GERMAN NATIONAL COMMITTEE ON GLOBAL CHANGE RESEARCH (NKGCF)

Global Change Research in Germany

Imprint

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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

Edited by Thomas Krafft and Wolfram Mauser

on behalf of the German National Committee on Global Change Research (NKGCF)

München, 2005

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 Adaptation 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 Computing Centre
DLR	Deutsches Zentrum für Luft- und Raumfahrt/German Aerospace Center
DWD	Deutscher Wetterdienst/Germany's National Meteorological 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 Center 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
GAIM	Global Analysis, Integration and Modelling
GBF	Gesellschaft für Biotechnologische Forschung/German Research Centre for Biotechnology
GBIF	Global Biodiversity Information Facility
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 Center 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 Environmental Change
IEA	International Energy Agency
IFM-GEOMAR	Leibniz-Institut für Meereswissenschaften/Leibniz 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
MARCO-POLI	Marine, Coastal and Polar Systems
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 Committee 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 Globale 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/ Center for Development Research
ZMAW	Zentrum für Marine und Atmosphärische Wissenschaften/Centre for Marine and Atmospheric Sciences
ZMT	Zentrum für Marine Tropenökologie/ Center forTropical Marine Ecology

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GLOBAL CHANGE RESEARCH – SCIENCE FOR A SUSTAINABLE FUTURE

Global Change summarises the effects of a growing interference of humankind 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 of human population and facilitated by a rapid development of technologies to 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, and mechanisms to create extraordinary wealth in certain regions of the world. Given the vigorous force and mostly uncoordinated fashion these per se positive developments take place, it is not surprising that adverse phenomena are beginning to show. Human interactions with the Earth System are affecting the climate of the planet, altering its water cycle, emptying non-renewable resources and starting to stress the life-support system of the planet (Figure 1).

Global Change

Over the past few decades, evidence has mounted that planetary-scale changes are occurring rapidly. These are, in turn, changing the patterns of forcings and feedbacks that characterise 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 in 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., Schellnhuber, H.-J., Turner II, B.L., Wasson, R.J., 2004, Global Change and the Earth System. A Planet Under Pressure.

There are no signs for a deceleration or reversal of this development. Therefore, coping with the adverse phenomena of Global Change becomes a major challenge for human societies. Because human activities cause, are affected by and alter change simultaneously, not only changes in the global climate system have to be analysed, 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 chances 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.

The Earth System: Challenges and Strategies

Great 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's (ICSU's) and the International Social Science Council's (ISSC's) 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 led to a deeper and more detailed understanding of the past and present functioning of the Earth as a system. Despite this progress, the intellectual complexity related to the questions on how suitable pathways of sustainable development can be identified and implemented has generally been 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 devoted to the understanding of the evolution and the impacts of the processes which trigger and drive change and to the derivation of possible alternatives to deal with change in a constructive way. Global Change research develops procedures to distinguish between natural variability and real changes as well as prognostic abilities to foresee changes and their consequences, to identify options for counteractions and to balance adaptation to change and mitigation of causes. In this respect, scientific progress can only be achieved by interdisciplinary approaches. Global Change research relies on sophisticated observing systems to identify changes and optimise decision alternatives at the earliest stages possible.

Questions of Scale

Both global and regional strategies have to be developed in order to balance the interaction of 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 towards sustainable development are most likely to be implemented and where actions takes place. The focus on regions and common efforts to bridge the gap between global perspectives on change and both the analysis of regional impacts and the development of regional sustainable management options must be intensified.

Prospects

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 contribute best to the international efforts to bring the very challenging practical questions of Global Change research closer to a solution.

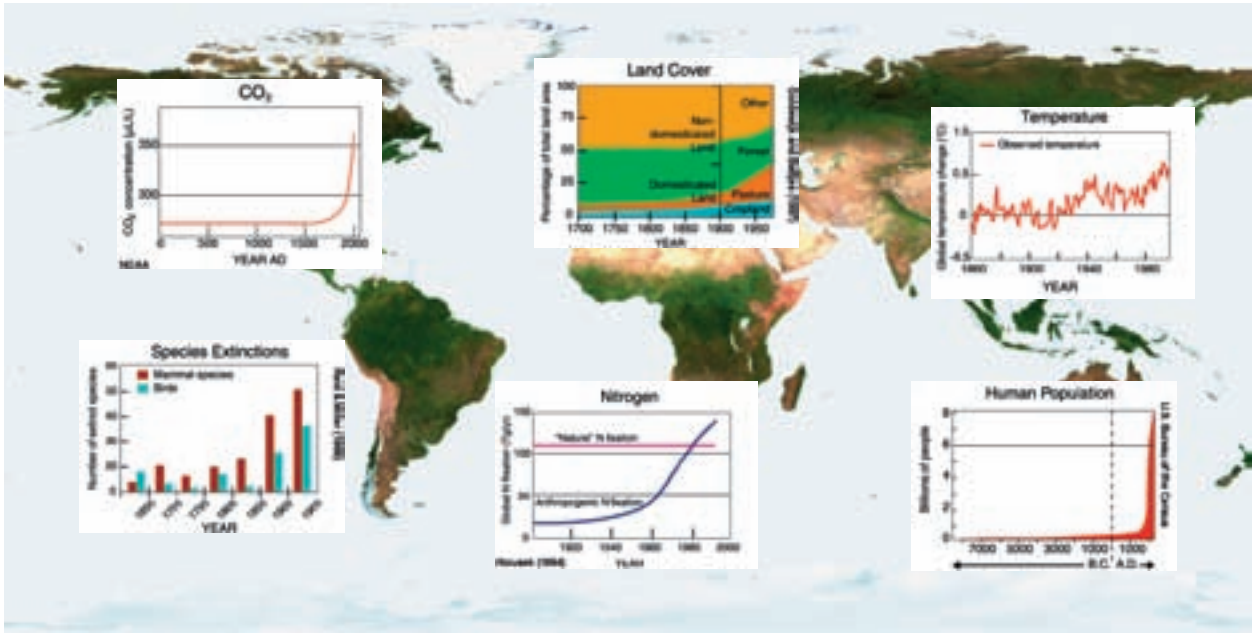


Figure 1: Selected aspects of Global Change: Changes of atmospheric composition, temperature, biodiversity, nitrogen fixation, population, land use.
Sources: Nitrogen: Vitousek, 1994, Beyond global warming: Ecology and Global Change, Ecology 75: 1861-1876 | Species Extinction: Reid and Miller, 1989, The scientific basis for the conservation of biodiversity, World Resources Institute, Washington DC | CO_2: National Oceanic and Atmospheric Administration (NOAA) | Ozone Data from NASA Goddard Space Flight Center | Human Population: International Database, U.S. Bureau of the Census | Land Cover: Goldewijk and Battjes, 1997, One hundred year database for integrated environmental assessments, National Institute for Public Health and the Environment (RIVM). Bilthoven, Netherlands | Temperature: Source not specified. Note: temperature graph shows temperature anomaly of global average temperature from the 1960-1991 mean. All information has been compiled by IGBP (International Geosphere-Biosphere Programme). [www.igbp.kva.se]

WATER CYCLE AND WATER AVAILABILITY

Water, and in particular an adequate supply of clean freshwater, is a key to the future development of 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, this fraction of the population could not be reduced during the last years. Furthermore, freshwater is essential for agriculture. Agricultural water supply directly translates into yield and food. Freshwater is also needed in large quantities and defined quality for industry and energy production.

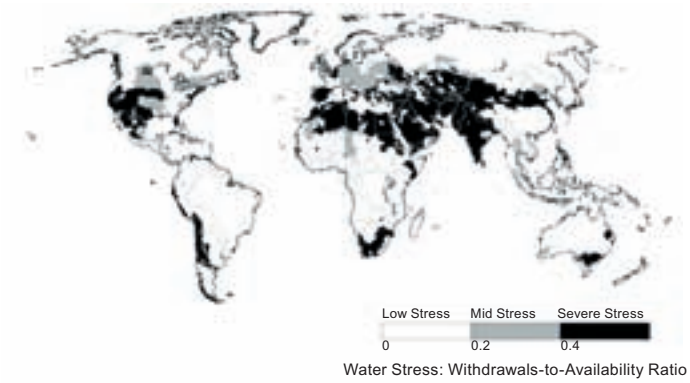
Clean freshwater for agricultural, industrial and household use is part of the Earth's life support system. This life support system, consisting of physical, biogeochemical and biological cycles on the land surface and in the oceans, contains the most powerful and cost efficient water treatment and supply process we know, outperforming all known water treatment technologies developed by human beings. Nevertheless, water technologies play an important, yet expensive role in supporting nature in maintaining its productivity.

ZEF

Figure 1: Irrigation in Ghana. In many parts of the world, food production relies on irrigation, supplementing insufficient rainfall. Changing climate and demand as well as the capacity of the ecosystem to hold and purify water (see sparse vegetation and erosion in the background of the image) will affect the availability of water for irrigation in the future.

Earth's life support system critically relies on sufficient water, space and diversity to maintain its functioning and stability. Global Change is increasingly putting stress on this system. As a result, the conflict between the water demand of the human population, mainly in form of irrigation, and the water demand of nature to sustain the natural water cycle is growing. 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 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.

Especially irrigation causes water stress, which has been assessed globally (Figure 2). This stress will increase as a result of population increase and development as well as climate change, leaving progressively less water reserves for the global life support system. Because of the complexity of the water issue, including natural and anthropogenic factors and many yet unquantified interactions, and despite some first attempts, the future development of the global water system can not yet be accurately predicted and deserves further research attention.



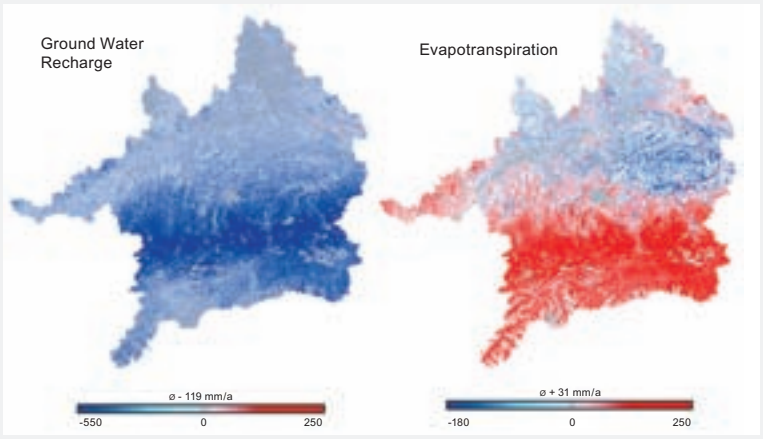
In order to develop management skills to adapt to foreseeable climatic and population development and to manage adaptation on the regional level, the GLOWA research initiative (see box) was launched by the German Federal Ministry of Education and Research (BMBF).

Figure 2: Global estimate of the current water stress. Water stress is depicted by the current average withdrawal-to-availability ratio as computed by the WaterGAP model. Water withdrawals are represented for the situation in 1995, computation of water availiability are based on the climate normal period 1961-1990.
Source: Alcamo et al., 2003, WaterGAP 2: A model for global assessment of freshwater resources, Hydrological Sciences Journal, 48(3): 317-338, doi:10.1623/hysj.48.3.317.45290.

GLOWA (Global Change in the Hydrological Cycle)

Programme Duration: 2000 – 2008
Funding: BMBF

The GLOWA initiative, launched as a 9-year research programme, aims at developing integrated water resources management tools, which allow considering both natural and human impacts on the water cycle on the regional level of large watersheds. Simulation models are developed and used within GLOWA to treat complex scenarios of how determining factors of 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 development and cultural and political differences between regions, it aims at preparing regional decision makers for a sustainable use of their water resources. GLOWA works in different regions of the Globe.



Scenario simulations of the future change in annual water balance components of the Upper Danube watershed. The northern part represents the river Danube, the southern part consists of the German and Austrian Alpes. The simulations cover the change in ground water recharge and evapotranspiration in the period 2006-2105 under the assumption of the IPCC-scenario B2 for course of the CO_2-emissions. A severe and spatially heterogeneous decrease in ground water recharge as well as an increase in evapotranspiration along the Alpes can be seen due to climate change. Towards the East and in the North of the watershed, evapotranspiration will sharply decrease according to the model runs over the next 100 years due to the onset of water stress.

First results from climate change impact studies on water resources show that, using the climate change scenarios from the Intergovernmental Panel on Climate Change (IPCC), not only water stressed regions will be affected. The above figure shows the severe impact of the IPCC-B2 climate change scenario on the recharge of the groundwater reservoirs as well as on the evapotranspiration of the land surface in the Upper Danube watershed, which today represents a region without water stress symptoms. From the considerable reduction of evapotranspiration in the farming areas of the watershed due to reduced rainfall, it can be anticipated that farmers will have to start irrigation. This, in turn, may considerably affect river flow and the water availability downstream 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.

[www.glowa.org]

GLOWA Danube	IMPETUS	GLOWA Volta	GLOWA Jordan	GLOWA Elbe
Integrative Techniques, Scenarios and Strategies for the Sustainable Water Management in the Upper Danube	An Integrated Approach to the Efficient Management of Scarce Water Resources in West Africa	Sustainable Water Use, Changing Land Use, Rainfall Reliability and Water Demands in the Volta	Global Change and the Integrative Water Resources Management in Arid Regions	Global Change Impact on Environment and Society in the Elbe Region
Coordination: München University	Coordination: Köln University	Coordination: Bonn University (ZEF)	Coordination: Potsdam University	Coordination: PIK Potsdam

The first results of the GLOWA Danube project show the complexity of the water cycle being equally affected by human beings and nature. GLOWA contributes to create the regional knowledge necessary to form a global knowledge base and prepares the necessary tools facilitating an integrated and sustainable management of the global water resources. On this broader view, 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 goal, 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. It will provide important parts for a scientific picture of the global water cycle, eventually serving as base for sustainable management strategies of the global water resources.

BIODIVERSITY

Biodiversity forms 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 thought in keeping Earth´s environment within habitable limits" (IGBP). Living organisms have 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 for human life. Therefore, the dramatic decline of biodiversity at all scales (ecosystems, species richness, genetical diversity) is threatening not only the use potential of the degraded area, but might entail many cascading effects and negative long-term consequences for ecosystem functions and adaptation potentials within the Earth System. In view of the rapid decrease in biological diversity, research is needed in order to be able to favorably influence developments. The main goals of biodiversity research have been formulated within the science plan of the DIVERSITAS programme and its three core projects and is implemented within German research activities.

bioDISCOVERY:

Discovering Biodiversity and Predicting its Changes

The protection of biodiversity and maintenance of its ecological, social, cultural and economic values still face a striking lack of knowledge on how much biodiversity exists on Earth and what the causes and effects of its changes are. It is estimated that 90% of the existing species still have to be described or discovered. bioDISCOVERY focuses on reducing this knowledge gap by developing tools for assessing current biodiversity, monitoring, understanding and predicting biodiversity changes. German activities within bioDISCOVERY focus on the development and establishment of standardised biodiversity observation sites at the local, regional and global scales (see GBIF and BIOTA East).

Networking – Diversitas Germany

Diversitas Germany is a scientific network that identifies problems with regard to safeguarding biodiversity and the sustainable utilisation 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]

ecoSERVICES:

Understanding Relationships between Biodiversity, Ecosystem Functioning and 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, or ground-water recharge). At the global scale, but often even locally, ecosystem functioning constitutes critical natural capital that can hardly be substituted by human-made capital. In Germany, research projects of ecoSERVICES focus, for example, on the role of functional plant diversity on ecosystem functions, and on the connection between ecosystem services, their use and economic valuation (see Jena Experiment and Mata Atlântica).

Mata Atlântica

Programme Duration: 2000 – 2008 (projected)
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.mata-atlantica.ufz.de]

S. Schlüter, BLUMEN, FH Köln

Region of Teresópolis: Change from timbered areas to pasture or agriculture.

bioSUSTAINABILITY:

Developing the Science of the Conservation and Sustainable Use of Biodiversity

The discovery and analysis of biodiversity and its impacts on ecosystem functioning are far from complete. Still, there is enough scientific knowledge to warrant swift and efficient protection of our planet's biota.

A central field of Germany's contributions to bioSUSTAINABILITY is research on the protection of biodiversity in cultural landscapes (see BioTeam).

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. Mixtures of one to 60 plant species and of one to four plant functional groups have been seeded as newly established communities on plots of 20 x 20 m.

The species assemblages serve as 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.

[www.the-jena-experiment.de]

J. Baade

Aerial view of the field site, May 2003.

Biodiversity and Global Change (BIOLOG)

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 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, Germany, Ivory Coast, Kenya, Namibia, South Africa and Uganda, aims at a holistic scientific contribution towards sustainable use and conservation of the biodiversity of the African continent.

[http://pt-uf.pt-dlr.de/277_123.htm]

BIOTA East Africa

Project Duration: 2001 – 2009 (projected)
Funding: BMBF

BIOTA East Africa links a set of thematically coordinated analyses of biodiversity changes in East African highland rain forests. Investigations take place along a fragmentation/disturbance gradient and include various types of habitats – from moderately disturbed primary forest to secondary forests and completely degraded areas.

Major aims are defined as follows:

- Analysis of changes of biodiversity and ecosystem function along gradients of degradation.
- Analysis of changes of economic use of habitats along these gradients.
- Identification of an optimum relation between maintaining a high level of biodiversity and a tolerable economic profit from sustainable forest use.
- Innovations for sustainable use of biodiversity and biodiversity management, development of recommendations and information policy according to the aim of fair benefit sharing.

[www.biota-africa.de]

T. Bergsdorf, BIOTA East Africa

Kakamega Forest, Kenya. Women carrying fuelwood for private use.

GBIF Germany

Project Duration: 2001 – 2006
Funding: BMBF

The international GBIF (Global Biodiversity Information Facility) initiative has the objective of networking the existing worldwide data on biological diversity and making it freely available on the Internet. Presently, 77 countries and institutions participate in the establishment of databases for the international system.

Under the leadership of the German Federal Ministry of Education and Research (BMBF), seven GBIF nodes focussed on large groups of organisms are currently being established in Germany.

