMPRS for Atmospheric Physics and Chemistry**
This Research School is a joint initiative of the MPI for Chemistry, Mainz, and Mainz University. Other partners are the Atmospheric Physics Department of the MPI for Nuclear Physics in Heidelberg and the Universities of Heidelberg and Frankfurt. The Research School investigates atmospheric physical-chemical processes and the human influence on Global Change. Improved understanding of these processes contributes to the development of atmospheric chemistry and climate models which will play an increasingly important role in the assessment of global climate change. The research topics address sensitive regions of the atmosphere that have received relatively little attention up until now, for example in the tropics. By combining high quality research, state-of-the-art instrumentation and innovative education methods, the initiators attract talented and highly motivated young scientists from all over the world.
» www.atmosphere.mpg.de/enid/1280 «

**IMPRS on Earth System Modelling**
The Research School on Earth System Modelling offers Ph.D. students from all over the world the possibility to pursue their studies in Earth System sciences. The research contributes to the development and examination of models that evaluate the mechanisms of the Earth System by taking into account a number of time and spatial scales and by assessing these mechanisms from different scientific viewpoints. The research is combined with courses on basic and specific aspects of the Earth System; the lectures are geared to the interdisciplinary background of the students who work at internationally renowned institutes in Germany, performing research into Global Change. The Research School is financed in nearly equal parts by the MPG and the ZEIT Foundation Ebelin and Gerd Bucerius as well as the partner institutes: Hamburg University, GKSS Research Centre, Hamburg Institute of International Economics, Centre for Environmental Systems Research and the Potsdam Institute of Climate Impact Research (PIK). The school focuses on international cooperation, which strives among other things to facilitate the exchange of students and to admit junior scientists, particularly from emerging and developing countries.
» www.earthsystemschool.de «

# Helmholtz Association

» www.helmholtz.de «

The Helmholtz Association identifies and addresses the huge challenges facing society, science and industry, in particular through its research into highly complex systems. Its 15 national research centres carry out scientific-technical and biological-medical research. Helmholtz concentrates its core competences and resources on strategic programmes aimed at increasing the efficiency, flexibility and target-oriented focus of its research. Funding is provided by the federal and state governments.

**Earth and Environment**

The work done by the scientists aims to provide the most accurate description possible of the consequences of the far-reaching and complex changes to the earth and the environment in order that government and society can plan ahead. The research field "Earth and Environment" brings together researchers from the natural sciences and social sciences to work in close collaboration for the benefit of science, society and government.

Their environmental research focuses on addressing the major challenges identified by national and international bodies: Natural disasters, climate fluctuations and climate change, the availability of and access to clean water, sustainable use of resources, biodiversity and ecological stability as well as the socio-political dimension of Global Change. The research field "Earth and Environment" addresses these central challenges through six programmes:

Interest Groups were established on Megacities, Natural Disasters and Technology Assessment. In addition, six Helmholtz Centres are combining their resources in a project called Helmholtz-EOS (see box). In the German Marine Research Consortium (Konsortium Deutsche Meeresforschung, KDM), ten partners from universities, Helmholtz Association, Max Planck Society and Leibniz Association plan and coordinate their marine, polar and coastal research activities.

Other subjects related to Global Change research are found in the field of "Aeronautics, Space and Transport" addressing, amongst others, questions related to the development of innovative solutions for environmentally friendly and energy-efficient transport, and in the research field "Energy" (renewable energies, efficient energy conversion).

