Departments

Five Scientific Departments to Advance the Knowledge Base

PIK's five scientific departments maintain and develop the methodological tools, model capabilities and data pools on which the institute's interdisciplinary work programme is based. The actual research at PIK is carried out in a number of medium-termyear, multi-disciplinary research groups ('projects'), in which several departments generally participate. These projects are guided by, and are an integral part of, the main overall research themes of PIK - the TOPIKs (cf page 25). The main function of the five departments within the PIK research structure is to develop, maintain and support the resources for the research projects and the TOPIKs, and to ensure the quality of scientific results. The five departments of PIK are: Climate System, Global Change & Natural Systems, Global Change & Social Systems, Data & Computation, and Integrated Systems Analysis. The first two departments are rooted in the natural sciences, the third in the socio-economic field, and the last two in what could be classified as 'structure sciences', namely computer science and mathematics. Within the past ten years, a rich treasure of more than one hundred simulation models of various scopes and applicabilities has been developed, and it is continuously being extended and enlarged (cf Catalogue of Tools on page 28). The departments are also responsible for promoting the scientific skills and careers of junior researchers at the institute.

Important Acronyms

AIM	Agriculture emphasising Integrated Modelling
BEAR	Biodiversity and Nature Protection Enhancement through Participatory Action Research
BEST	Brandenburg Simulator of Environmental and Socioeconomic Transformations
BIS	Biosphere Interactions in the Earth System
CLAWINE	Climate Adaptability of European Wine Industry
CLIMBER	Climate and Biosphere
EMIC	Earth System Model of Intermediate Complexity
DFG	Deutsche Forschungsgemeinschaft
EUROPA	Modelling, Reflecting and Communicating Possible Futures of Europe in the Context of Global Change
EVA	Environmental Vulnerability Assessment
EVITA	Exergy, Vegetation and Information: Thermodynamics Approach
GAIM	Global Analysis, Integration and Modelling
GloGov	Global Governance - Policy Analysis for Earth System Management
GLOREM	Global Water Resources Modelling and Management
GLOWA-Elbe	Integrated Analysis of Global Change Impacts on the Environment and the Society in the Elbe River Basin
GPP	The Geoscope Preparatory Project - Observing the Anthropocene for Sustainability Science
GRAIN	Guardrails and Indicators for Climate Protection
HSPN	Hochschulsonderprogramm - Nachwuchs
IGBP	International Geosphere-Biosphere Programme
IMEQ	Integrating Models and Ensuring their Quality
INTEGRATION	Integrated Assessment of Changes in the Thermohaline Circulation
LPG-DGVM	Lund-Potsdam-Jena Dynamic Global Vegetation Model
PIAM	Potsdam Integrated Assessment Modules
PIRSIG	Pirsig's Quality
PRUNE	Propagation of Uncertainties in Earth-System Models
QUEST	Quaternary Earth-system Stability
QUIS	Qualitative Intelligence Service
ReCSim	Regional Climate Simulation Models
SAFE	Sensitivity and Adaptation of Forests in Europe under Global Change
SFB	Sonderforschungsbereich
SIMENV	An Integrated Simulation Environment for Quality Assurance and Scenario Analyses
SYNAPSE	Syndrome Assessment and Policy Strategy Evaluation
TRIPEDES	Theoretical Research In Planetary Ecological Dynamical Earth Systems
WADI	Management of Water related Disasters

Climate System

Head: Martin Claussen
Deputy Head: Friedrich-Wilhelm Gerstengarbe

Overview
Understanding the interplay between the various components of the climate system is the key to a comprehensive Earth system analysis. Therefore the Climate System Department focuses on climate analysis and scenarios, climate-system modelling and ocean modelling. The research in these areas includes: i) the statistical analysis of past and present-day climatic data as well as the construction of future climate scenarios; ii) the development of a climate-system model of intermediate complexity; and iii) the investigation of ocean currents, in particular ocean-atmosphere feedbacks.