[www.gbif.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 threatened?

Several projects investigate the potentials of the UNCBD Ecosystem Approach and the Access and Benefit Sharing mechanism. For example, one project focuses on the threat on 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).

[http://pt-uf.pt-dlr.de/277_58.htm]

GLOBAL CHANGE IN THE OCEAN

The ocean is Earth's largest reservoir that stores and exchanges heat and climatically active gases with the atmosphere and, therefore, 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 into the interior of the ocean.

Much effort has been directed towards understanding the variability of the current system in this region. From the history of hydrographic observations it has been evident that the North Atlantic circulation and the deep wintertime mixing in the Labrador Sea has experienced strong changes. The wintertime heat loss associated with the strength of cold, westerly winds and the input of low-salinity water from the Arctic determines the intensity of the deep water formation. It is expected that future climatic changes and increasing ice melt will have the potential of significantly decreasing 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.

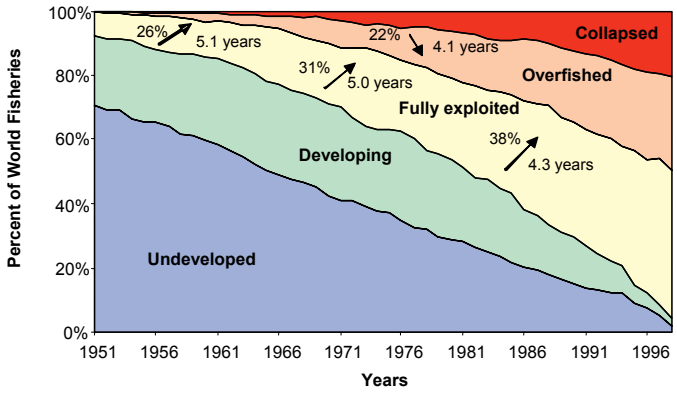
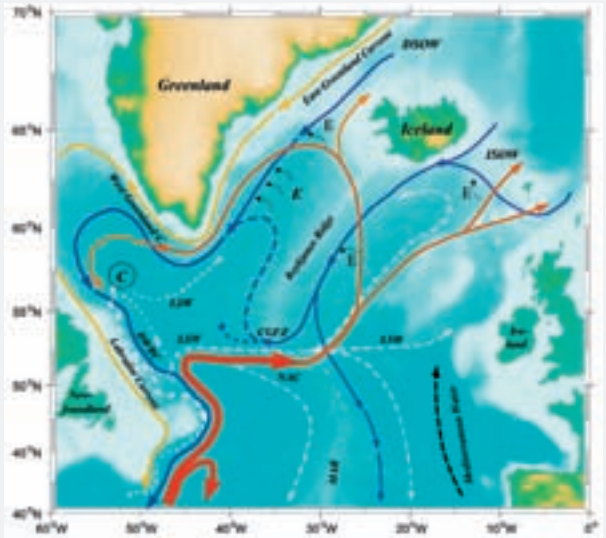


Figure 1: Trends in global fisheries during the last 50 years. In 1999, about 50% of world fisheries were overfished or collapsed.
Source: Froese and Pauly, 2003, Dynamik der Überfischung. In: J. Lozán, E. Rachor, K. Reise, J. Sündermann, H. von Westernhaben (eds), 2003, Warnsignale aus Nordsee und Wattenmeer - eine aktuelle Umweltbilanz. GEO.

The ocean is one of the largest and least known resources for living and mineral materials. Exploitation of these resources is advancing fast. In particular, fish stocks are being depleted at a much faster rate than can be naturally replenished (Figure 1). This is the most dramatic direct effect of human activities on the ocean.

Dynamics of Thermohaline Circulation Variability



Source: Schott et al., 2004, Circulation and Deep-Water Export at the Western Exit of the Subpolar North Atlantic. J.Phys.Oceanogr. 34: 817-843.

As part of the thermohaline circulation, temperate, northward flowing upper-ocean waters of the Gulf Stream and its extension, the North Atlantic Current (NAC) are converted in relatively small regions in the subarctic Atlantic Ocean (indicated by C) by cooling and increasing salt concentrations to cold deep waters flowing southward between 1.000 m and 4.000 m depth.

Programme Duration: 1996 – 2006
Funding: DFG

The main goal of Collaborative Research Centre 460 (Sonderforschungsbereich, SFB) is to investigate fluctuations of water mass formation and transport processes in the subpolar North Atlantic, and to gain a better understanding of their significance for the dynamics of thermohaline overturning and oceanic uptake of anthropogenic CO_2.

The research programme is based on a combination of observations in physical oceanography, ocean chemistry and meteorology. They closely interact with a hierarchy of numerical models of medium, high and very high resolution which allow a simulation of current structures and variability across a wide range of space and time scales. Of primary interest are water mass formation processes and circulation of the deep water in the subpolar North Atlantic, as well as their interaction and integral effects, in particular with respect to the uptake of anthropogenic CO_2. Furthermore, the large-scale interaction between ocean and atmosphere is investigated, both in uncoupled models and in products of joint models by collaborators, as well as paleoclimate data sets of past decades.

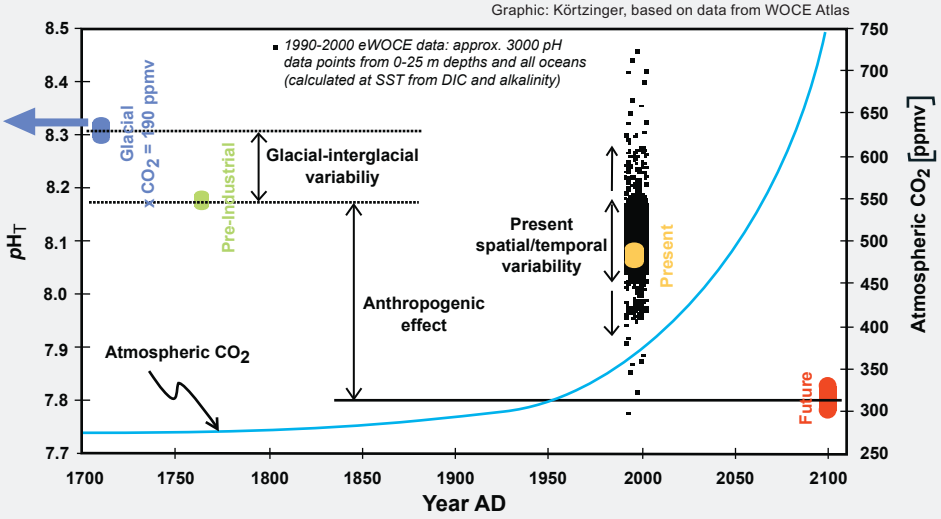
[www.ifm-geomar.de/index.php?id=575&L=1]

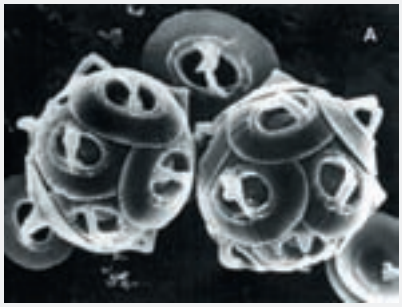
Acidification of the Ocean

Rising CO_2 concentrations will lead to acidification of sea water. The pH of sea water is usually extremely well buffered, but it is expected that it may drop by 0.3 units in the next 100 years compared to now. The pH change between the glacial and the present ocean is only 0.5 units. On the right axis, the atmospheric concentration of CO_2 (blue curve) is indicated.

The acidification affects the biological production of calcium carbonate in marine organisms, such as corals, microscopic algae (Coccolithophorids) and small drifting animals (pteropods, foraminifera).

Graphic: Körtzinger, based on data from WOCE Atlas





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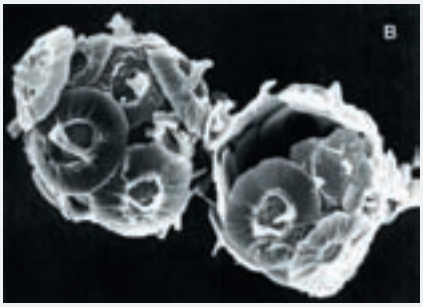


These effects of ocean acidification can be shown in experiments.

A) Normally growing Coccolithophorid *Geophryocapsa oceanica* at 300 ppm CO_2, and

B) growing under high CO_2 of 780–850 ppm expected for the year 2100. It is at present not clear what this means for the ecosystem as a whole.

Indirect effects on the marine biology and chemistry are expected from rising CO_2 concentrations, which cause acidification of sea water (see box). Increasing sea surface temperatures and long range transport of dust from land to the ocean are also likely to alter biological processes on a large scale. Dust provides the microscopic plants with essential iron which in large ocean regions is a controlling factor for ocean productivity (Figures 2a, b). Future changes in these indirect impacts are likely to have a far reaching effect on the ocean ecosystem that can not yet be quantified.

Unlike on land, there are very few possibilities to observe changes in the ocean. 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 layers of the ocean are much more difficult to observe and present efforts are directed to develop observation technology to trace critical changes in physical, chemical and biological processes.

Provided by SeaWiFS Project, NASA/GSFC and Ombricage

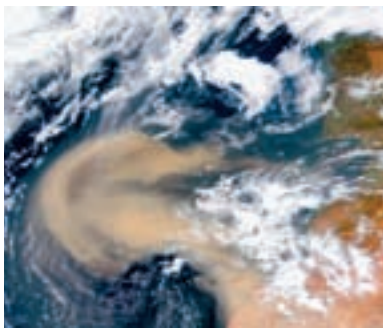


Figure 2a: Dust storms over Africa supply the tropical Atlantic with essential trace elements.

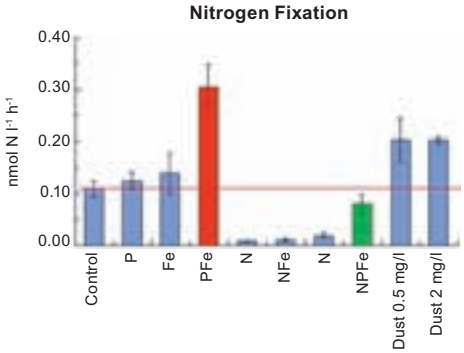


Figure 2b: Additions of iron (Fe) and phosphorus (P) as well as dust from Africa are able to stimulate nitrogen fixation by "blue green algae" in the tropical Atlantic which, in turn, enhances the productivity of the tropical ocean.

Source: After Mills et al., 2004, Iron and phosphorus co-limit nitrogen fixation in the eastern tropical North Atlantic, Nature 429: 292-294.

POLAR RESEARCH

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 characterized 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 time scales and directly influence global sea level change and hence impact on coastal regions. Due to extremely long recovery cycles polar ecosystems are highly susceptible to perturbation.

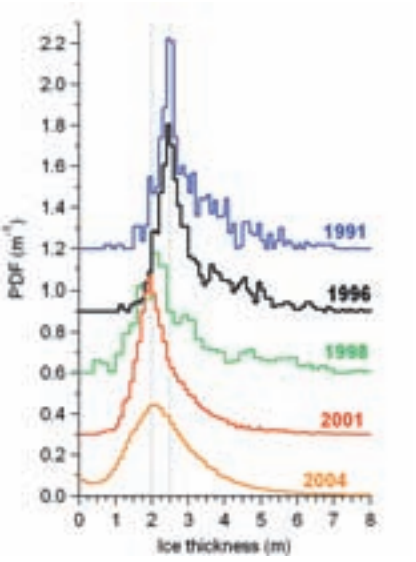


Figure 1: Thickness distribution of extensive sea ice thickness measurement in the Arctic.
PDF: Probability Density Function.
Source: C. Haas, AWI.

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; 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, on the other hand driving changes, e. g. by altering global albedo while growing or shrinking. They also act as archives of palaeoclimate. Polar ice cores are unique because, of all palaeo-records, they are most directly linked with the atmosphere and 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. Sea ice also is a habitat for many species of marine flora and fauna which in turn influence the physics of sea ice. Sea ice effectively channels primary productivity of small algae to stocks of large animals despite harsh environmental conditions. Excellent global satellite observations of sea ice extent are available for the past three decades indicating a significant retreat, especially in summer. Large-scale measurements of sea ice thickness, on the other hand, are still a great challenge. A new electromagnetic technique to measure the thickness of sea ice floes has been developed recently which can now also be used from helicopter covering larger distances. During five expeditions with the research icebreaker Polarstern, an extensive data set has been collected which indicates a thinning of the sea ice cover between Spitzbergen and the North Pole from 2,5 m in 1991 to 2,0 m in 2001 and 2004 (Figure 1).

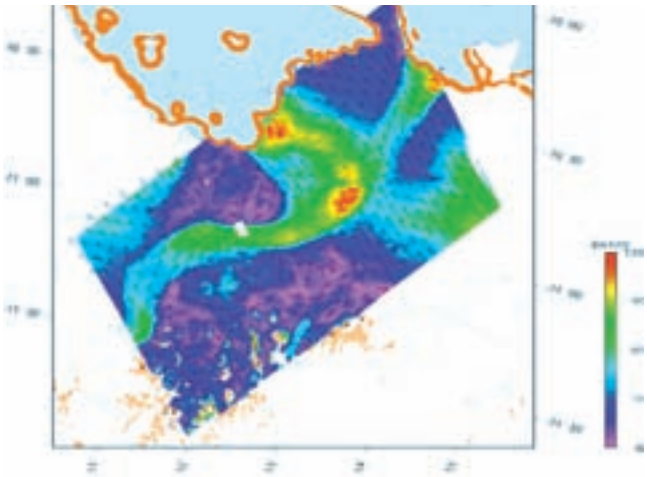
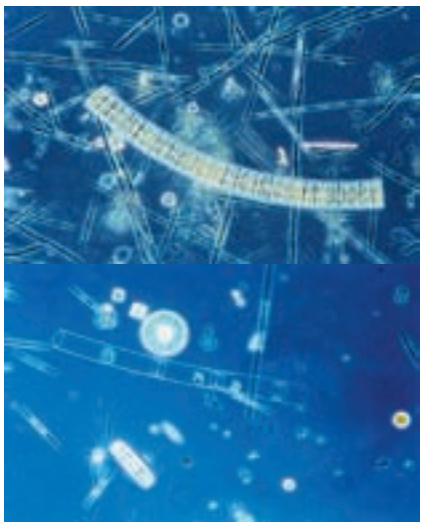


Figure 2: Interferomeric SAR (Synthetic Aperture Radar) analysis gives a detailed picture on horizontal ice velocities (region of Schirmacher Oasis, central Dronning Maud Land, Antarctica).
Source: R. Dietrich, Technical University, Dresden.

Ice sheets store a significant amount of fresh water. Accordingly, their variations have a large impact on sea level height with major consequences for coastal regions. Specific measurements of the Antarctic ice mass balance and the consequences for sea level and Earth's gravity field have been performed in the region of the Schirmacher Oasis using satellite and in-situ measurements. With the help of radar-interferometry, horizontal ice velocities are determined (Figure 2), which are then converted to mass flux data. Using repeated GPS and gravity measurements, an uplift of the continental crust was observed in response to the reduced ice mass.



B. Assmy, AWI

Figure 3: Microscopic view of phytoplankton within (top) and outside (bottom) of the iron-fertilized region.

Of special importance is to understand 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. For instance, certain species of large diatoms and shrimp-like krill play key roles in the element cycles and food-webs, respectively, of the Southern Ocean. The high nutrient concentrations coupled with low algal productivity characteristic of the Southern Ocean have puzzled researchers for many decades. The paradox has now been solved by means of open ocean experiments in which large areas (100 km^2) of the surface ocean were fertilized with several tonnes of dissolved iron. The Alfred Wegener Institute for Polar and Marine Research (AWI) has carried out two such experiments south of South Africa which both resulted in large phytoplankton blooms (Figure 3). The results indicate that iron limits algal growth in the Southern Ocean. Artificial fertilisation can enhance ocean uptake of carbon dioxide from the atmosphere at the same time providing more food for organisms such as krill which in turn represent the food supply of large animals such as seals and whales.

Research Infrastructure

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

AWI

Research and Supply Vessel RSV "Polarstern"

An important tool in Germany's polar research programme is the "Polarstern". Since it was first commissioned in 1982, the "Polarstern" has completed a total of 27 expeditions to the Arctic and 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. Refrigerated 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-bremerhaven.de/polar/polarstern.html]

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 Ekström Shelf Ice as a research observatory for geophysical, meteorological and air chemistry measurements, as well as a logistics base for summer expeditions.

The German Federal Ministry of Education and Research (BMBF) is now financing the new polar station Neumayer III in the Antarctic. 30 million EUR are earmarked for the 3.300 m^2 structure made of environmentally compatible materials until its completion in 2008.

[www.awi-bremerhaven.de/polar/neumayer1.html]

AWI

DRYLANDS AND DESERTIFICATION

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

Drylands make up 41% of the global land surface, and a third of the human population (2000) lives in these drought- and desertification-prone areas (Figure 1). The Millenium Ecosystem Assessment (2005) estimates with medium certainty that approximately 10-20% of the drylands – thus, between 6 million and 12 million km² – are already degraded. These ecosystems, mainly desert margins, semi-deserts and steppes, are characterized by a very high sensitivity and vulnerability when exposed to global environmental changes. Inadequate land use leads to a degradation of ecosystem function and productivity. Costs of agricultural losses due to desertification are estimated at 28 billion $ annually. If possible at all, restoration costs by far exceed costs of prevention measures.