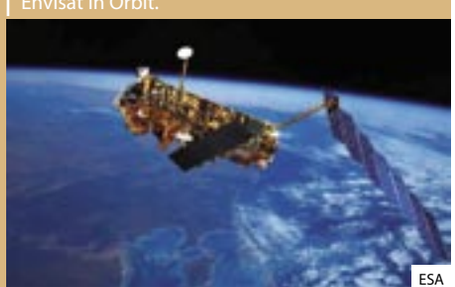
## Helmholtz Centres Involved

Alfred Wegener Institute for Polar and Marine Research (AWI)
German Aerospace Center (DLR)
Research Centre Jülich (FZJ)
Research Centre Karlsruhe - Helmholtz Centre for Infection Research (HZI)
GeoForschungsZentrum Potsdam (GFZ)
GKSS Research Centre Geesthacht
Helmholtz Zentrum München –German Research Centre for Environmental Health
Helmholtz Centre for Environmental Research (UFZ)

## Helmholtz-EOS (Integrated Earth Observation System)

The network is intended to facilitate the work of scientists in depicting and modelling processes spatially and temporally at high resolution and in monitoring the status and trends of the Earth System. The physical and chemical tolerances of processes critical for human life also need to be defined, as well as long-term monitoring of global, regional and local changes.
Thanks to their expertise, scientific infrastructure and facilities, the Helmholtz centres AWI, DLR, Forschungszentrum Karlsruhe, FZJ, GFZ and GKSS have the necessary preconditions for jointly pursuing crucial research topics in this context and achieving added value.
The Helmholtz research fields "Earth and Environment" and "Aeronautics, Space and Transport" are being linked to create an "Integrated Earth Observing System". Its purpose is to concentrate expertise and share infrastructure and data, in seven research programmes: Climate Changes in Polar Regions, Global Changes and Processes in Oceans, Coastal Zones and Land Surface, Trends in the Hydrological Cycle, Changes in Chemistry and Dynamics of the Atmosphere, Global Risks Assessment and New Methods of Radar Remote Sensing. These activities are financed from the resources contributed by each participating centre for the work each carries out within the network's individual research programmes. Coordination of topics and allocation of resources are handled by the network's steering committee. The network can be expanded to address further topics with the participation of additional Helmholtz centres, universities and research institutions.

Envisat in Orbit.



ESA

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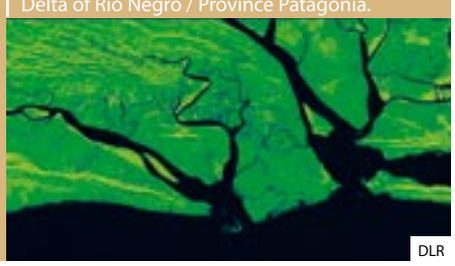


DLR

# Leibniz Association

» www.leibniz-association.eu «

The Leibniz Association is a network of 82 scientifically, legally and economically independent research institutes and scientific service facilities. Leibniz Institutes carry out strategic and thematically oriented research and offer scientific services of national significance. They strive to find scientific solutions for major social challenges.

Leibniz Institutes employ more than 13,700 people, 5,700 of whom are academics, including 2,100 junior scientists.

Leibniz Institutes contribute to clusters of excellence in fields such as mathematics, optical technologies, materials research, medicine, climate and environmental research, bio- and nanotechnology as well as humanities, economics and social sciences. Leibniz Institutes foster close cooperation with universities, industry and other research institutes, both in Germany and abroad. The Leibniz Association has developed a comprehensive system of quality management. In the unique peer review evaluation process, independent experts assess every institute at regular intervals.

**Leibniz Institutes and Global Change Research**

Several Leibniz Institutes work in the field of climate research. They try to promote the understanding of climate and its influence on ecosystems, climate reconstruction, modelling and climate policies. The research done at the PIK is wholly dedicated to questions of global warming.

Due to the huge impact of the oceans on the global climate, the Leibniz Association's marine research institutes are intensely involved in climate research. An entire research division, "Ocean Circulation and Climate Dynamics" at the Leibniz Institute of Marine Sciences at the Christian-Albrecht University of Kiel (IFM-GEOMAR), is working on a multi-faceted approach to climate investigations on different timescales. The Leibniz Institute for Baltic Sea Research in Warnemünde (IOW) is hosting a project aimed at the development of Policies & Adaptation Strategies to Climate Change in the Baltic Sea Region. The Centre for Tropical Marine Ecology (ZMT), an associated member of the Leibniz Association, is involved in an interdisciplinary research project aimed at assessing and modelling the impact of ENSO (El Niño Southern Oscillation) induced climate variability on the Humboldt Current Large Marine Ecosystem (HCLME) and its resources and resource users.