Martin Claussen

Climate Analysis and Scenarios
Group leader: Friedrich-Wilhelm Gerstengarbe

A prerequisite for any research related to climate is a thorough analysis of past and present-day climate based on high-quality data. Therefore, a PIK DATA Base System has been set up and is continuously expanded and updated in co-operation with the Data & Computation Department. The database contains high resolution, long term time series from all relevant climate stations of the world. Secondly, new multivariate statistical methods have been developed which are used for climate data analysis as well as for the validation of climate models.
For constructing regional climate change scenarios a new method has been formulated. This method considers results from climate models and observed regional climate parameters. It is based on an expanded cluster analysis algorithm and Monte Carlo simulations. The climate change scenarios are used in all PIK projects related to regional climate change.

Climate System Modelling
Group leader: Martin Claussen

In the Climate System Department a climate-system model of intermediate complexity called CLIMBER-2 (for CLIMate and BiosphERe, version 2) has been developed. It is used to focus on an efficient description of the feedbacks between all major components of the natural Earth system on time scales of centuries and millennia. Examples are simulations of the last glacial cycle, changes in carbon isotopes during the last 10,000 years, the greening and aridification of Northern Africa, and an analysis of the effects of volcanism, solar variability and land use on climate change of the past millennium. CLIMBER-2 includes dynamic models of the atmosphere, ocean, vegetation, and inland ice as well as models of terrestrial and oceanic carbon cycles. Currently it is the major tool used in the QUEST project.
For studies of the natural Earth system which require higher spatial and temporal resolution, a new model framework, CLIMBER-3, is under development in co-operation with both the Global Change & Natural Systems and the Data and Computation Departments.

Ocean Modelling
Group leader: Stefan Rahmstorf

Work in the ocean modelling group focuses on understanding the role of the oceans and sea ice in climate change, past and future. A major effort during the past two years has gone into developing the ocean component for the new coupled model CLIMBER-3. This ocean component is based on the GFDL MOM-3 model, which has been extended in various aspects and coupled to a state-of-the-art sea ice model. Further development work has focused on coupling to the atmosphere and on the implementation of an ocean carbon cycle model. Scientific issues that have been looked at were, for example, the role of sea ice in lowering the carbon dioxide levels during glacial times, or the dynamics of the Antarctic Circumpolar Current.

Another avenue of research is the development of simple conceptual, stochastic models of oceanic processes such as open ocean convection, to study aspects of their nonlinear dynamics.

Global Change & Natural Systems

Head: Wolfgang Cramer
Deputy Head: Petra Lasch

Overview
The planet's land surface is covered by a fine-scaled pattern of ecosystems and water bodies. These are all sensitive to changes in the environment and human life depends on them. To assess such changes, including their importance for human society, as well as the feedbacks from them to the atmosphere, is the primary goal of the department.

Most of our work is concerned with "human" scales of time and space. For ecosystems (natural and managed), we focus on landscape processes, such as tree and canopy development. In hydrological systems we assess the potential and risks environmental change might imply for human land use of river catchments. For the analysis of the entire biosphere we study interactions between human exploitation and the global carbon cycle. In none of these three cases can the direct human influence through management (or sometimes destruction) be ignored - often it is found to be the primary reason for concern. Our spatial scope is at multiple levels, ranging from the Elbe catchment, through pan-European studies, to global assessments.

Ecosystems
Group leader: Franz-W. Badeck

The ecosystems group uses empirical data and theoretical concepts to assess changes in ecosystem dynamics related to climate and land use change. It uses a suite of numerical models at different degrees of complexity, as well as major GIS data bases. An important contribution is made to the assessment of the vulnerability of ecosystem services (cf TOPIK projects EVA and SAFE, pages 38 and 50).

Water
Group leader: Zbigniew Kundzewicz

The water group develops a comprehensive understanding of the flow of water and substances transported in it through all stages of the hydrological cycle. The group studies issues of water shortage as well as flood risk, but also broader aspects of land cover change, such as the implications of economic trends on the use of land (cf TOPIK projects BEST and WADI, pages 46 and 37).