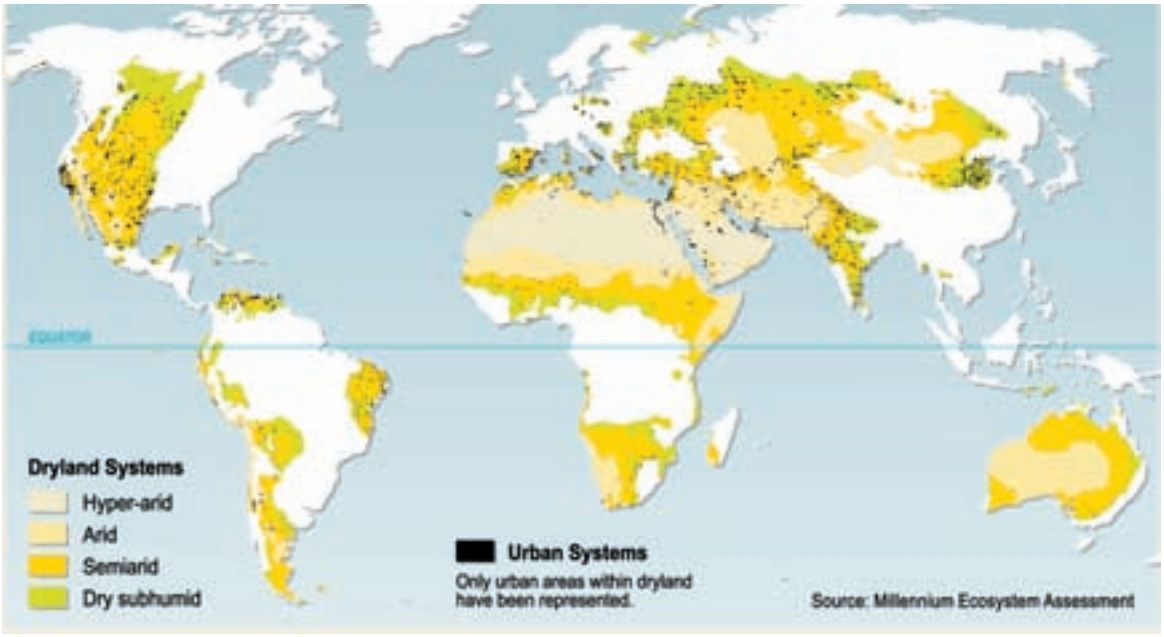


Figure 1: Overlap of urban areas with the four dryland categories.

Scientific Cooperation – Desert*Net

The German Scientific Network to Combat Desertification (Desert*Net) was founded as an interdisciplinary network that serves as an interface for communication and knowledge transfer to prevent and combat desertification. Desert*Net's expertise is based on an interdisciplinary group of scientists with long-term field and laboratory experience in basic and applied research on 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. Furthermore, the dialogue between science and policy level should be strengthened, Desert*Net closely cooperates with the United Nations Convention to Combat Desertification (UNCCD).

[www.desertnet.de]

Desertification processes mainly hit the poorer countries, resulting in rural poverty, conflicts, and environmental refugees. Conflicts with regard to ownership, use of and access to limited natural resources often cross national boundaries and create regional conflicts. Desertification forms a major obstacle to sustainable development and poverty reduction in many developing countries.

From a scientific viewpoint, processes of desertification are driven by a complex interaction of many factors, including human and human induced activities in the first place, like overgrazing, deforestation, land cultivation, but also involving non-linear feedbacks based on ecosystem properties and climatic changes. Desertification involves processes and mechanisms at various scales, ranging from the single field or pasture to the global biosphere. Decision makers are found at various levels, including the local farmers as well as global players on the worlds financial markets. Similarly, combating desertification integrates ecological, technical, social and political measures, based on knowledge from both

natural and socio-economic scientific disciplines. The problem of desertification can also be turned into its reciprocal value: sustainable use of natural resources.

Important fields of research and activity are:

- understanding processes and mechanisms of desertification,
- predicting, modelling future changes,
- monitoring drylands margins by remote sensing, airborne systems, aerial photography and satellite systems,
- establishing early warning systems,
- defining preconditions and management forms for sustainable use of natural resources,
- developing rehabilitation techniques for already degraded systems,
- embedding scientific tools in the local realities of the affected areas, taking into account problems of land use rights,
- implementing stakeholder involvement and participation processes.

Research on desertification and related issues involves various institutes and universities in Germany. Research topics cover a wide range of disciplines, with research regions and countries located all over the world.

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

Project Duration: 2002 – 2012 (projected)
Funding: BMBF

Since the 1920s, irrigation cultivation in Uzbekistan, withdrawing water from the Aral Sea, has been continuously intensified. Water has been delivered in extensive irrigation systems, expensive to maintain, and the monocultures have been heavily treated with fertilisers and pesticides. The population is still exposed to low water availability, soil degradation and salinisation, in economically centralised structures.

The basic idea of the project is an integrated, interdisciplinary approach, considering 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), economical aspects (investigating of economic incentives for saving water, as a water price based on an economic "River Basin" model for individual farms), and legal-administrative factors (e.g. investigation of decision structures and water allocation mechanisms).

[www.khorezm.uni-bonn.de]

ZEF

Irrigation equipment.

BIOTA Southern Africa

Project Duration: 2000 – 2009 (projected)
Funding: BMBF

The BIOTA South projects in Namibia and western parts of South Africa are investigating the changes in biological diversity caused by humans and climate change. To this end, 25 observatories have been set up over an expanse of 2.000 km.

BIOTA Southern Africa

Overview of a marked grazing-induced fenceline contrast in the semi-arid dryland of southern Namibia. The yellow colour indicates intact perennial grassland, the dark soil marks the overgrazed area.

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]

COASTAL ZONE MANAGEMENT

Coastal zones are wide areas of transition between continents and the open ocean, encompassing drainage basins, coastal lowlands, estuaries, and the adjoining shelf seas. The coastal ocean and marginal seas have always been reactors for the processing of land-derived materials and this way have exerted important control on ocean input dynamics. The development of modern industrialised societies has, however, resulted in drastic, both qualitative and quantitative changes in terrestrial emissions to coastal seas. More than half the human population, with increasing tendency, now lives within 60 km of the coast. Inevitably, conflicts of interest arise between all forms of human environmental modification including exploitation of natural resources (harbours, wind energy, minerals, fisheries, aquaculture) as well as utilisation for recreational and conservation purposes. Sustainable use of this broad land-ocean interface, therefore, has to be based on scientific understanding of the interacting physical, chemical, biological and geological forces shaping these systems across space and time scales ranging from local to global.

GKSS Research Centre, Institute for Coastal Research

Figure 1: Estuary of the Elbe River, seen from space.

German research activities are mainly focussed on the coasts of the North and Baltic Seas, but with a global perspective. Thus, they include coastal zones of similar type and with similar problems as in other parts of the world. The German coasts can hardly be regarded as natural environments as they have been much affected and have undergone major modifications by past and ongoing human activities particularly coastal defences and industrial development. New forms of utilisation such as offshore wind farms and aquaculture will compound these impacts. Coastal zones are threatened by weather extremes such as storm surges, flooding, and wave activity which are likely to be aggravated by ongoing climate change. Other threats are due to contamination by hazardous substances, eutrophication, and oil spills which degrade water quality.

Concurrently, coastal zones are areas of high productivity and biological richness. They harbour unique habitats and are the breeding and feeding grounds for many commercial fish stocks and migrating birds. Because of this fact and their value for recreation, many coastal zones are protected areas. As an example, most of the German North Sea coast has been declared a National Park with different zones of utilisation. A sustainable use of coastal zones requires rational management which entails balancing the various human activities with the requirements of ecosystem conservation in the framework of democratically formulated goals. Thus, the main challenge and task of coastal research is to provide policy makers and society at large with reliable knowledge concerning the functioning and potentials of the system "coast" as the basis for an Integrated Coastal Zone Management. Acquiring this knowledge depends on our ability to monitor and interpret ongoing environmental trends in the framework of long-term change with an aim to construct scenarios of possible future developments.

The coastal zone is studied from different perspectives: to understand natural dynamics and consequences of human activities, and to explore the potentials for improved use, exploitation and protection. In fact, in order to satisfy societal needs, coastal research has to focus on integrated studies on multiple aspects of land-ocean and human interactions. As the backbone for informed decisions, Operational Monitoring Systems combine efficient analytical and measurement skills, strategies and information management with the timely transfer of the knowledge achieved to stakeholders and the public. All this serves the overarching goal of biogeochemical and physical assessment of the North Sea, the Baltic Sea and other shelf seas, as well as the adjacent land areas.

GKSS Research Centre, Institute for Coastal Research

Figure 2: Scientist installing a measuring platform for Coastal Zone Monitoring.

This goal addresses two different aspects and two different sorts of clients. The first is short term operational assessment, which needs efficient instrumental (in-situ and remote) measuring systems, operational model-assisted data analysis and forecast systems; it allows administrations to respond to ongoing developments. The second aspect deals with long-term changes, which is based on the evaluation of recent and historical data and Regional Environmental Models (REMs). Such documentations of past and ongoing change addresses the political process. The REM-methodology is an important element in another challenge, namely scenarios of the coastal environment in the next decades.

K. Reise, AWI

Figure 3: Collection of sediment samples in the mudflats of Sylt.

Such scenarios not only consider environmental change but also economic and land-use change as well as changing public preferences and perceptions. Process knowledge and detailed data- and model-based reconstructions of the coastal environment in the past decades serve the goal of understanding the role of the changing coastal environment for ecosystem function and biodiversity. Most species of microscopic organisms in the coastal sea are still unknown to science, and genetic analyses of some species described by conventional means reveal that they comprise many 'hidden species'. Society is faced with challenges to improve its knowledge on the biota of the coastal sea, their spatial and temporal patterns, the spread of diseases and toxic algal blooms, the extinctions and the great global interchange of species mediated by human transport. Models should be based on solid knowledge of the species that play key roles in marine food webs.

GKSS Research Centre
Institute for Coastal Research

Figure 4: Measurement device for the determination of abiotic parameters.

MARCOPOLI (Marine, Coastal and Polar Systems)

The Helmholtz-Programme "MARCOPOLI" (Marine, Coastal and Polar Systems) aims at developing the scientific base for the assessment of observed environmental change as well as sustainable ecosystem utilisation, by investigating the multiple physical, chemical, biological and geological interactions within the marine and associated terrestrial systems and by quantifying their interaction with other compartments of the Earth System. The programme combines the methodological, technical and scientific competence of two Helmholtz research centres with marine expertise, Alfred Wegener Institute for Polar and Marine Research (AWI) and GKSS Research Centre, associated partners are the German Aerospace Center (DLR) and GeoForschungsZentrum Potsdam (GFZ).

Coastal Dynamics and Causes of Change (CO)

This programme topic, an integral part of the MARCOPOLI Programme, advances fundamental coastal science and provides a scientific basis for rational coastal management. The approach integrates basic research on climate, ecosystem diversity, biogeochemistry and ecological chemistry in the coastal zone with applied perspectives, including regional impacts of Global Change. Three approaches have been adopted:

(1) Integration at the system level, with provision of a synergistic description and anticipation of geophysical and ecological coastal change under the influence of human pressure on decadal and longer time-scales.

(2) Analysis of fundamental processes in the coastal ecosystem, and fundamental marine ecological research, to determine the specific and complementary roles of diversity and interactions of chemical compounds in the function of coastal ecosystems.

(3) Design and implementation of advanced technology, with development of appropriate observational monitoring strategies supported by modelling tools to document ongoing change on a relevant range of temporal and spatial scale.

Close cooperations exist with the newly established Zentrum für Marine und Atmosphärische Wissenschaften (ZMAW), Hamburg, comprising the geo-scientific institutions at the Hamburg University and the MPI for Meteorology, Hamburg. Links are also established to the Center for Tropical Marine Ecology (ZMT), Bremen, Kiel University, the Institute for Chemistry and Biology of the Marine Environment (ICBM), Oldenburg, MPI for Marine Microbiology, Bremen, Baltic Sea Research Institute Warnemünde (IOW), and to the Leibniz Institute of Marine Sciences (IFM-GEOMAR), Kiel. External Networking comprises, among others, contributions to the International Geosphere-Biosphere Programme (IGBP) via its participation in GLOBEC (Global Ocean Ecosystem Dynamics) and the IGBP core project LOICZ (Land-Ocean Interactions in the Coastal Zone); GKSS has recently established the LOICZ core project office.

[www.gkss.de] [www.awi-bremerhaven.de]

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 used at an ever increasing rate as the main energy supply for human society. The CO_2 released by burning of these fossil fuels is a climatically active gas influencing earth's heat balance. Rising surface temperatures and changes in climatic conditions are consequences of the mounting CO_2 concentrations in the atmosphere. This perceived danger has precipitated intensive research into the natural and anthropogenically influenced carbon cycle as well as its societal relevance world wide.

In Germany, particular research effort has been directed towards the role of the North Atlantic in sequestering anthropogenic CO_2, determination of the European carbon balance, understanding the impacts of climate and land use change on terrestrial carbon fluxes and development of alternative carbon-free technologies for energy production. Involved institutes include, among others, MPI for Meteorology, Hamburg, MPI for Biogeochemistry, Jena, Leibniz Institute of Marine Sciences (IFM-GEOMAR), Kiel, and the Potsdam Institute for Climate Impact Research (PIK).

Marine Carbon Sources and Sinks Assessment (CARBOOCEAN)

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. Main questions of the project are:

- How large are the Atlantic and Southern Ocean CO_2 sinks precisely, i.e. how efficient is the downward transport of carbon in the deep-water production areas of the world 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 uptake 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]

The ocean contains 50 times more CO_2 than the atmosphere and, hence, small changes in the flux between ocean and atmosphere have a very large impact on the concentration of this greenhouse gas in the atmosphere. One of the most important regions for oceanic uptake of CO_2 is the North Atlantic (Figure 1). About one quarter of the anthropogenically produced CO_2 is transported into the ocean interior by physical processes of deep water formation in the subarctic Atlantic. In addition to such physical processes, also biological uptake and transport of CO_2 determines the ocean's carbon balance.

Models of high spatial resolution that couple ocean physical processes with biological and chemical processes show that there is a strong fluctuation of the uptake of CO_2 from year to year, caused mainly 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 the biological production significantly alter the carbon uptake and, therefore, the ocean can not be assumed to be a constant sink for anthropogenic carbon.

The carbon balance of Europe is determined by fossil fuel emissions (total of 1.8 Pg C y^{-1}) as well as climatic impacts and changes in vegetation or land use. The largest terrestrial sink is the net ecosystem production (NEP), mainly growth of

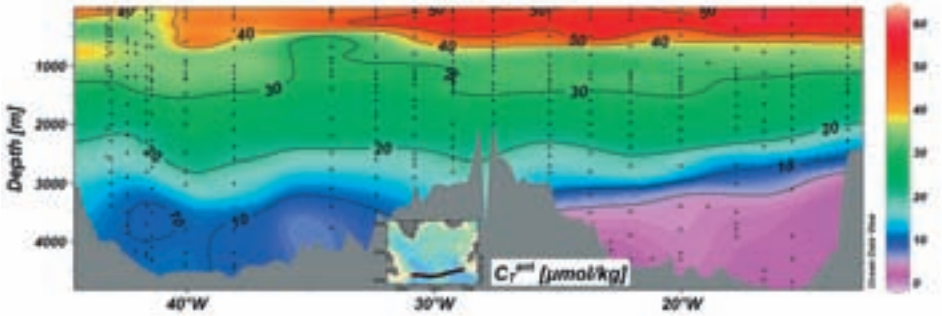


Figure 1: Concentration of anthropogenically released CO_2 (C_T^{ant}) on a transect across the North Atlantic at 50°N (track see inset). The surface waters have absorbed a relatively high amount of C_T^{ant} already, but it is also apparent that the western deep Atlantic is enriched relatively to the eastern side. This is due to sinking of surface waters in the western subarctic Atlantic which is one of the most important mechanisms of long term sequestration of CO_2 by the ocean.
Source: EU Projects CARINA/CARBOOCEAN.

forest. Model simulations, covering the period from 1948-2003, showed a significant decrease in NEP in Southern Europe (especially Spain and Southern France) and Eastern Europe during the draught year of 2003 (Figure 2). In those areas, NEP declined by more than 100% relative to the long term mean. The model results show that enhanced nitrogen deposition, increased CO_2 concentrations and moisture availability play an important role for enhanced growth of forests, especially the young ones. An observation system to detect changes of carbon stocks and fluxes related to the European commitments under the Kyoto protocol is an important part of the European research project CarboEurope (see box).

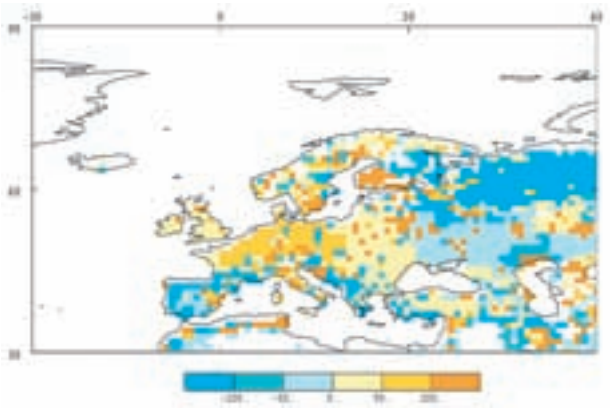


Figure 2: Anomalies of net ecosystem production (NEP) in 2003 were calculated as difference between annual NEP in 2003 and annual mean NEP for 1948-2003 and are expressed in percentage change. NEP was calculated with BIOME-BGC model.
Source: CarboEurope.

In 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 one – 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 considered. The Kyoto Protocol already takes account of the terrestrial carbon sink in the form of biomass. Sequestration of carbon in the deep oceans and on land are considered in research and there are already some test projects. Still, there remain considerable research needs before the knowledge for a full carbon management becomes available and policy measures are developed which make such management feasible. The European emissions trading system for CO_2 is a first step into this direction (Figure 3).

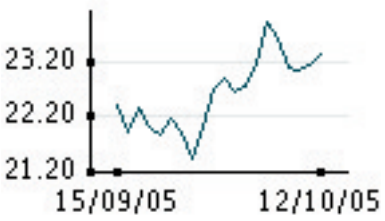


Figure 3: Carbon Prices in the EU
Source: www.pointcarbon.com

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 started in January 2004, coordinated by the MPI for Biogeochemistry, Jena. CarboEurope aims to understand and quantify the present terrestrial carbon balance of Europe and the associated uncertainty at local, regional and continental scale. This means to determine the European carbon balance with its spatial and temporal patterns, understand the controlling processes and mechanisms of carbon cycling in European ecosystems and how these are affected by climate change and variability and human management, and develop 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]


CarboEurope

Flux tower to measure emissions of CO_2 from different types of vegetation cover. Such flux towers are stationed throughout Europe.