The regional impacts of climate change on the north-east of Germany were simulated by the Leibniz Centre for Agricultural Landscape Research (ZALF). The Leibniz Institute for Tropospheric Research (IfT) in Leipzig concentrates on the investigation of aerosols, i.e. small airborne particles, and clouds and their strong but relatively poorly understood relationships with climate and health.

The economic impact of climate change is the subject of the work of the Kiel Institute for the World Economy (IfW) whose research area "Climate and Energy" concentrates on the complex interaction of energy demand, the supply of exhaustible fossil energy and climate goals. The research department "Energy, Transportation, Environment" of the German Institute for Economic Research (DIW) specifically examines ways in which a climate-friendly, competitive and secure energy system can be ensured.

Five Leibniz Institutes (IOW, IfT, IfW, IFM-GEOMAR, PIK) are partners in the German Climate Consortium (DKK), founded in 2007 as a new platform for climate research at the interface of society, economy and environment.

The Leibniz Institute of Marine Sciences (IFM-GEOMAR) and the Kiel Institute for the World Economy (IfW) are partners of the University of Kiel in the cluster of excellence "The Future Ocean" (see box).

## The Future Ocean

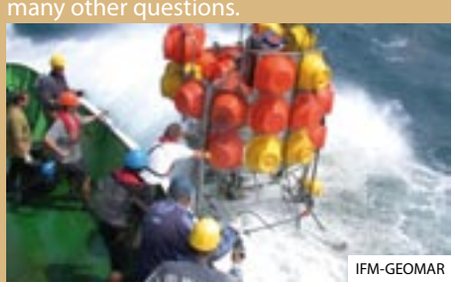
(Cluster of excellence approved by the German Research Foundation)

Project Duration: 2007 – 2012
Funding: German Research Foundation

The ocean covers more than two thirds of our planet. Even so, we know more about the surface of the moon than about the depths of the seas. This, in spite of the fact that mankind's future lies in the world's seas. They determine the climate of tomorrow across the entire globe – and are already suffering from the advance of global warming. New raw materials and sources of energy can be found on the seafloor– how can we exploit them? Many marine organisms may harbour the secrets to cures for diseases – if they are still around tomorrow.

These are just some of the aspects that the Kiel cluster „The Future Ocean" is investigating. The aim: to increase our understanding of ocean change and its associated potential and risks, in order to enter into a new symbiotic relationship between humans and the sea.

In "The Future Ocean", experts from diverse specialist areas are combining their expertise: For example, lawyers and geoscientists are investigating questions on how and who has the right to exploit resources on the seafloor. Climatologists and economists are working on the question of what conditions make $CO_2$ storage on the seafloor a relevant option. Marine scientists, medics, mathematicians, chemists, engineers and social scientists are working on many other questions.