Wolfgang Cramer

The Biosphere
Group leader: Wolfgang Lucht

The biosphere group is the primary developer of a leading process-based biosphere dynamics model (LPJ), which is validated against observations from space and the ground. The model and supporting data bases are used to investigate the role of biospheric processes in the overall Earth system, particularly with respect to its stability on the decadal time-scale (cf TOPIK project BIS, page 30).

Interactions
We aim at playing a useful role within several national and international consortia that are concerned with challenging issues such as: vulnerability of ecosystem services, management of agricultural, forest and water resources, impacts and dynamics of land cover change, and the global carbon cycle. This includes the co-ordination of several collaborative research projects, and contributions to the International Geosphere-Biosphere Programme (cf page 103).

Global Change & Social Systems

Head: Carlo C. Jaeger
Deputy Head: Ottmar Edenhofer

Overview
To act responsibly in view of global environmental change will require a socio-economic shift of historic proportions, a sustainability transition. The Department of Global Change and Social Systems investigates the possibilities for and obstacles to such a transition. Sustainable development will involve a whole array of specific transitions. We have formed three research platforms to investigate some of these in depth.

Technology and the Energy Transition
Group leader: Ottmar Edenhofer

The pros and cons of various approaches to climate policy hinge to a very large extent on the prospects for restructuring the global energy system after the age of cheap oil. Sustainability science requires analysing the interaction between technological change and economic growth. Using new modelling techniques, we identify bifurcation points that offer viable policy options.

Social Discourse and the Lifestyle Transition
Group leader: Fritz Reusswig

How many billion cars will be running on planet Earth a few decades from now? What kinds of cars will there be? Such questions show how intimately issues of sustainability are connected to shifts in lifestyles. We combine stakeholder dialogues and lifestyle research to investigate linkages between sustainability and preference changes.

Resilience and the Management Transition
Group leader: Richard Klein

Identifying and alleviating vulnerabilities to various aspects of global change is a key task for a sustainability transition. Protection against specific risks must be embedded in efforts to increase overall resilience and innovative capacity. We study such management patterns by drawing on comparative regional studies and modelling efforts.
The three platforms support flexible task forces working on specific research questions. To connect our research to international research communities we use two interfaces: the European Climate Forum and the concept of a Geoscope (cf the GEOSCOPE project, page 44). The

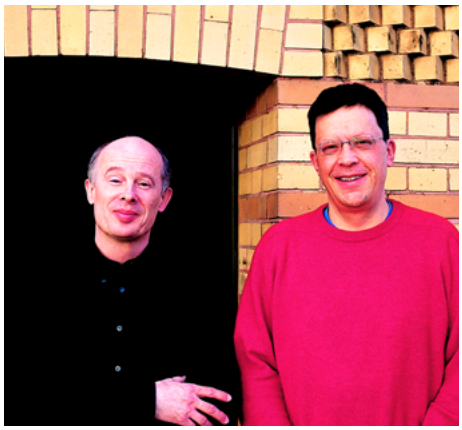

Carlo C. Jaeger

former provides a network involving research institutes as well as stakeholders. The latter provides a vision of a sustainability transition unfolding through a strategy of learning by doing, gradually developing the worldwide monitoring capability required for this task.

Exemplary Research Tasks
The task force "Endogenous Growth" studies the effect of different investment policies on energy efficiency. A Model of Investment and Technological Development has been developed for this purpose. It turns out that a climate-friendly policy may be economically much more attractive than is often assumed.
The task force "Diffusion of Innovations" develops a simulation tool for the consumption side of the economy. We use it to study diffusion processes of innovative environmentally relevant products.
No comprehensive list of research tasks shall be attempted here, as they are meant to form a rich and fast-changing pattern of activities. For further information on research performed with the help of the Social Systems Department, see the PIK projects on prospects for European climate policy (EUROPA), on risks of changing ocean circulation (INTEGRATION), regional sustainability issues (BEST, AIM), water resources (GLOREM), political institutions for a sustainability transition (GLOBAL GOVERNANCE), and last not least on vulnerability (EVA).
Out of these tasks, we develop software modules that can be coupled for purposes of integrated assessments (cf PIAM). Each assessment, then, can be based on developing and combining relevant software modules according to frameworks defined within an ongoing stakeholder dialogue.