ATMOSPHERIC CHANGES

In the past century, the composition of the atmosphere has changed strongly, with direct consequences for air quality, the earth's energy budget, protection from ultraviolet radiation, weather events and the water cycle, all being primary conditions for life. Evidently, 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 needed for a timely response to atmospheric and climate change, whether anthropogenic or natural in origin. This requires the extension of the current generation of computer models into predictive tools, which are adequately verified and validated through the comparison with observations. A vital aspect is therefore the expansion of the measurements of key atmospheric parameters.

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, since it can facilitate operations with a suite of instruments at altitudes up to 15,5 km, with a range of about 8.000 km.

Gulfstream/DLR

HALO (Artwork)

HALO will open 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.

DLR

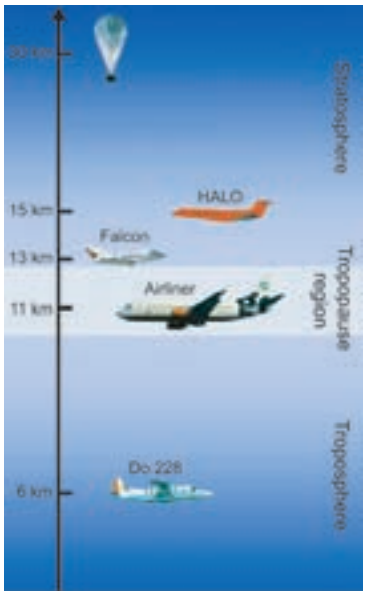
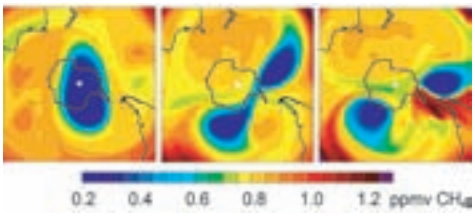


Figure 1: Airborne research platforms used in atmospheric research, indicating the investigated altitude ranges.

Atmospheric research with aircraft has a long tradition in Germany (Figure 1). In 2008, a new research aircraft, HALO (see box), will be taken 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 strongly expanded its capabilities in remote sensing from space with ENVISAT, the largest environmental satellite to date. ENVISAT comprises ten sensors measuring a multitude of parameters in the atmosphere and at the earth 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 model advancements, initially via the development of atmospheric general circulation models. Since about a decade, coupled ocean-atmosphere-land models have advanced to perform transient climate simulations and seasonal climate anomaly predictions. In the last few years, the first high resolution regional coupled models, including interactive hydrology for detailed regional climate scenario calculations, are also emerging.

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



MPI for Chemistry

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

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 their changes. 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 in view of ozone layer and climate predictability and impacts on ultraviolet radiation. This area highlights the role of water vapour in the energy budget and dynamics of the stratosphere, and how studies of dynamical 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 between the nitrogen and carbon cycles.
- "**Aerosols, clouds and the water cycle"** focuses 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"**, in which the processes that lead to floods and droughts are of special concern. The question is how these processes act under climate change, and how precipitation forecasts can be improved. While global warming is expected to generally accelerate the water cycle, regional precipitation may become more intense in some regions and decrease in others.
- **"Seasonal to inter-decadal 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 in which biogeochemical, aerosol and cloud processes will be represented 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 directed 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 analysed trace gases and aerosol parameters. This one-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 flew on a Boeing 767 of LTU between Germany and destinations in the Indian Ocean, Southern Africa, and the Caribbean. Since 2004, the new airline partner Lufthansa carries CARIBIC on an Airbus 340-600 with even longer endurance to South America and Eastern Asia. This partnership is planned to last at least ten years. Instead of few and highly expensive datasets from research aircraft, CARIBIC yields systematic long-term intercontinental data on composition and processes in a sensitive region of the atmosphere, which is stressed by increasing burdens of commercial air traffic and by the flux of anthropogenic emissions from the earth's surface. The sum of 600.000 flight kilometers corresponds to a distance of 15 times around 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 consortium of CARIBIC 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 special experimental or modelling competence.

[www.caribic-atmospheric.com]

U. Kröner, Lufthansa

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

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 other productive utility serves human well-being, but also causes changes in environmental processes that are shaping ecosystem functions and services on which mankind depends. Since environmental change often leads to environmental damage which is very difficult to restore, research on land use change needs to be based on proactive management of land resources with a long-term perspective to avoid irreversible mistakes. This requires not only a sound understanding of the land use change processes, 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 at the forefront of analysing these complex processes and developing tools to optimize the management of these critical natural resources.

Land use change is a phenomenon that emerges from the interactions among 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 land plots. These short-term/localised changes are the results of multiple decisions made by individual human actors under diverse socio-ecological conditions. Temporal accumulation of short-term changes and spatial aggregations of localized changes generate emergent patterns of both socio-economic dynamics and land-use changes on larger scales. Changes on the macro level such as infrastructural or policy interventions influence the behavior of the individuals that produce 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).

STORMA (Stability of Tropical Rainforest Margins in Indonesia)

Programme Duration: 2000 – 2012 (projected)
Funding: DFG

Tropical rainforests disappear 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 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, such as nature conservation, poverty reduction, and economic development of rural areas. The main objective of STORMA as a multidisciplinary research programme is to analyse processes that may contribute to the stability of rainforest margins and to develop integrated models of spatially explicit land-use scenarios.

[www.storma.de]

W. Lorenz

Traditional land-use in Sulawesi (Indonesia).

Land-use scenario	Gross soil loss[a] (t/yr)	Soil loss reduction[b] (%)
Current condition (baseline)	77,608	0
Protection of areas with slope > 15%	**58,005**	**25**
Protection of areas with soil loss > 25 t/ha/yr	38,041	51
Protection of gullies and their buffer (25 m wide)	**36,837**	**53**

Table 1: Application of USP to predict soil loss under different land-use management in two catchments of Tigray, Northern Ethiopia. Source: ZEF.

[a]calculated for Adikenafiz and Gerebmihiz catchments in Tigray, Northern Ethiopia
[b]compared to the soil loss rate of the baseline scenario

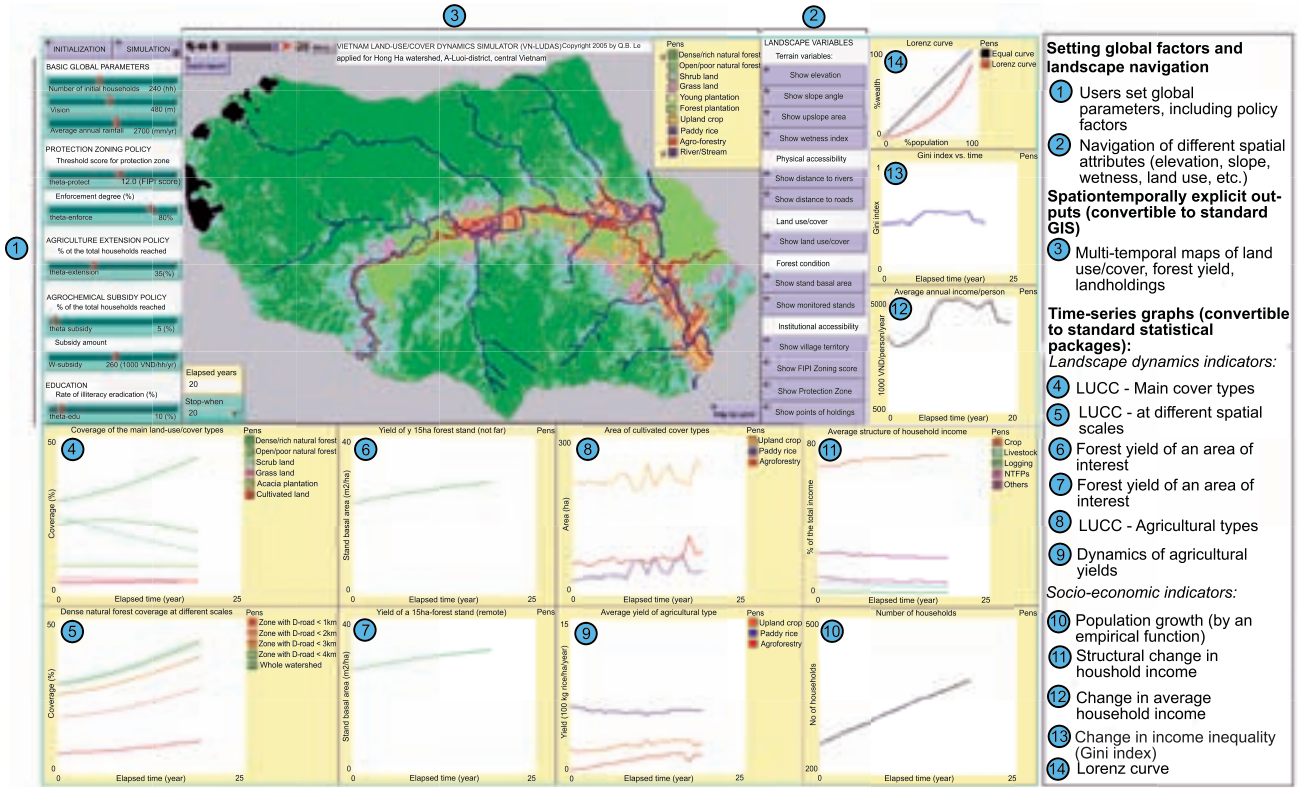
Because of the close relationships with ecological processes, land-use change studies should be integrated with studies on changes in the functionalities of land ecosystems, e.g., soil erosion and its effect on subsequent biomass productivity. In the past few decades, progress has been made in the distributed assessment of soil erosion/deposition processes. Different models have been developed to identify areas of high erosion risk in order to apply management interventions. Studies of the Center for Development Research (ZEF) have successfully applied such spatially distributed soil erosion models in Ethiopia to identify hotspot areas of

erosion. The model that best observed sediment yield and soil redistribution (Unit Stream Power-Based Model, USP) has been used for scenario analyses to identify the best land use/management practices to reduce the rate of soil loss and reservoir siltation (Table 1). Results show that changes in land use from cultivation and/or open grazing to vegetative cover drastically reduce soil loss. However, 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 behavior of the land using person can not be addressed. Thus, as the explicit roles of human actors in changing soil landscapes are ignored, such models are currently weak in linking and transforming environmental change and human actions.

Progress in non-linear dynamics of complex-system research, e.g. cellular automata, has contributed to a radical change in the modelling of landscape dynamics involving human-environment interrelations. According to this approach, the coupled human-environment system is described as autonomous objects which have their specific roles as well as internal structure/ mechanisms, and thus are separate loci of control in the system. In this decentralized system, models of different social and ecological processes can be incorporated into the object structure, enabling them to act autonomously in an ever-changing situation. These models also capture both micro interactions and consequent landscape changes. This organisational approach offers a promising means to overcome the limitations of conventional approaches to modelling complex land use change processes.

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 form of land automata, i.e., land units hosting natural processes and change 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 structure of land automata. 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 to evaluate the consequences of such policy interventions. Efforts to fine-tune the model structure and its validation in different geographical environments are underway.



A 25-year multi-agent simulation run of land-use changes related to policy options with graphic depiction of the bio-physical and social consequences (1-14).
Soure: Q. B. Le, ZEF.

[www.zef.de]

MEGACITIES – URBAN DYNAMICS OF GLOBAL CHANGE

By 2007, more than half of the world's population (3,3 billion people) will live in cities – an increase from 30% in 1950 to 47% in 2000 – and will probably reach 60% in 2030. In the developing countries of Asia and Africa urbanisation is proceeding rapidly. Megacities, i.e. cities with more than 5 million inhabitants, are particularly significant in this world-wide process of urbanisation. Almost 60 of them, with together more than 600 million people, are expected to exist by 2015.

Megacities are characterized by new scales, new dynamics, new complexities, i.e. the largest population figures and densities and highest development dynamics, as well as intense and complex interaction of different demographic, social, political, economic and ecological processes. Moreover, highly dynamic processes take place simultaneously, thereby often reinforcing themselves. In economically booming megacities, strong opportunities exist as well as 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 strain 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 generalized statements since differences of economic development, social polarisation, quality of infrastructure and governability should not be ignored.

Megacities of Tomorrow

Programme Duration: 01/2005 – 12/2016 (projected)
Funding: BMBF

German Federal Ministry of Education and Research's (BMBF's) new research programme focuses upon future megacities or mega-urban regions, i.e., rapidly growing cities, approaching the threshold to megacity status in the coming decade. These cities and regions still have the chance to practice precaution, chart sustainable courses to their future and utilise proactively the momentum of the inevitable transformations. The programme aims at the development and implementation of solution-oriented, innovative and integrated planning and management concepts. Fifteen projects have been earmarked for start-up funding. After two years, the projects will undergo evaluation and (if approved) pass into implementation. The projects considered strike a geographic as well as thematic balance. They deal with urban agglomerations in Brazil, China, Ethiopia, India, Iran, Mexico, Morocco, Peru, South Africa, Tanzania and Vietnam. The projects are dedicated towards specific practical needs, exigencies as well as innovation potentials of urban living such as: housing and construction; nutrition and urban agriculture; public health and quality of life; urban planning and governance; energy supply and consumption; mobility and transport; water supply, waste treatment, environmental management.

The programme is part of the "fona - Research for Sustainability" framework programme by BMBF. fona promotes the use of research for sustainability by providing information on research activities and supporting the networking of researchers and stakeholders in sustainable development.

[http://pt-uf.pt-dlr.de/englisch/9_178_ENG_HTML.htm]

Megacities: Informal Dynamics of Global Change

Programme Duration: 2006 – 2012 (projected)
Funding: DFG

Megacities are a phenomenon of the urbanisation process that can be observed worldwide. These oversized cities, with a high concentration of population, infrastructure and capital accompanied by excessively accelerated development, lead to increasing social fragmentation and become increasingly difficult to control and govern. The consequence is that more and more processes are allowed to take place in an uncontrolled and informal manner. The Priority Programme "Megacities: Informal Dynamics of Global Change", coordinated by Köln University, will investigate these highly complex processes, focussing on the regions of Dhaka in Bangladesh and the Pearl River Delta (Guangzhou, Shenzhen and Hong Kong) in China. The aim is to use an interdisciplinary approach to develop a new methodological basis in order to pave the way to a more thorough understanding of the dynamics of megacities.

[www.geographie.uni-koeln.de/megacities-spp]

Under the dynamics of Global Change – understood as global environmental change as well as global socio-economic and political change – megacities are facing growing options: On the one hand they are prone to growing socio-economic vulnerability because of pronounced poverty, socio-spatial and political fragmentation, sometimes with extreme forms of segregation, disparities and conflicts. The juxtaposition of very different local living conditions, life-forms and lifestyles (including ethnic, social and behavioural groups) plays a significant differentiating role. On the other hand – and often neglected – megacities offer positive potential for global transformation, e.g. minimisation of "space consumption", high effectiveness of resources applied, efficient disaster prevention, sufficient health care – if good strategies are developed. Megacity research is therefore about to become a central element of complex global peace policy as megacities represent both global growth and innovation areas as well as global risk areas.

T. Krafft/NKGCF

Figure 1: Mumbai: Dhobi (washermen) community in the city center.

F. Kraas

Figure 2: Bangkok: Striking construction disparities are testimony to the intense building activities during the boom years of economic development.

Against this background, the German National Committee on Global Change Research (NKGCF) successfully encouraged scientific communities in 2002 to bundle their previous research efforts in large research groups, focussing on most important challenges of megacities research. Following this, several different initiatives emerged: In 2004 the German Federal Ministry of Education and Research (BMBF) launched the programme "Research for the Sustainable Development of the Megacities of Tomorrow". In 2005, the German Research Foundation (DFG) granted one of its Priority Programmes to "Megacities – Mega-Challenge: Informal Dynamics of Global Change". In November 2005, the Helmholtz Association started a project on "Risk Habitat Megacities". 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. All programmes are based on proven international partnerships among interdisciplinary academic communities as well as major stakeholders from local governments, private enterprises, non-governmental organisations and the civil societies, particularly in developing countries like China and India.

Current major research projects focus, among others, on megaurban sustainability, comprehensive environmental and social management, mobility and transportation, water/energy supply and consumption, food supply and nutrition, waste treatment, urban health problems, public health and quality of life, megaurban planning and governance: loss of governability and steering capabilities, fragmentation and social coherence, social innovation, the dynamics of informal processes, security issues and disaster prevention. New methodologies have to be applied for megaurban contexts, such as high resolution satellite data, decision support systems, scenario methodologies.

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

Programme Duration: 2005 – 2013 (projected)
Funding: BMBF

Urbanisation, as a social phenomenon and physical transformation of landscapes, is one of the dramatic current global changes. Its speed, scale and global connectedness turns the urban habitat, particularly in megacities and large agglomerations, 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-urbanisation? How can we predict and describe the transformation of the complex risk habitat megacity? What strategies can steer the urban system towards sustainable development? What institutional and organisational preconditions must be in place for their effective implementation?

These questions are the focus of a new research initiative, in which scientists from currently five research centres within the Helmholtz association 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. It applies these themes to a set of megacity-typical problem areas such as socio-spatial polarisation, water supply deficits, air pollution and associated health risks, land use conflicts and energy supply.

Geographically, the research concentrates on megacities and large agglomerations in Latin America. With the establishment of a Centre for Sustainable Urban Development, Santiago de Chile will serve as a platform for coordination of research and dissemination of results. In Germany, the initiative interlinks with the programme "Research on Sustainable Development in Megacities of Tomorrow", launched by the German Federal Ministry of Education and Research (BMBF) and a core programme of the German Research Foundation (DFG) on informal dynamics in megacities.

[www.ufz.de/index.php?en=6143]

GLOBAL CHANGE AND HEALTH

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 pressures on the biosphere in recent decades will have diverse (mostly adverse) impacts on economic, social and environmental conditions, the ultimate risk is to human well-being, health and survival.