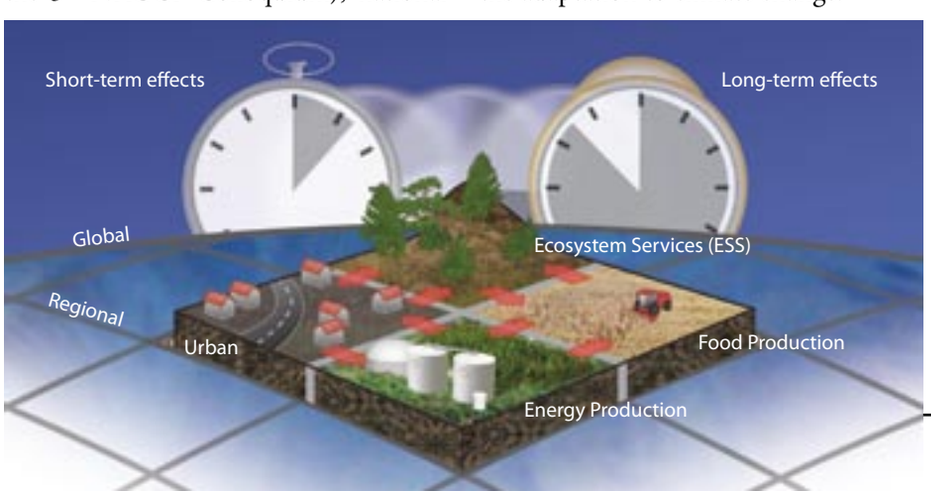


IFM-GEOMAR

A coherent research strategy on Global Change, embedded in the societal context, needs to connect the concept of sustainable development and its implementation into politics and society. The fundamentals of such a strategy are basic skills, orientation skills and applicable skills. On all three levels, skills generation has improved during recent years. However, skills gaps not yet covered need to be systematically filled through scientific research and development. In order to identify the most urgent research questions, the following criteria have been established by the German National Committee on Global Change Research (NKGCF). The questions should:

- be embedded into the overall context of Global Change, and simultaneously, cover questions of relevance to human society,
- lead to a better understanding and an improved prognostic ability on a global and regional scale,
- address interactions between natural and societal components within the Earth System,
- lead from fundamental research questions to options for action,
- be embedded in ESSP, i.e. in the international coordinated research programmes WCRP, IGBP, IHDP, DIVERSITAS, or be a complement to such programmes.

Taking into consideration the criteria mentioned above, NKGCF, in a dialogue with the scientific community (during the 3rd NKGCF-Colloquium), national science partners and research and funding institutions, compiled a policy paper in 2005 prioritising central research topics for the future strategy of Global Change research. Three years later, this policy document is supplemented with an implementation strategy for a national research programme (this will be discussed with the scientific community at the 4th NKGCF-Colloquium). Apart from interdisciplinary research, such a research programme also aims at dissolving the boundaries between academic research and research carried out at research institutions. A further idea behind the setting up of such an ambitious research programme is that it will lead to networking between the national institutions that fund the research. The proposed interdisciplinary national research programme "Coping with Global Change – Land Use in the Area of Conflict of Resource Conservation, Food and Energy" should focus on areas like ecosystem services, food, energy and urbanisation as being in conflict over the finite resource that is the global land surface. Since changes in regional land use also have a global effect, the research interests of the programme should be on the regional (defined as hotspots of Global Change) and global scale and should focus on different timescales (short- and long-term) as well as the interactions between the scales. National research should contribute to European and global efforts in understanding the Earth System and its interaction with humankind as well as in understanding the adaptation to climate change.




Scientific Secretariat NKGCF(K. Schmid)

Illustration about the contents of the National Research Programme "Coping with Global Change".

## Thematic Area I: Development of the Components of the Earth System – Understanding Specific Processes, Course of Action

Variations and Trends in the Earth System
Change of Composition and Dynamics of the Atmosphere
Ocean Circulation and Sea Level Changes
Change of Biosphere and Biodiversity
Change of Intensity/Frequency of Extreme Events and their Predictability
Material Flows in the Earth System
Biogeochemical Cycles
Water Cycle
Options and Instruments for Global Carbon Management
Energy – Mobility – Climate

## Thematic Area II: Global Change and Society

Technology Change
Consumer Patterns
Integration and Reorganisation of International Environmental Regimes
Health and Global Change
Migration

## Thematic Area III: Regional Effects of Global Change – Integrative Analysis and Management

*Integrative Analysis and Management of the Anthroposphere*
Urban and Peri-Urban Habitats
Rural-Peripheral Habitats
Coastal Zones
Dryland Areas
Mountainous Regions
Permafrost Regions

*Preservation, Stabilisation and Rehabilitation of Natural Resources and Functions of Ecosystems*
Soil Fertility
Water Availability and Water Quality
Air Quality
Biodiversity

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