Integrated Systems Analysis

Co-Heads: Hans Joachim Schellnhuber, Yuri Svirezhev
Deputy Head: Gerhard Petschel-Held



H. J. Schellnhuber, Gerhard Petschel-Held

Overview
The development of tools and methods within this department takes place within three groups on i) analysis, ii) integration and iii) modelling.

Analysis
Group leader: Hermann Held

This group seeks to develop methods and approaches for analysing characteristic features of coupled systems, particularly the Earth system. This comprises uncertainty analysis, by Bayesian or risk assessment methods (PRUNE project), multi-criteria decision-making analyses (e.g. GLOWA-Elbe project), or methodological issues of sustainability science and vulnerability theory. A particular focus is the switches and chokes within the Earth system (in co-operation with GAIM). Switches and chokes are defined as crucial constituents of the system, where small and relatively continuous changes in few parameters can induce rapid and abrupt changes in the whole system. Examples include the instability of the North Atlantic Deepwater Formation, the possible outburst of methane from the Siberian permafrost regions, or the imaginable collapse of the Amazonian rainforest. Critical events of that type may announce themselves by short- to medium-term signals. Based on this idea, work in the GRAIN project seeks to systemize these signals with regard to properties necessary to use them within an adaptive management strategy to prevent them. (All projects see page 27.)

Integration
Group leader: Matthias Lüdeke

This group develops methods to integrate disciplinary knowledge and models from different scientific fields or societal arenas and which is possibly valid on different spatial or temporal scales.
With respect to model integration, one can distinguish between methods for coupling stand-alone models (*modular approach*) and methods for developing reduced-form models for a particular purpose. The latter include spatiotemporal abstraction and strategic cycling of inductive and deductive model formulation. Spatiotemporal abstraction uses so-called Empirical Orthogonal Functions of a General Circulation Model in designing "climate-impact-response functions" which assess the impacts on aggregated areas, e.g. countries or continents. Though spatially explicit, the reduced-form model needs only the global mean temperature as an input. The impact components of PIK's present integrated assessment model (cf ICLIPS1.0 page 61) rely on this method. Knowledge integration from different disciplines is at the heart of the syndromes approach (SYNAPSE) which seeks to recognize basic patterns of (un)sustainable development through a portfolio of methods, ranging from GIS and fuzzy logic to qualitative modelling and case study integration. Other activities relate to the usage of possibility theory for integrated assessment.

Modelling
Group leader: Siegfried Franck

This group develops specific models of complex, coupled systems. Approaches include dynamic systems theory, e.g. neural networks, structural stability or multifractal analysis, as well as soft and set based modelling techniques, e.g. qualitative modelling or fuzzy logic.
Methods of dynamic systems analysis are helpful, for example, to get conceptual ideas about the ecological niche of a system. Within the TRIPEDES project the lifespan of the Earth as a habitable planet was assessed by these means to be about 1.4 billion years - much less than by pure geological methods. Qualitative differential equations can be used if we know only qualitative features of the relationships between variables (QUIS, SYNAPSE). More specific modelling efforts are now undertaken in the development of regional simulators (cf TOPIK 5 page 46), heading for comprehensive decision support models on a regional scale.

Data & Computation

Head: Rupert Klein
Deputy Heads: Karsten Kramer, Michael Flechsig

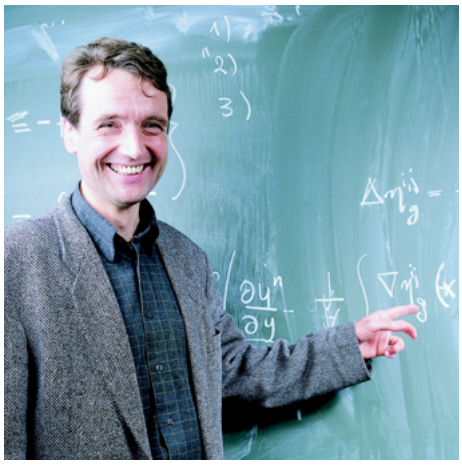
Overview
The D&C Department manages the institute's IT hardware and software infrastructure, and maintains its high technological standards. It is responsible for Scientific Data and Metadata Management, and it operates a Scientific Computing division.