Most likely, health effects will not be new, but will represent gradual increases of existing disease burden. The World Health Report 2002 estimates that in the year 2000 current climate change caused 2,4% of worldwide diarrhoea, 6% of malaria in some middle-income countries and 7% of dengue fever in industrialized nations. WHO attributed 154.000 deaths (0,3%) and 5,5 million (0,4%) DALYs (disease-adjusted life years) to climate change.

WHO/Virot

Figure 1: Woman filling water in a jar near Alem Kitmama North East of Addis-Ababa, Ethiopia. Clean drinking water is a prerequisite for human health.

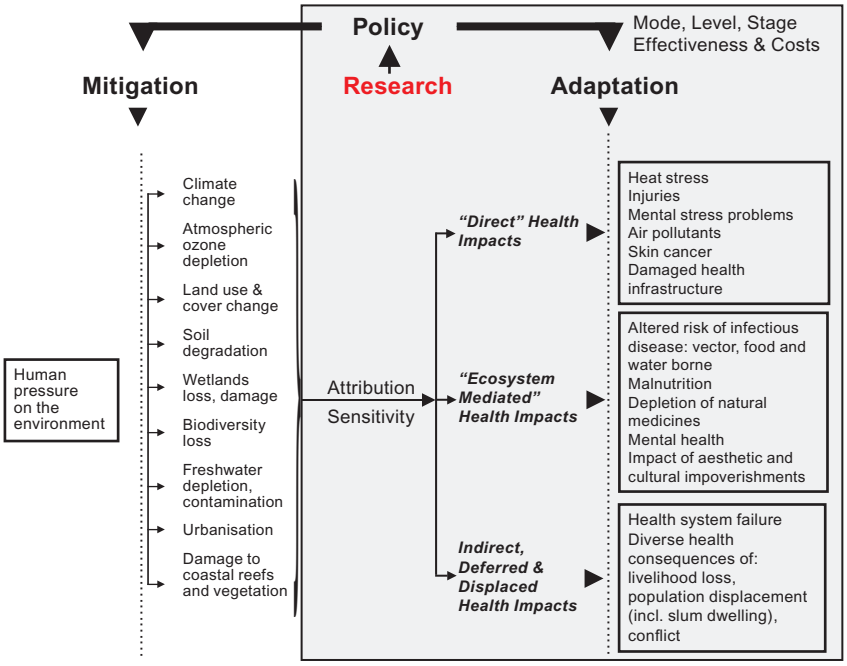


Figure 2: Schematic diagramme of the types of pathways by which Global Change can affect risks to human health.
Source: Science Implementation Plan for ESSP Joint Projects on Global Change and Human Health.

Figure 2 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 with 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 the climate-health relationships and how health impact levels are likely to change in future. The area shaded in grey is the suggested focus of the emerging ESSP Human Health Science Plan.

Environmental changes contribute to the outbreak or re-emergence of infectious diseases like SARS, West Nile virus, and avian influenza virus or malaria, tuberculosis, and bacterial pneumonias. Furthermore, both long- and short-term economic impacts 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, hurting the poultry industry in parts of South-East Asia.

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, should be considered in future research on Global Change. Local actions should be combined with enhanced co-operation at global and regional levels, for example the implementation of local measures such as the elimination of unnecessary standing water to lower the risk of malaria together with worldwide efforts to ensure safe water and improved sanitation.

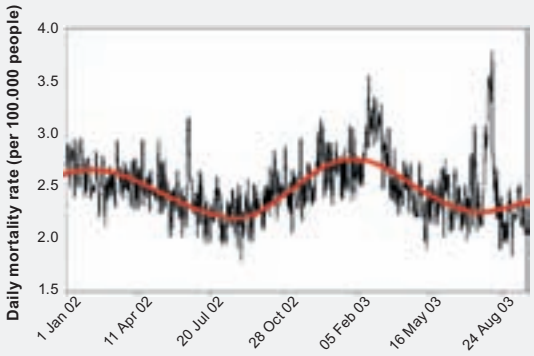
Direct Health Impact: The Effect of Heat Stress on Mortality

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. New record extreme events occur 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. The number of excess deaths in Germany was estimated at around 7.000.

Heat waves, the health impact of heat, aspects of prevention and adaptation such as heat health warning systems, urban planning elements and aspects of building design are examined within the cCASHh (climate Change and Adaptation Strategies for Human health) project, a combination of impact and adaptation assessment for different climate-related health outcomes, funded by the EU and with numerous European partners involved. Germany is represented by the National Meteorological Service (DWD) and the Potsdam Institute for Climate Impact Research (PIK).

[www.dwd.de/en/wir/Geschaeftsfelder/Medizin/Forschung/Forschung.htm]

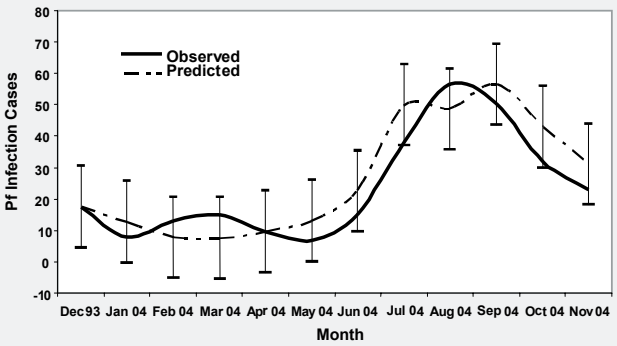


Daily mortality rate in Baden Württember, Germany, over a period of 20 months, including the August 2003 heat wave. Total daily mortality data are in black, with the mean seasonal evolution in red.
Source: Schaer and Jendritzky, 2004, Hot news from summer 2003, Nature, 432, 559-560; doi:10.1038/432559a.

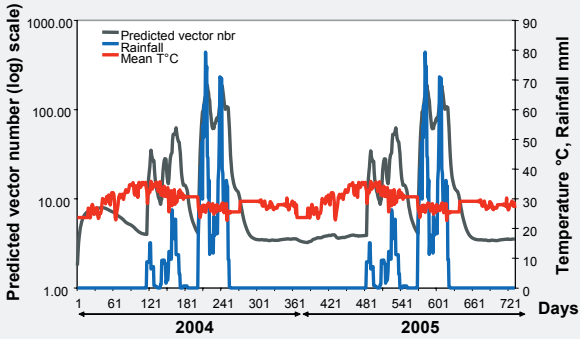
Ecosystem-mediated Health Impact (Vector-borne Disease): Incorporating Environmental Factors in Modelling Malaria Transmission in under Five Year old Children in Rural Burkina Faso

In the Nouna health district, Burkina Faso, malaria contribution 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 1980's, the country has been involved in various studies aimed at identifying locally appropriate 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 to broaden our understanding of malaria transmission. The hypothesis was that malaria incidence 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 holo-endemic area, and uses the model to forecast malaria outbreaks in holo-endemic areas of Sub-Sahara Africa.



Seasonal pattern of model-predicted and observed cases of childhood malaria.
Source: Research Training Group 544, Heidelberg University.



Net biting rates (nbr) of Anopheles gambiae mosquitoes, daily rainfall and temperature patterns.
Source: Research Training Group 544, Heidelberg University.

The above figure shows the strong association of vector biting rates (black lines) with rainfall, while temperature is not an important factor in mosquito behaviour, while the figure on the left shows the predictive power of the model comparing the temporal pattern of malaria cases as observed compared with the model based pattern.

The studies are conducted by the Research Training Group 544, Control of Tropical Infectious Diseases, Heidelberg University, funded by the German Research Foundation (DFG).

[www.hyg.uni-heidelberg.de/sfb544]

EXTREME EVENTS

Over the last few years, Europe has been hit by several extreme events. Heavy precipitation led to major flooding in different drainage basins of European rivers, like the Oder flood in 1997 and the Elbe flooding in 2002 (Figure 1). Almost every year there was an unusual flooding (see table). These events were often connected to weather conditions, which were associated with heavy precipitation. Contrary to the precipitation and flooding events, which lasted only a few days and cover relatively small regions, like individual catchment areas, a severe drought occurred in the summer of 2003 (Figure 2). This drought associated with a heat wave was not a sudden climate event, but because of its long duration and large regional extent covering major parts of Europe it was of catastrophic nature.

Figure 1: Flooding of the city of Dresden in 2002.
Source: Spiegel Nr. 7, 2003; Quarterly Report of the DWD, Special Topic July 2003.

Major Extreme Events in Europe 1993 - 2005

1993	*December*	Century flood of Rhine and Moselle
1995	*January*	Century flood of Rhine and Moselle
1997	*July*	Century flood 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

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.

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, possibilities to better predict these events need to be explored. In order to do so, existing long term records of measurements have to be analysed. However, heavy precipitation as well as wind gusts are difficult to measure accurately due to their very limited regional extent.

The statistical analysis of the time series of daily temperatures at Karlsruhe (Figure 3), which has been performed at Frankfurt University, shows that during the last 30 years the probability for summer heat waves, like that of 2003, 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 (Figure 4).

Possible changes in the frequency and intensity of extreme events such as hurricanes, heat waves, droughts and floods are likely to have a large impact on society, since they can cause considerable damage.

Therefore, one focus within future climate change research should concentrate on the development of statistical as well as dynamical 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 been published recently. In the warmer climate of 2070-2099 under the IPCC SRES A2 scenario, the researchers conclude, among others, the following:

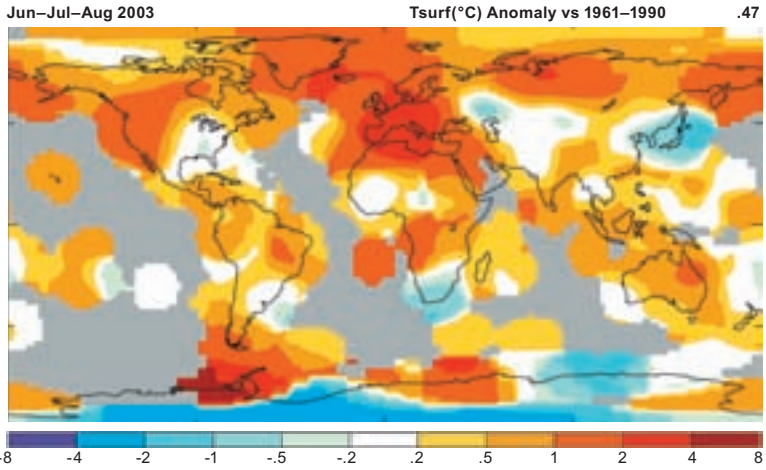


Figure 2: Global temperature anomalies during the European heat wave in 2003.
Source: Nasa Goddard Institute for Space Studies.

- 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:

- Focus more on the near future 2020s instead of 2080s.
- Reduce uncertainty by more reliable climate modelling.
- Make research results more accessible for the lay-person.
- Bridge the gap between what scientists can produce and what end-users require.

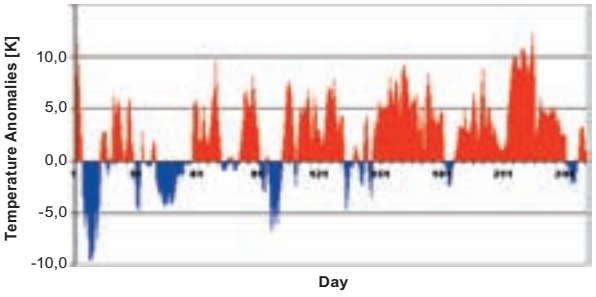


Figure 3: Daily temperature anomalies in Karlsruhe in 2003, deviation from long term mean (1876-2000).
Source: Institut für Meteorologie und Klimaforschung, Karlsruhe University.

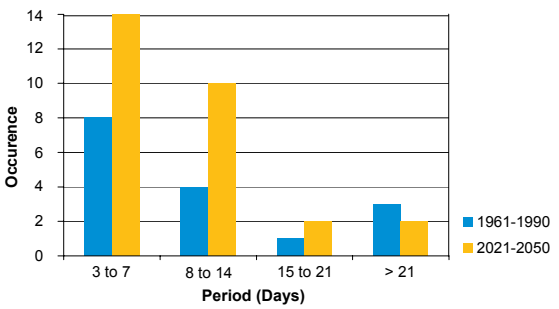


Figure 4: Occurrence of low water periods (water flux less than 750m²/s) in the Rhine under the IPCC B2 scenario.
Source: MPI for Meteorology.

VASClimO (Variability Analysis of Surface Climate Observations)

Project Duration: 2001 – 2006
Funding: BMBF

VASClimO is a climate research project of Germany's National Meteorological Service (DWD), Global Precipitation Climatology Centre, and Frankfurt University, Institute for Meteorology and Geophysics – Working Group for Climatology, and is part of the German climate research programme DEKLIM. Numerous tasks in modern climatology require accurate knowledge of the observed climate and its spatio-temporal variability. High-quality observations are needed in order to obtain robust estimates of sign, magnitude, and significance of global and regional climate change. Concerning a possible future climate change, a firm database of observational data is important.

VASClimO has two goals: The development of an optimal data base of global climate observations to be made available for other research projects within DEKLIM, and the discovery of statistically significant spatio-temporal structures within the observed climate data.

[www.geo.uni-frankfurt.de/iau/klima/Deklim/vasclimo_intro_e.html]

ENERGY – MOBILITY – CLIMATE

Fossil energy resources have been one of the main drivers of economic growth and prosperity since the 19th century. The growth in production paired with the process of globalisation has been dependent on an ever increasing volume of transport and improving efficiency in mobility services. Today, the tourism industry that relies heavily on transport services belongs to the largest – or is even the largest – economic sectors of the world economy. Mobility 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.

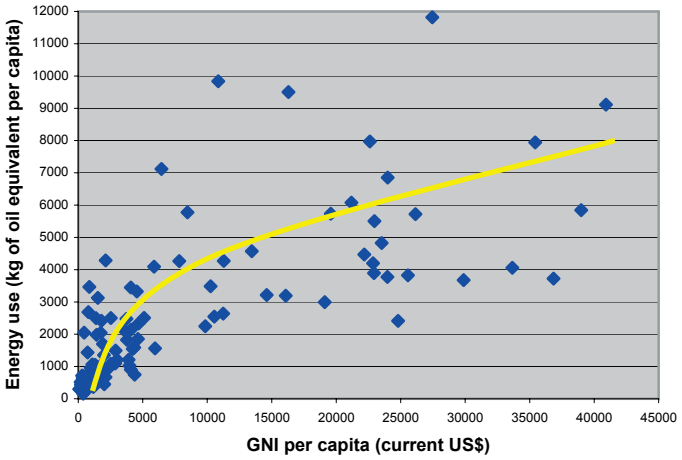


Figure 1: Energy use at different income levels (GNI: Gross National Income).
Source: Own calculations, based on World Bank's World Development Indicators 2005.

The main source of fuel for road and air transport is oil which is becoming scarcer and – more importantly – more expensive as it is increasingly difficult to meet the rising demand for oil especially from the fast growing Asian economies. Figure 1 illustrates how the energy use per capita increases with higher income levels. It also shows that at a particular income level very different amounts of energy may be consumed. This suggests that different energy efficiency, different life-styles, or different policy instruments to control energy use may be responsible for the energy needs for reaching a certain income level. According to projections by BP, passenger car numbers are forecast to grow from some 700 million today to 2 billion by 2050. Transport is estimated to be the second fastest growing source of Greenhouse gas (GHG) emissions globally after power generation, and transport's GHG emissions will grow as much as 85% between 2000 and 2030.

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, see also Figure 3) 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).

Using improved transport emission inventories, better evaluated and hence more reliable models, these new forecasts in QUANTIFY will represent a considerable improvement of current predictions. Long time scales are involved in the transport system and its effects on climate: Some transportation modes have long development and in-service times; some emissions have long residence times and the thermal inertia of the climate system is protracted.

The impact of short-lived species, however, depends on location and time of the emissions. So several transport scenarios and potential mitigation options need to be assessed to identify the most effective combination of short and long-term measures and to inform policy-makers and industry. The project aims to provide such guidance by focused field measurements, exploitation of existing data, a range of numerical models, and new policy-relevant metrics of climate change.

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.

[www.pa.op.dlr.de/quantify]

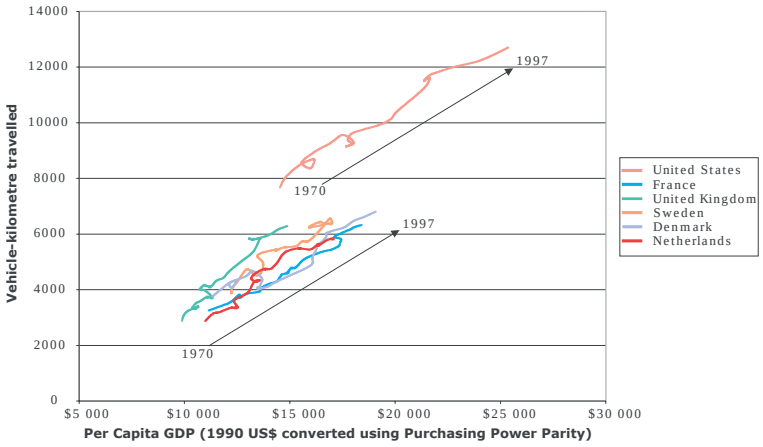


Figure 2: Vehicle-kilometres travelled per year per capita and GDP (Gross Domestic Product) per capita in a selection of IEA countries, 1970-1997 (IEA: International Energy Agency).
Source: IEA and Berkeley National Laboratory.

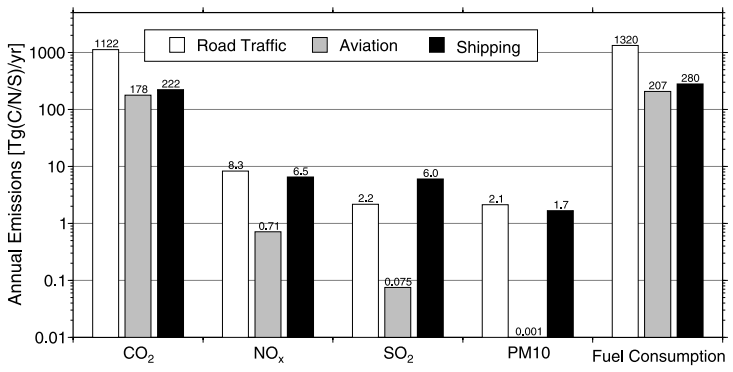


Figure 3: Transport-related annual emissions of CO_2 in Tg (C), NO_x in Tg (N), SO_2 in Tg (S), and PM10 in Tg (PM) and the fuel consumption in Mt estimated for the year 2000. PM10 from road traffic includes black (BC) and organic carbon (OC) only.
Source: Eyring, V., H. W. Köhler, J. van Aardenne, and A. Lauer, 2005, Emissions from international shipping: 1. The last 50 years, J. Geophys. Res., 110, D17305, doi:10.1029/2004JD005619.

In the United Nations Framework Convention on Climate Change (UNFCCC), the vast majority of countries has agreed to achieve a "stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (Art. 2). Such a goal can only be achieved by a comprehensive strategy aimed at reducing CO_2 emissions from all sources by a large percentage.

The share of transport in the oil consumption of the industrialized world – and consequently the CO_2 emissions – will reach 60% in the next decade, meeting the demand for mobility while simultaneously controlling CO_2 and other emissions will be a major scientific, technological, and societal challenge. In addition, with rising incomes in the Third World, traffic is expected to expand similar to that in the industrial world since the seventies as Figure 2 indicates.

Research projects such as QUANTIFY (see box) are underway which try 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 these services.

Several research questions 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 impact of the use of natural resources for mobility services on the functioning of the Earth's material cycles and on climate change?
3. What is the potential of current and future technologies in the field of energy and transport with respect to the sustainable use of natural resources?
4. How can a successful transfer of new technologies in the transport sector into the fast growing regions of the developing world be achieved?
5. 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?

Consequently, the relevance of this research complex is also reflected in the new 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.

GOVERNANCE AND INSTITUTIONS

BMU/Brigitte Hiss

Figure 1: Implementation of international standards: FSC-Certification by an independent institution, Forestry Office Berlin-Grunewald, Germany, 2005.

Scholars analysing institutions have commonly looked for structures of how societies maintain order and are steered towards political goals. State based formal institutions exist alongside informal societal norms both constituting a complex mix of governance. On the side of formal structures in addition to command and control measures, economic instruments such as the pricing of resource use have widely been discussed and sometimes closely scrutinised by states. With the increasing frequency of transborder relationships, international systems have become an ever more prominent object of institutional analysis. Besides the growth in number and variety of international treaties and organisations, informal institutions have attracted attention. All in all, the growing variety of institutions has rightly been coined as a plurality of regimes or legal pluralism. However, such preoccupation with new structures and instruments of governance has somewhat neglected inquiries into the problem which must be solved. The globality of environmental change reflected in Earth System analysis demands a new kind of institutional analysis. Just as the view on the earth as a natural and developing system requires the assembling and – if possible – modelling of many different factors, institutional research should strive for an overarching view on the multitude of institutions. All of them make a contribution to global governance, and should be analysed as to what the "division (or misfit) of labour" looks like. Rather than only taking the perspective from "below", i.e. that of individual freedoms vis à vis state law, and of state sovereignty vis à vis international law, it is necessary to take a bird´s eye view from "above", i.e. a view on social structures and states each having a share in causing and solving global environmental problems.

For the purposes of this article, an institution is defined as common values, perceptions of the real world, and rules of behaviour established for a group of states or individuals. If institutions are supported by specialised personnel, acting bodies, a budget, etc., they are also organisations. If the organisation does not only exist on paper but is operative it qualifies as a regime. Governance is a function of regimes and organisations, i.e. the steering of themselves ("self-governance") or of others. Governance may be based on informal or formal (i.e. state based) powers and rules. If formal powers and rules are involved, the arrangement is called government.

A working group of the research project on the Institutional Dimensions of Global Environmental Change (IDGEC) has proposed to structure this kind of inquiry along three analytic themes (questions 1-3). Additionally, the author raises questions on the individual contributions of the states to global governance (questions 4-5) and, based on democratic values, the question of legitimacy (question 6). The following exemplifies the questions and points out related research areas in Germany.

1. The Question of Scale

The **question of scale**, asking on what level (local, state, international) a problem is to be tackled, and how instruments have to be adjusted to the particular nature of the envisaged level. For instance, the pricing of resource use may prove to be less appropriate if employed as an instrument of international law addressing states than as a domestic tool addressing individuals.

✧✧✧

With reference to questions of scale, political science took part in the global debate on under what conditions international regimes emerge and are installed. It can be regarded as a German input to the debate that the factual and potential role of discourse and institutions was stressed, as opposed to rational choice or realist approaches.

1. Scale - Links

International Regimes Database (IRD), TU Darmstadt
[www.tu-darmstadt.de]

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

2. Problem Fit - Links

Münchner Projektgruppe für Sozialforschung e.V.
[www.m.shuttle.de/mpsev]

2. The Question of Problem Fit

The **question of problem fit**, asking what kind of instrument is appropriate to solve a problem. For instance, emission limit values may be ineffective if not adjusted to the different technologies of industrial branches.

✧✧✧

Concerning the question of problem fit, the choice of instruments has been a matter of controversy among lawyers and economists. For a long time, conduct measures have prevailed, but more recently economic instruments have been found to be worth trying. For example, the allocation, trading and generation of climate gas emission allowances has attracted much research, although the focus has been on elaborating the legal instruments and refining the underlying rationale of the approach more than on an empirical and detached analysis of its outcome. Sociologists have contributed studies on cultural and life conditions of peoples as a prerequisite of effective governance.

3. The Question of Interplay

The **question of interplay**, asking in what way conflicts between regimes with different orientations are resolved. For instance, the WTO regime supporting free transnational trade conflicts with trade related multinational environmental agreements such as the Convention on Trade in Endangered Species (CITES).

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In relation to questions of interplay, many studies have been undertaken on the conflict among trade and environmental regimes. In general, German authors have taken the view that the WTO regime can and should be accommodated to environmental concerns. However, the focus has often been on human health issues rather than on environmental effects. In relation to inner-environmental conflicts of regimes, the founding of an overarching world environmental organisation has been a subject of study and controversy.

4. The Question of Joint but Differentiated Governance

The **question of joint but differentiated governance**, asking how states go individual ways possibly inducing equivalent outcomes both in causing and mitigating Global Change.

✧✧✧

As for the question of joint but differentiated governance, important research has been conducted on "horizontal diffusion" of legal concepts, i.e. the transfer of law by mimesis, global discourse, economic pressure, etc. Another stock of knowledge stems from studies in comparative law and politics although this research tends to concentrate on comparing forms rather than assessing how different forms have their own way in causing and mitigating Global Change.

5. The Question of Self-Regulation

The **question of self-regulation**, asking if a problem rather than being tackled by state or international formal institutions can be solved by private actors, either within a national system or in the transnational dimension.

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In relation to questions of self-regulation, older research on the practises within states has more recently been extended to the transnational dimension. Progress has been made in particular concerning the environmental self-regulation of multinational corporations, transnational production networks, transnational business associations, and producer/consumer stewardship councils.

6. The Question of Legitimacy

The **question of legitimacy**, asking how it can be ensured that governance originates from the people and is acceptable for it. Means must be found to democratise international regimes as well as transnational private governance.

✧✧✧

Concerning questions of legitimacy, German political science focussed on the participation of the global public in international regimes. It has been asked how regimes can be "constitutionalised" (ensuring respect for basic values and legitimacy). As for basic values guiding environmental regimes, the communality of environmental resources has attracted much attention.

UN

Figure 2: International Institutions: General Secretary of the UN, Kofi Annan, opening the 2005 World Summit.

In conclusion, it can be noted that German research in the institutional dimension of Global Change has made significant contributions. Besides ever remaining lacunae there is a more fundamental need of integrating the many branches of study to produce a common perspective on multilevel and multiarea global governance. Many different groups and individuals work separately, but could cross-fertilize their research by better coordination. Ambitious attempts in this direction in Germany, involving many other nationalities, include the yearly "Berlin Conferences" on IHDP, and an interdisciplinary network called "Transnational Institutions on Environment" (TIE), based at the Research Center for European Environmental Law (FEU), Bremen University. In addition, the analysis of institutions is being developed as an extension of science based research networks. It is to be hoped that more such joint ventures spring up, and that IHDP and in particular IDGEC can serve as a contact point and stimulus for them.

3. Interplay - Links

Max Planck Institute for Comparative Public Law and International Law [www.virtual-institute.de]

Research Network GLOGOV of Free University Berlin (FU), Potsdam Institute for Climate Impact Research (PIK), Oldenburg University and Vrije Universiteit Amsterdam. [www.glogov.de]

4. Governance - Links

Environmental Policy Research Centre (FFU) [ww.fu-berlin.de/ffu]

Wissenschaftszentrum Berlin [www.wzb-berlin.de]

5. Self-Regulation - Links

DFG SFB 597, Transformations of the State, Bremen Universiy [www.state.uni-bremen.de]

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

6. Legitimacy - Links

Centre for International & European Environmental Research (ECOLOGIC) [www.ecologic.de]

Max Planck Institute for Research on Collective Goods [www.mpp-rdg.mpg.de]

OBSERVING SYSTEMS

Measurements of Earth System parameters allow an objective determination of the effects of Global Change and their spatial distribution and temporal development forming 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, examining ocean processes; the diverse fleet of earth observing satellites, which measure a variety of physical and biogeochemical parameters ranging from trace gases and ice movements to chlorophyll content of vegetation; a multitude of ecological research sites, studying the role of vegetation in the Earth System; and a network of drifters, measuring temperature and salinity distribution in the oceans (Figure 1). 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 (see box on Biodiversity Observatories) and GLOWA projects.

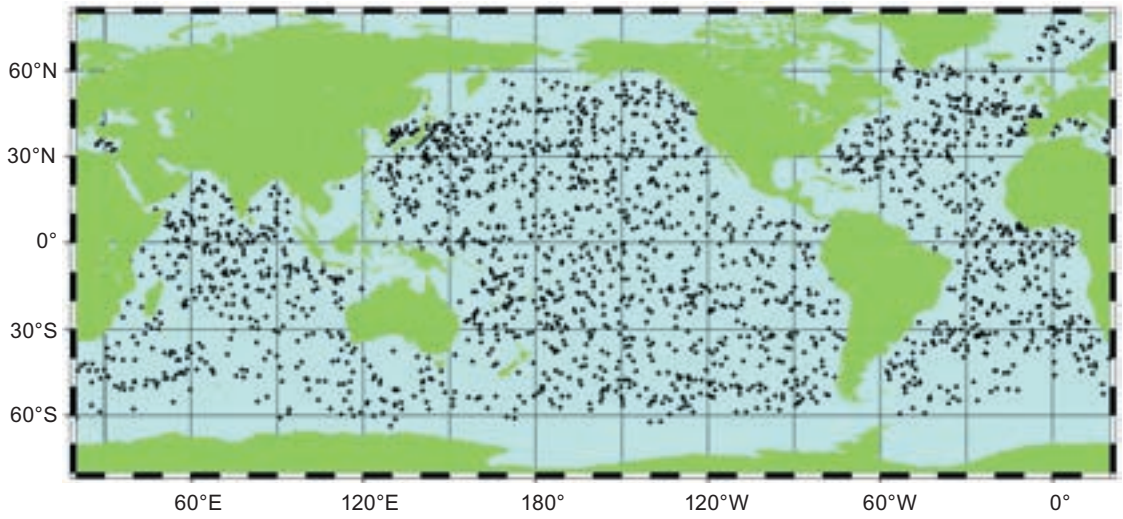


Figure 1: Current position of free-drifting profiling floats that measure the temperature, salinity and velocity of the upper 2.000 m of the ocean. This will allow, for the first time, continuous monitoring and prediction of the ocean. The number of floats in the ocean is approaching the number of weather stations on the continents.

[www.argo.ucsd.edu]

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 Earth System models, to user-related products, providing a solid basis to decision makers for a sustained management of resources. For a comprehensive effective monitoring of the Earth Systems parameters, a comprehensive, integrated observation system for Global Change is required, linking observation technologies globally for tracking environmental changes, thus enabling policy makers to make more informed decisions affecting people's lives, the environment, and economies. 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 predict droughts, prepare for weather emergencies and other natural hazards, plan and protect crops, manage coastal areas and fisheries, monitor air quality, 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 and, if required, the deployment of additional sensors to consistently deliver the full range of data from all major fields of natural and social sciences. Scale is a key issue in all observations. Changes in the environment usually happen gradually and continuously. Thus, a Global Change Observing System requires a long time perspective.

Scientific needs for this end-to-end process requires

- integrated observation, data management, and information delivery systems,
- quantifying environmental processes by direct or indirect observations,
- improved coupled Earth System models, integrating the best state of knowledge,
- assimilation of the earth observation data streams into models (possibly in real time),
- testing of our Earth System models over varying time and spatial scales against observations,
- understanding the drivers of climate variability and change, the rates of change and the possible precursors to climate variability and change,
- understanding and explaining the mechanisms underlying 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, where detailed, integrated measurements of all coupled natural and socio-economic parameters are taken. These represent the input for regional models to enhance the understanding of the Earth System and to develop alternatives for local and regional decision makers. This network of observation sites is supported 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 data to fill the gaps between the observation sites. Because of their global coverage, they provide a global picture of changes and their causes. 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.

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.

Biodiversity Observatories

There is great demand for an adequate global observation system for the measurement of the change of biodiversity at all levels (genetic, species, ecosystem diversity). Until now, changes of biodiversity have rarely been measured directly. Only indirect information, e.g. changes in the structural composition or in functional qualities are used as indicators or proxies. However, these data rarely supply evidence with regard to the causes of change. Furthermore, the processes and mechanisms of change also remain largely unknown.

In future, such proxy data and remote sensing information should (at least for an adequate number of observation sites) be complemented with data which directly describe the change of biodiversity within ecosystems at all levels. In practical terms, an adequate number of biodiversity observatories should be established which measure the composition of taxa, populations and communities with harmonised methodology.

Simultaneously, environmental data controlling the composition and the change of biodiversity should also be sampled. In the reciprocal sense, a limited number of observation sites should also be equipped to measure the effects of the change of biodiversity on climatic factors, nutrient fluxes, the water cycle, soil fertility, land use, etc. Prior to implementation, an adequacy analysis of the affordable number of sites which allow for these measurements at different levels of intensities should be carried out. Such an analysis should include a strategy for the evaluation of sampled data.

MODELLING THE FUTURE

Modelling Climate Change Scenarios

Predictions of natural climate variability and the human impact on climate are inherently probabilistic, due to uncertainties in the initial conditions of forecasts, the representation of key processes within models, and climatic forcing factors. Hence, statistically reliable estimates of climate risks can be made only through ensemble simulations. In such ensemble simulations, a model, or a suite of models, is run many times over the same time period under consideration 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 reflects the uncertainty of the prediction.

With a number of institutes, Germany participates in the European project ENSEMBLES which develops a common ensemble climate forecast system for use across a range of timescales (seasonal, decadal, and longer) and spatial scales (global, regional, and local). This model system will be used to construct integrated scenarios of future climate change, including non-intervention and stabilisation scenarios that will provide a basis for quantitative risk assessment of climate change and climate variability. There will be an emphasis on changes in extremes, including changes in storminess and precipitation and the severity and frequency of drought, and the effects of "surprises," such as the shutdown of the thermohaline circulation. As a first result, new simulations were performed showing a mean global warming between 2.5 and 4.1 degrees Celsius until the end of this century (Figure 1) – dependent on the scenario of greenhouse gases emissions into the atmosphere. One of the consequences: the seasonal varying sea ice decreases – the arctic could become ice free during late summer when the emissions will not be reduced.

DKRZ (German Climate Computing Centre)

DKRZ is the national german service center for climate researchers, sponsored by the German Federal Ministry of Education and Research (BMBF). By its article of association, DKRZ is responsible to install and operate 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 computer power for quantitative computation of complex processes in the climate and Earth System with sophisticated, realistic numerical models. The DKRZ also maintains facilities for storage and management of extremely large data sets including software tools and hardware and is a coordinating node in the national and European network of climate researchers.

[www.dkrz.de]

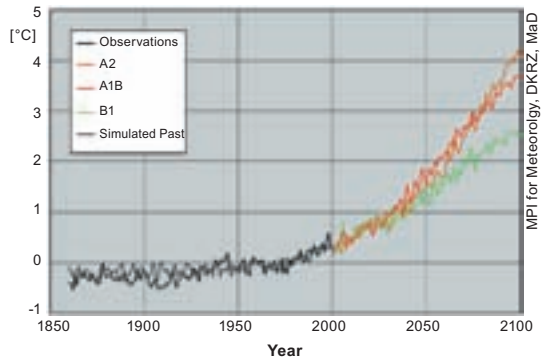


Figure 1: IPCC SRES Scenarios: Temperature Change relative to 1961-1990.

All simulations were done on the HLRE – the High Performance Computing System for Earth System Research – at DKRZ. About a quarter of the total resources were necessary in the last year 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 World Data Centre for Climate (WDCC), and the results of this project feed directly into the fourth IPCC (Intergovernmental Panel on Climate Change) Report, scheduled for early 2007.

Assessment of Potential Ecosystem Changes

The vulnerability of human life support systems to global change is strongly mediated through the biosphere: multiple drivers of global change (atmospheric CO_2, climate, land use, etc.) affect socially and economically important elements of the biosphere (food provisioning systems, recreation values, etc.). A key concept for the management of the biosphere is the idea of "ecosystem goods and services", describing all values that humans derive from ecosystems. In order to provide scientific support for a better management of these values, the UN have called for a "Millennium Ecosystem Assessment" (MA), which is designed to support the biosphere-related international conventions, as well as other national and international policies. In the MA, four principal scenarios were defined, considering social, demographic and economic trends worldwide and involving social and natural scientists. Subsequently, current conditions have been assessed and upcoming scenarios have been interpreted. Numerical model development for social, economic and ecological processes was also crucial.