Hardware and Software IT Infrastructure
Group leader: Karsten Kramer

The year 2000 was shaped by intense evaluations of bids for PIK's new high-performance parallel computer (cf page 100), by the selection of an outstanding offer by IBM Corporation and the installation of this machine in the newly built basement of PIK's new headquarters. The IT Infrastructure team guided the design and implementation of the new building's networking system and with remarkable skill and professionalism managed the transition into the new building in late 2001. This move involved about 35 offices and the entire computation, application, and data server infrastructure. During 2001 the new parallel computing environment has rapidly been accepted, and has already been operating at the expected average load since the spring of 2001. New procedures for the management of an increasing number of scientific workstation computers and the rapid deployment of applications have been introduced during 2001. The servers used in this area are characterized by a very high application flexibility and performance.

Scientific Data and Metadata Management
Group leader: Michael Flechsig

PIK's research depends heavily on the availability of a large variety of data, including long-time weather records, various computer simulation results, sociological data, and satellite observations. The Scientific Data Management group supports PIK scientists in handling these data through its xDat-System. This software flexibly integrates a variety of metadata bases with professional quality graphic user interfaces for database inquiries and the mapserver-based graphic representation of query results. Importantly, the system also allows direct access to stored data that have been identified in a metadata search. The system holds 400 metadata sets in the group's CERA-2 system and data from 50,00 measurement stations, amounting to 500 million data entries. During the last six months of the reporting period 30 regular users of the system produced 2,500 logins, and downloaded 200 million time series data entries from 3,000 stations.


Rupert Klein

Scientific Computing
Group leader: Rupert Klein

In 2001 the German climate research community adopted the German Weatherforecast Service's local area model (LM) as the basis for their future common regional climate model. An extension of LM, developed by the Climate System Department and D&C, serves as the base code. Having identified key numerical issues in the dynamical kernel of modern meteorological models, the group has developed a "balanced" numerical scheme which solves the full non-hydrostatic flow equations while still properly representing near-hydrostatic flows. Key ideas for this development stem from the group's unified mathematical representation of simplified meteorological models based on systematic multiple scales asymptotics.
The problem of flexible coupling of existing submodels is a central task in many PIK projects. The group contributes through its "Typed Data Transfer" library, which combines fast data transfer with platform-independent data descriptions using the XML standard.

Project Activities
The department leads the PIRSIQ, ReCSim, and SIMENV projects, and it is developing links to the Scientific Computing group at Freie Universität Berlin through a joint DFG-SFB proposal.

Research

The Evolution of PIK's Research Programme

The real research at PIK takes place not in the departments, but in interdisciplinary projects that have all the departmental know-how at their disposal. How did this come to pass?

From Core Projects to TOPIKs

Relatively early, the classic structure of research organized along departmental and mainly disciplinary lines was rejected at PIK. It soon became clear that transdisciplinary research cannot be organized in a traditional way. The present research structure was arrived at in three stages:

1) 1992-1994 stage of definitions
2) 1994-2000 Core Projects stage
3) from 2001 TOPIK stage

STAGE OF DEFINITIONS

Establishing the departments meant entering the stage of definitions. How was PIK's mission to be translated into a work programme? First of all, the mission had to be specified into concrete tasks, then the necessary know-how had to be identified. In addition, strategic partners would have to be found and contacted, since the challenge of PIK's mission could only be met in alliance with scientific partners.