The work carried out by the "Millennium Ecosystem Assessment" (MA) connects to recent developments in scientific investigations in Germany. The conceptional framework and the scenario development drew on results from research carried out at the Potsdam Institute for Climate Impact Research (PIK) 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 have also been described in earlier work to the support of the German Advisory Council on Global Change (WBGU). The conceptual framework of the MA, as well as the Working Group on "Sub-Global Assessments", drew on the methods and findings of the EU-funded integrated project ATEAM, coordinated by PIK. In this project, ecosystem goods and services have been assessed with regard to their sensitivity to climate and land use change with high quantitative precision, using a range of different models, applied for multiple scenarios of climate and land use change. The project produced high resolution maps of vulnerability for many economically relevant sectors in Europe. ATEAM and its connected concerted action AVEC helped communicating MA results to stakeholders at the European Environment Agency (EEA) and to students from all over Europe at the AVEC Summer Schools. One of the central modelling tools for the scenarios was the WaterGap model, providing quantitative assessments of water availability and use in all regions of the world and for a range of different conditions.

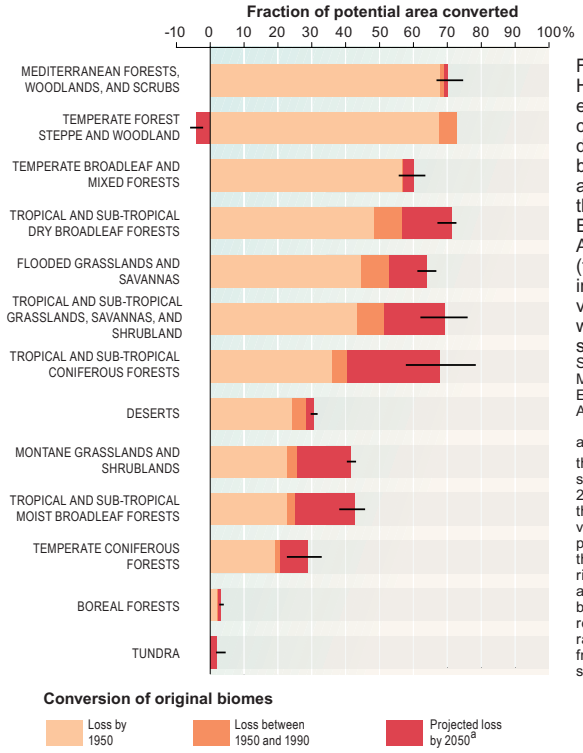


Figure 2: Historical and expected land conversion for different biomes as assessed by the Millennium Ecosystem Assessment (the error bar indicates the variation between the four scenarios). Source: Millennium Ecosystem Assessment

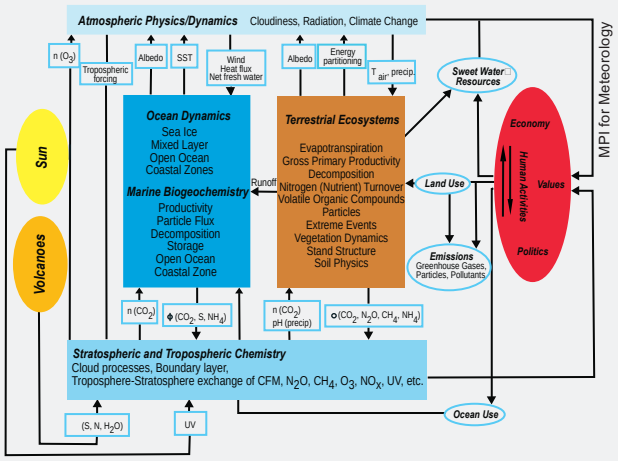
[a] According to the four MA scenarios. For 2050 projections, the average value of the projections under the four scenarios is plotted and the error bars (black lines) represent the range of values from the different scenarios.

The key finding of the MA is that historical changes to the biosphere have led to fundamental improvements in ecosystem service provision for human society. Most of these changes are unsustainable and will entail further degradation in the coming decades. Scenarios differ regarding the amount of this degradation, being largely a function of the reactive or proactive nature of biospheric management, but also due to the influence of global environmental policy related to equity and poverty issues.

COSMOS (Community Earth System Models)

COSMOS is a new initiative involving different Max Planck Institutes (MPI), Potsdam Institute for Climate Impact Research (PIK), and approximately 20 other institutions in Germany and abroad. The purpose is to develop a comprehensive Earth System Model, ESM (atmosphere, ocean, land), dealing with dynamical, physical, chemical and biological processes at the global and regional scales.

International programmes, including the World Climate Research Programme (WCRP) and the International Geosphere-Biosphere Programme (IGBP), coordinate Earth System Modelling initiatives through their WGCM and GAIM projects, respectively. The MPI for Meteorology, Hamburg, has developed global and regional climate models (atmosphere, ocean, cryosphere). Models describing biophysical and biogeochemical processes are being developed at the MPI for Biogeochemistry, Jena. Models focussing on tropospheric and stratospheric photochemistry and aerosols and transport are developed and used at the MPI for Chemistry, Mainz and at the MPI for Meteorology, Hamburg. PIK has developed a spectrum of Earth System models at various levels of complexity, and accounts for the socio-economic aspects of importance for the fate of the Earth System.



Bretherton diagram of the Earth System showing the different spheres and coupling processes to be described in an Earth System model.

[http://cosmos.enes.org]

PAST RECORDS OF GLOBAL CHANGE

There is no doubt that climate predictions for the 21st century are afflicted with great uncertainties. Especially the distinction between a potential human influence on the climate and naturally induced climate variations constitutes a particular challenge for climate research. Paleoclimatological data allow quantification of environmental variations beyond the instrumental range and can therefore be used to examine this vital aspect of Global Change. Paleoclimatological data thus represent a significant surplus value for the questions tackling Global Change. Meanwhile, their significance is also acknowledged by the IPCC. Their 4th report, consequently, contains an independent chapter covering the reconstruction of climate variations by earth sciences. Recent findings of paleoclimatological research indicate a notably higher variability of the climate system, also during interglacials (e.g. the Holocene) than assumed so far. Moreover, results of paleoclimatological research contributed significantly to a paradigm shift in climate research. Accordingly, abrupt climate changes with partly global implications cannot be excluded for the future. Modern approaches in paleoclimatological research link all available archives containing climate information (terrestrial, marine, ice cores), so as to attain a most comprehensive analysis of global environmental variations. Furthermore, a tight linking of paleoclimatological reconstructions and results of climate modelling allows far-reaching insights in the dynamics of climate variations, that are highly significant for future climate predictions. The spatial occurrence of variations of the Earth System can be detected by a close interaction of different research approaches on a global scale. This approach constitutes a fundamental base for a detailed analysis of regional aspects of Global Change.

Marine Archives (sediments, biogenic precipitate) represent the chronologically furthest reaching archives of natural climate variations, containing information on changes of the entire marine environment and its influence on the marine biosphere. Examination of these archives, therefore, allows the quantification of the effects of changing climates on the oceans, especially on oceanic circulation systems. Especially shallow-water marine archives offer ideal requirements for analysing variations of socio-economically relevant modes of climate variability (e.g., El Niño, North Atlantic Oscillation) during the last millennia, and a better understanding of their dynamics (Figure 1). Likewise, shallow water marine archives offer excellent preconditions to clarify the climate relevant mechanisms of ocean-land coupling. Thus, marine paleoclimatological archives extend the data base for assessing climate variability influencing the anthroposphere.

Lake Sediments, also serving as climate archives, occur worldwide and, hence, are especially suitable to point out regional variations of climate variability, e.g. between continental and oceanic affected climates. Therefore, changes in climatological border zones (e.g. semi-arid regions) with implications for the local population can be detected. Especially old seasonally layered sediments are of particular importance, showing seasonal variability and enabling precise statements on short-term climate dynamics. Moreover, annual layers allow 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 prospective occurrence can be better estimated.

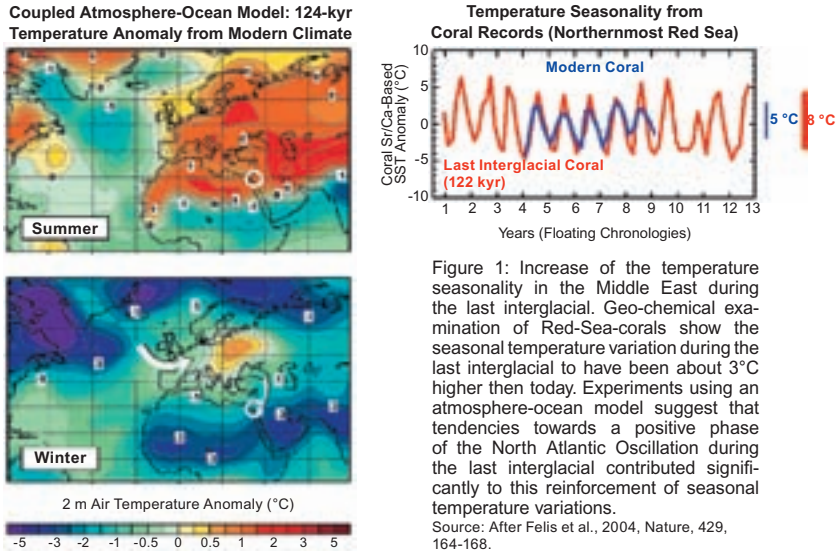


Figure 1: Increase of the temperature seasonality in the Middle East during the last interglacial. Geo-chemical examination of Red-Sea-corals show the seasonal temperature variation during the last interglacial to have been about 3°C higher then today. Experiments using an atmosphere-ocean model suggest that tendencies towards a positive phase of the North Atlantic Oscillation during the last interglacial contributed significantly to this reinforcement of seasonal temperature variations.
Source: After Felis et al., 2004, Nature, 429, 164-168.

Ice Cores constitute archives of the precipitation and the aerosols (e.g. sea salt, mineral dust, volcanic and biogenic sulphur) therein. While examining ice cores, temperature and precipitation rates can be determined, changes in sources of particulate matter and its atmospheric transport pattern can be reconstructed. Moreover, ice encloses air trapped in bubbles. Thus, ice cores represent the only natural climate archive which enables direct investigation of paleocomposition of the atmosphere. That is of prime importance for reconstructing the coupling of cli-

mate and greenhouse gases and their biogeochemical cycle in the past, respectively. The climate history recorded in polar ice sheets covers several glacial cycles (Figure 2) with annual resolution over a long period. Because of their geographical position in high latitudes, these ice cores are especially suitable for documenting circumpolar teleconnection pattern (e.g. Arctic oscillation/Northern Atlantic oscillation, Antarctic vortex). Ice core surveys on alpine glaciers can also be done in the tropics and mid-latitudes, not dating back as far as their polar representatives, but delivering insights into the variability of regional climate conditions. Because of the increasing anthropogenic warming and the associated deterioration of alpine glaciers, these ice core archives are increasingly threatened.

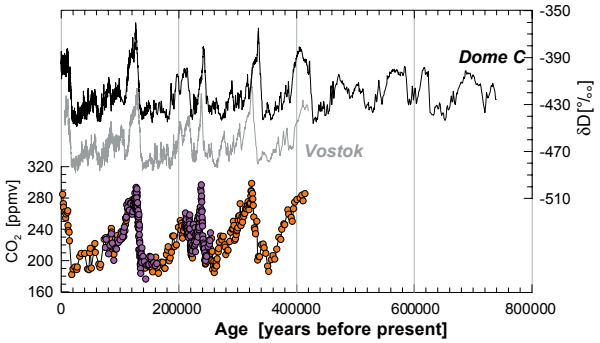


Figure 2: The isotopic composition of ice (top, center) is a measure for temperature change on the ice cap. The longest ice core climate record (740.000 years) is found in the ice core of Dome C, Antarctic (1). Concentration of the greenhouse gas carbon dioxide are available at the Antarctic Vostok ice core, covering the last 420.000 years (2, bottom). They exhibit a strong correlation with temperature changes in the Antarctica and the Southern Ocean, respectively.
Source: 1) EPICA community members, 2004, Nature, 429, 623-628; 2) Petit et al., 1999, Nature, 399, 429-436; Fischer et al., 1999, Science, 283, 1712-1714.

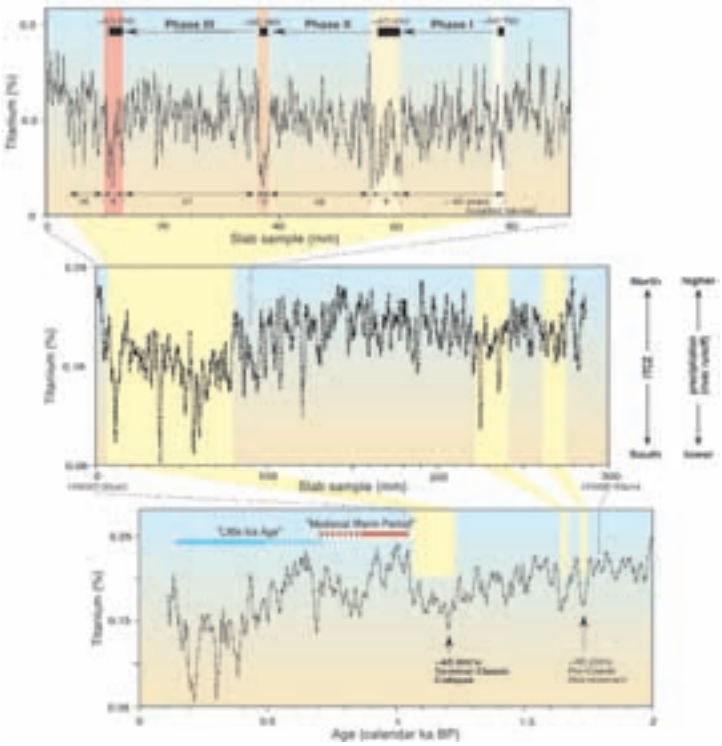


Figure 3: Influence of the climate on classic Maya civilisation. Geochemical examination of laminated sediments of the Cariaco Basin off Venezuela suggest a close linkage between Holocene drought periods and phases of collapse in Maya civilisation.
Source: After Haug et al., 2003, Sciene, 299, 1731-1735.

It is of more than academic interest to ponder how modern society will fare in the face of an uncertain climate in the years ahead. Understanding the responses of ancient cultures to climatic changes in the past may thus provide important lessons for humanity in the future. An increasing body of evidence argues about a direct relationship between climatically induced changes in environmental conditions and twists and turns of history. Milli- to micrometer-scale geochemical data in the laminated sediments of the anoxic Cariaco Basin have been interpreted to reflect variations in the hydrological cycle and the mean annual position of the Intertropical Convergence Zone (ITCZ) over tropical South America during the past millennia. These data with decadal to (sub)annual resolution show that the Terminal Collapse of the Classic Maya civilisation occurred during an extended dry period. In detail, the Cariaco record reveals evidence for three separate droughts during the period of Maya downfall, each lasting a decade or less. The data suggest that climate change was potentially one immediate factor leading to the demise of Maya civilisation, with a century-scale decline in rainfall putting a general strain on resources and several multi-year events of more intense drought pushing Maya society beyond the carrying capacity of their environment.

Climate Variability and the Human Habitat

Programme Duration: 2003 – 2007
Funding: BMBF

The programme is part of the programme oriented research of the Helmholtz Association. Participating institutions are the GeoForschungs-Zentrum Potsdam (GFZ), the Research Centre Jülich (FZJ) and the Centre for Environmental Research Leipzig/Halle (UFZ). The major goal of this programme is the reconstruction of past climates with a focus on two major threats to the human habitat: a) Rapid climate shifts and extreme climate events, and b) Changes in the background state of the ocean-atmosphere system such as rising greenhouse gas concentrations and potential thresholds in large-scale biogeochemical cycles, ocean circulation patterns and their interactions with the human habitat.

[www.gfz-potsdam.de/pb3/pb33/download/POFTopic3.pdf]

GERMAN CONTRIBUTIONS TO INTERNATIONAL GLOBAL CHANGE PROGRAMMES AND ESSP

The German National Committee on Global Change Research (NKGCF) was constituted in October 1996 by Germany's major research funding agency, 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).

Scope of NKCGF

- act as scientific advisory committee to DFG and BMBF;
- play 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;
- aim at improving the internationalisation of Global Change research in Germany and at promoting the integration of German contributions into the international programmes;
- act as advisory committee to the German representation to the International Council for Science (ICSU) and the European Science Foundation (ESF).

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

German National Committee on Global Change Research (NKGCF), Members 2003 - 2005

				Ex-Officio
		Co-Chair & Coordinator DIVERSITAS		
Prof. Claussen Climate System	**Prof. Grassl** Meteorology	**Prof. Jürgens** Botany	**Prof. Kalko** Ecology & Morphology of Animals	**Dr. Binder** German Federal Minstry for Education and Research (BMBF)
Co-Chair & Coordinator IHDP	Co-Chair & Coordinator WCRP	Co-Chair & Coordinator IGBP	Chair	
Prof. Klepper Environmental & Resource Economics	**Prof. Lemke** Climate System Regional Circulation	**Prof. Lochte** Biological Oceanography & Marine Microbiology	**Prof. Mauser** Hydrology & Remote Sensing	**Dr. Karte** German Research Foundation (DFG)
Prof. Radtke Physical Geography	**Prof. Sauerborn** Tropical Hygiene & Public Health	**Prof. Renn** Sociology	**Prof. Vlek** Tropical Agriculture	**Dr. Krafft** Scientific Secretariat
				Permanent Guest
Prof. Voss Energy Economics	**Prof. Wefer** Marine Geology	**Prof. Weisser** Terrestrial Ecology	**Prof. Winter** European Environmental Law	**Dr. Paulini** Federal Environmental Agency (UBA)

Bringing together scientists from all fields of Global Change research and from the four international programmes under the umbrella of one committee, Germany has anticipated early the need for close collaboration of all scientific disciplines for Global Change research within the framework of the ESSP. This organisation 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 connection or embedding of all research activities into the four international programmes and ESSP joint projects.

Activities of NKGCF

- Four regular **Committee Meetings** per year.
- **National Colloquia** to discuss achievements and to reconstruct and refocus future needs of the Global Change research programmes.
- **Scientific Workshops** to develop new methodologies and scientific programmes, organized with the financial support from DFG and BMBF, to discuss new methodological approaches and to develop new research initiatives or new programmes.
- **Scientific Conferences** to evaluate 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 major results 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 help to develop new programme components.

[www.nkgcf.org]

Earth System Science Partnership (ESSP)

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 undertakes 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 well-being: carbon cycle/energy systems (GCP), food systems (GECAFS), water resources (GWSP) and human health.
- **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 change in global biodiversity.

Structure: Three interrelated areas for further development: (1) discovering biodiversity and predicting its changes – bioDISCOVERY; (2) assessing impacts of biodiversity changes on ecosystem functioning and services – ecoSERVICES; (3) developing the science of the conservation and sustainable use of biodiversity – bioSUSTAINABILITY.

[www.diversitas-international.org]

IGBP (International Geosphere-Biosphere Programme)

Objectives: Studying the interactions between biological, chemical and physical processes and human systems.

Structure: Six projects are centred on the three major Earth System compartments (ocean, land and atmosphere) and the interfaces between them. Two projects, PAGES and AIMES, focus on a whole system perspective. Additionally, there are two projects of Phase I continuing: GLOBEC (the OCEAN interface consists of GLOBEC and the new project IMBER) and LUCC (part of the LAND project interface with the Global Land Project, GLP).

[www.igbp.kva.se]

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 projects are focussing 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 leads to the development of atmospheric circulation models for both climate studies, numerical weather prediction, and coupled ocean/atmosphere/land models.

[www.wcrp.org]

IHDP (International Human Dimensions of Global Environmental Change Programme)

Objectives: Promoting, catalysing and coordinating research, capacity-building and networking on the human dimensions of global environmental change, working at the interface between science and practice.

Structure: Seven core projects: Global Environmental Change and Human Security (GECHS), Institutional Dimensions of Global Environmental Change (IDGEC), Industrial Transformation (IT), Urbanisation and Global Environmental Change; co-sponsored with IGBP: Land-Use and Land-Cover Change (LUCC), Land-Ocean Interactions in the Coastal Zone (LOICZ), Global Land Project.

[www.ihdp.org]

RESEARCH FUNDING AND INSTITUTIONS

The main contributors financing 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 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. Besides that, scientific institutions throughout Germany receive institutional funding of BMBF and their respective federal states. These budgets are managed independently and in self-administration. Additionally, significant amounts are mobilised for scientific infrastructure.

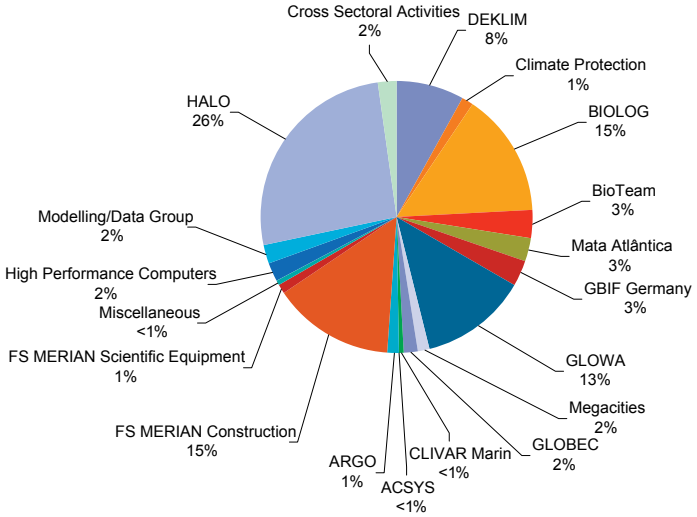


Figure 1: Financial contributions of BMBF to Global Change research programmes in 2005. BMBF's funding resources for **project oriented** Global Change research activities in 2005 summed up to about 65,6 million EUR in about 190 ongoing projects and programmes, including investment costs for research technology and infrastructure.

ACSYS	Arctic Climate System Study
ARGO	Array for Real-time Geostrophic Oceanography
CLIVAR	Climate Variability and Predictability
DEKLIM	German Climate Research Programme
GBIF	Global Biodiversity Information Facility
GLOBEC	Global Ocean Ecosystems Dynamics
GLOWA	Global Change of the Water Cycle
HALO	High Altitude and Long Range Research Aircraft

Amounts for **institutional** funding in 2005 are not yet available, but can be estimated to correspond to 2001 and 2003, with about 142 and 133 million EUR, respectively.

Carriers of institutional funding of BMBF are mainly 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 Association address questions of Global Change in research networks ("Earth System Science" and "Environmental Research").

[www.bmbf.de]

ARGO-TROPAT (Circulation Variability and the Spreading of Water Mass Anomalies)

Project Duration: 2004 – 2006
Funding: BMBF

This project, conducted at IFM-GEOMAR, Kiel, is part of the German ARGO programme with the latter also coordinated by IFM-GEOMAR, and containing subprogrammes from AWI, Bremerhaven, and the Federal Maritime and Hydrographic Agency (BSH), Hamburg. ARGO-TROPAT has two components. The first part is a contribution to the international ARGO programme in which a large fleet of profiling floats (up to 3.000 floats globally) establishes a global observational network of temperature, salinity and ocean currents. These data, distributed almost in real time, will be used to support large scale assimilation efforts (GODAE, MERCATOR) and investigations related to the climate variability (CLIVAR), and are made available to the public via internet. The scientific part of ARGO-TROPAT focusses on analyses of the spreading and evolution of heat and freshwater anomalies in the shallow tropical Atlantic. Profiling floats drifting along shallow trajectories but profiling down into the North Atlantic Deep Water (NADW) levels are used for this purpose. A second focus is on the deep interhemispheric exchange of NADW with deep (1.500 m) park levels of the floats.

[www.ifm-geomar.de/index.php?id=argo&L=0]

IFM-GEOMAR

North Atlantic: ARGO-float is deployed from the research vessel "Meteor".

For universities, the **German Research Foundation (DFG)** is the central funding organisation. 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 amount of funding dedicated to Global Change research is about 35 million EUR.

[www.dfg.de]

ACACIA (Arid Climate and Cultural Innovation in Africa)

Project Duration: 1995 – 2007
Funding: DFG
The interaction between humans and arid environments is the key theme of the multidisciplinary research project which combines humanities with natural sciences (participating: Egyptology, archaeology, social and cultural anthropology, history, African studies, botany, geography). Spatially fieldwork is restricted to the northeast and southwest of the continent and temporally it is confined to the holocene.

ACACIA

Surveying site Regenfeld (Egypt).

The underlying idea is that humans have had to reconsider and innovate their strategies in dealing with a highly unpredictable environment. Many case studies show that humans have intentionally and unintentionally contributed to the change in environmental features, frequently in the sense of degradation, but sometimes also with successful attempts to guarantee system stability and sustainable use, but always with the implicit aim to minimize risks to physical existence, material reproduction and cultural continuity. Since the middle of last century, Africas arid zones have been involved in a rapidly unfolding process of globalisation which lay the basis for an ambivalent position in todays world system. On the one hand, these zones are prototypical peripheries, the home of indigenous people and subsistence-orientated production systems, far removed from the global exchange of commodities and information. On the other hand, they present zones apt for hegemonic projections, which on the basis of arid Africas natural 'wilderness' assumes that these zones need internationally coordinated protection.

[www.uni-koeln.de/sfb389]

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

Collaborative Research Centres (Sonderforschungsbereiche, SFB)

389 Arid Climate, Adaptation and Cultural Innovation in Africa (ACACIA)
460 Dynamics of Thermohaline Circulation Variability
512 Cyclones and Climate System of the North Atlantic
552 Stability of Rainforest Margins in Indonesia
560 Local Practice in Africa in the Context of Global Influences
564 Sustainable Land Use and Rural Development in Mountainous Regions of Southeast Asia
574 Volatiles and Fluids in Subduction Zones: Climate Feedback and the Causes of Natural Disaster
641 The Tropospheric Ice Phase (TROPICE)

Priority Programmes (Schwerpunktprogramme, SPP)

527 (Integrated) Ocean Drilling Programme (IODP/ODP)
1090 Soils as Source and Sink for CO_2 Mechanisms and Regulation of Organic Matter Stabilisation in Soils
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

Research Units (Forschergruppen)

402 Functionality in a Tropical Mountain Forest: Diversity, Dynamic Processes and Utilisation Potentials under Ecosystem Perspectives
451 Impact of Gateways on Ocean Circulation, Climate, and Evolution
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

Research Training Groups (Graduiertenkollegs)

450 Natural Disasters
692 Formation and Development of Present-Day Landscapes
717 Proxies in Earth History
793 Epidemiology of Communicable and Chronic Non-Communicable Diseases and their Interrelationship
1086 The Role of Biodiversity for Biogeochemical Cycles and Biotic Interactions in Temperate Deciduous Forests

RESEARCH FUNDING AND INSTITUTIONS

Max Planck Society (MPG)

The Max Planck Society carries out independent and non-profit research in their own institutes and facilities, which are free in their selection of research foci, covering humanities, social sciences, life sciences, natural sciences and engineering sciences, working in close cooperation with other research institutions and universities. Up to now, there are 78 institutes and research facilities all over Germany and nearby.

Earth Science and Climate Research

Max Planck Institutes in Mainz, Hamburg and Jena and other partnering institutions plan an integrated approach, focussing on the interactions between human activities, land-based ecosystems, oceans and atmosphere and applying aircraft measurements, remote sensing and modelling. The understanding of the Earth System and its interactions are a basal prerequisite for the definition of economic and politic strategies for an ideal and sustainable use of the planets resources.

Contributing Institutions

MPI for Chemistry, Mainz
MPI for Biogeochemistry, Jena
MPI for Meteorology, Hamburg
MPI for Nuclear Physics, Heidelberg
MPI for Terrestrial Microbiology, Marburg
MPI for Marine Microbiology, Bremen
MPI for Solar System Research, Katlenburg-Lindau

[www.mpg.de]

Approaches involved are threefold: measurements and in-situ experiments are required to examine processes within the components. Secondly, the earth has to be analyzed 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. Third main pillar is modelling. Numeric models, for example, are theoretical tools for investigating interrelations into the Earth System.

Questions in the focus of research include

- Which feedbacks and long distance relations of the Earth System are especially important?
- What regions and components react particularly sensitive 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 on the long term?

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

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

International Max Planck Research Schools (IMPRS)

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 yet received relatively little attention, 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 to 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, Center for Environmental Systems Research, and 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]

Leibniz Association

The Leibniz Association is a research organisation made up of 84 non-university research institutes and scientific service facilities, performing problem oriented research. They foster close cooperations with universities, industry, and other research institutes, both in Germany and abroad.

The Leibniz Association is a network of scientifically, legally and economically independent research institutes and scientific service facilities. The tasks undertaken range from humanities, regional research, and economics to the social and natural sciences, life sciences, engineering, environmental research, and are characterized by an interdisciplinary approach. The institutes are funded by both the Federal Government and the German "Länder".

Leibniz Institutes and Global Change Research – Examples

Climate Research focuses on understanding the climate and its influence on ecosystems, climate reconstruction, modelling and climate policies. The projects and programmes are embedded in national and international research networks and groups like DFG Collaborative Research Centres (SFB 460, Dynamics of Thermohaline Circulation Variability, and SFB 512, Cyclones and Climate System of the North Atlantic), CLIVAR (Climate Variability and Predictability), and GEWEX (Gobal Energy and Water Cycle Experiment) of the WCRP (World Climate Research Programme). The research done at the Potsdam Institute of Climate Impact Research (PIK) is fully devoted to questions of global warming.

Some of the leading economics research institutes within the Leibniz Association investigate economic aspects of climate change. Further research include ecosystems and biodiversity (for example GLOBEC, see box) and the sustainable use of resources – like energy, biological resources, land – taking into account economical and social aspects and implications.

Networking

All institutes in section E, "Environmental Sciences" and three other institutes form the Environmental Research Network (Verbund Umweltforschung).
Irregular meetings and bilateral discussions faciliate scientific exchange and the establishment of joint projects.

Within the Biodiversity Expert Network (Kompetenzverbund Biodiversität), several Leibniz Institutes are occupied with questions of documentation, function and benefits of different aspects of biodiversity. Several institutes are participating in BIOLOG. Another aspect is projects in biodiversity informatics.

[www.wgl.de]

GLOBEC (Trophic Interactions between Zooplankton and Fish under the Influence of Physical Processes)

Project Duration: 2002 – 2007
Funding: BMBF

The project aims for a better understanding of the interactions between zooplankton and fish under the influence of physical processes in order to elucidate the principal mechanisms accounting for the high variability of copepod production and of reproductive success of fishes. The results will form the basis for strategic modelling of the recruitment success of fishes.

The influence of physical processes on zooplankton and on the spawn of two planktivorous fish species with different life histories, herring and sprat, and on their trophodynamic interactions are studied in the Baltic and the North Sea, two ecosystems with very different oceanographic characteristics. A combination of field studies, experimental investigations and modelling is used. Top-down and bottom-up processes are studied comparatively in both ecosystems. As the Baltic Sea has a considerably lower number of species, the importance of food web complexity for ecosystem functioning can be studied in a comparative manner between the two systems.

IOW

Fish net full of sprat.

The project network with participation of the Baltic Sea Research Institute Warnemünde (IOW) forms the central German contribution to the international GLOBEC-Programme implemented within the frame of the International Geosphere-Biosphere Programme (IGBP).

[www.globec-germany.de]

RESEARCH FUNDING AND INSTITUTIONS

Helmholtz Association

The Helmholtz Association identifies and addresses grand challenges facing society, science and industry, in particular by researching systems of great complexity. Its 15 national research centres carry out scientific-technical and biological-medical research. Helmholtz concentrates its core competences and resources within strategic programmes to increase the efficiency, flexibility and target-oriented focus of its research. Funding is provided by federal and state government.

Helmholtz Centres Involved

Alfred Wegener Institute for Polar and Marine Research (AWI)
German Aerospace Center (DLR)
Research Centre Jülich (FZJ)
Forschungszentrum Karlsruhe (FZK)
German Research Centre for Biotechnology (GBF)
GeoForschungsZentrum Potsdam (GFZ)
GKSS Research Centre Geesthacht
National Research Center for Environment and Health (GSF)
Centre for Environmental Research Leipzig-Halle (UFZ)

Earth and Environment

The work done by the scientists aims to describe the consequences of the far-reaching and complex changes to the earth and the environment as closely as possible so that politics and society can plan ahead. The research field "Earth and Environment" brings together researchers from the natural sciences and social sciences to collaborate closely on fulfilling these tasks for science, society and politics.

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 in six programmes:

- Geosystem: The Changing Earth
- Atmosphere and Climate
- Marine, Coastal and Polar Systems
- Biogeosystems: Dynamics, Adaptation and Adjustment
- Sustainable Use of Landscapes
- Sustainable Development and Technology

Interest Groups were established on Megacities, Natural Disasters and Technology Assessment. In addition, four 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.

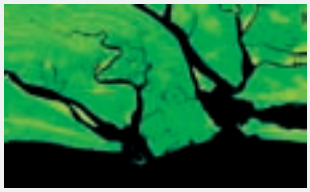
Other subjects related to Global Change research are in the field of "Transport and Space", addressing, among others, the questions of developing innovative solutions for environmentally friendly and energy-efficient transport, and in the research field "Energy" (renewable energies, efficient energy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

[www.helmholtz.de]

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 undertaken of global, regional and local changes.

DLR



Delta of Rio Negro/Province Patagonia.

Thanks to their expertise, science infrastructure and facilities, the Helmholtz centres AWI, GKSS, DLR and GFZ have the necessary preconditions for jointly pursuing crucial research topics in this context and achieving added value.

Andreas Labes

Drowning village, Elbe flooding, 2002.

The Helmholtz research fields "Earth and Environment" and "Transport and Space" are being linked to create an "Integrated Earth Observing System". Its purpose is to concentrate expertise and share infrastructure and data, initially in three research programmes: Ocean and Cryosphere, Disaster Management, and Land Surface Processes. These activities are financed from the resources each participating centre contributes toward the work it carries out in the individual research programmes of the network. Coordination of topics and allocation of resources are handled by the network's steering committee. The network can be expanded to address further topics upon the participation of additional Helmholtz centres, universities and research institutions.

[http://helmholtz-eos.dlr.de]

FUTURE RESEARCH

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. Basic skills, orientation skills and applicable skills are the fundamentals. On all three levels, skills generation has improved during the last years. However, gaps in skills not yet covered have to be filled systematically through scientific research and development. To identify most urgent research questions, the following criteria have been established by the German National Committee on Global Change Research (NKGCF):

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

Considering the above mentioned criteria and based on an intensive discussion within the scientific community, NKGCF compiled a first draft of a new research strategy on Global Change research in January 2005, prioritising central research subjects. This draft was discussed and extended in a dialogue with national science partners and research and funding institutions and resulted in a policy paper, which constitutes the basis for strengthening Global Change research in Germany by coordination and best possible allocation of potentials, funding and research infrastructure. The principal topics identified are embedded into three large thematical areas covering processes, society and regional effects.

BIOTA Southern Africa

Figure 1: Dryland areas: Sustainable stable rotational grazing (to the right of the fence) and overused grazing land on the left.

F. Kraas

Figure 2: Urban re-densification is an important characteristic for the high development dynamics of Seoul, South Korea. Compact and thoroughly planned cities avoid wide megaurban expansion into surrounding peri-urban agricultural landscapes.

Thematical Area I: Development of the Components of the Earth System – Understanding 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

Thematical Area II: Global Change and Society

Technology Change
Consumer Patterns
Integration and Re-organisation of International Environmental Regimes
Health and Global Change
Migration

Thematical 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

Stabilisation and Rehabilitation of Resources and Functions into Degraded Ecosystems

Soil Fertility
Water Availability and Water Quality
Air Quality
Biodiversity

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