CORE PROJECTS STAGE

Developing and implementing transdisciplinary Core Projects constituted an essential step in the transition from one-dimensional climate impact research to Earth System Analysis, since it is only within a larger and more complex scope that climate change impact may be investigated successfully. The dynamics of global change have to be taken into account, including both geobiophysical and socio-economic processes of the Earth system.

In August 1994, nine Core Projects dealing with essential issues of global change were selected from more than twenty proposals. As shown in the following list, the Core Projects investigated the Earth system from three different perspectives: global, regional, and sectoral, featuring important economic sectors:

Global perspective

POEM	Potsdam Earth System Modelling
ICLIPS	Integrated Assessment of Climate Protection Strategies
QUESTIONS	Qualitative Dynamics of Syndromes and Transition to Sustainability

Regional focus

EUROPA	European Network Activities
RAGTIME	Regional Assessment of Global Change Impacts Through Integrated Modelling in the Elbe River Basin
WAVES	Water Availability, Vulnerability of Ecosystems and Society in Northeast Brazil

Sectoral view

AGREC	Agro-economic Impacts of Climate Change on German Agriculture in the Context of Global Change
CHIEF	Global Change Impacts on European Forests
RESOURCE	Social Dimensions of Resource Use - Water Related Socio-economic Problems in the Mediterranean.

DEFINING NEW CENTRAL RESEARCH AREAS (TOPIKS)

The sum of experience accumulated in the roughly five years of successfully implementing the Core Projects led to a new concept for a transdisciplinary research programme that was to be even more strongly structured with regard to strategy and content. Incidentally, this was initiated by recommendations of PIK's Scientific Advisory Board in late 1998, in connection with PIK's evaluation by the Wissenschaftsrat (German Scientific Council) presented the following year. Evaluating PIK's work and progress as excellent, the Council in addition offered several suggestions and recommendations about how to proceed in the future.

Limiting research to those central areas of research in which PIK already excels, and focusing projects - including externally funded projects - on these areas, were among the main issues.

This resulted in the "TOPIK^{2k} Research Programme": Proposals were to be submitted internally and to be approved for a limited period of time; previous core projects were to be given one more year for their completion. During the transitional stage, in which internal contest of ideas was strongly encouraged, 51 proposals were handed in, leading to the implementation of 26 PIK projects (cf Table 1 on page 26).

The TOPIK Stage (from 2001 to date)

Essential characteristics of the new research programme are the following:

- definition of new thematic research areas called TOPIKs (cf Tables 2 and 3),

Table 1: Internal Contest of Ideas & Proposals

Date	Activity	Result
Jan. 2000	Internal Contest of Ideas	51
June 2000	Guided Call for Proposals	32
Jan. 2001	Start of Evaluated Projects	26

- departmental concentration on providing state-of-the-art methods and techniques (TOOLs, cf page 28)),
- a set of criteria for initiating, evaluating and concluding PIK projects within this framework,
- priority given to those externally funded projects that correspond thematically to PIK projects.

As a result, PIK projects are being evaluated internally every year. Guidelines have been developed for the approval of new projects (depending on resources being available after conclusion of other activities).

Table 2: TOPIK Research Areas

TOPIK 1 - Nonlinear Dynamics of the Ecosphere - e.g. ice age cycles or the effects of land vegetation and marine biota on climate
TOPIK 2 - Management of Singular Events, which are potentially disastrous - storms, droughts and floods or the risk of abrupt ocean circulation changes
TOPIK 3 - Socio-economic Causes of Global Change - studies of greenhouse gas emissions and options for environmental policy
TOPIK 4 - Emergence of a "Global Subject" in the form of information networks and institutions for global governance, such as the UN conventions on climate change and biodiversity
TOPIK 5 - Development of Regional Simulators - flexible modelling tools for regional environmental management, e.g. in the state of Brandenburg or north-eastern Brazil
TOPIK 6 - Sensitivity of Economic Sectors to climate change, e.g. the adaptability of viticulture, the vulnerability of European forestry and Moroccan agriculture
TOPIK 7 - 'PIKuliar' Scientific Culture at PIK - quality control, dealing with uncertainties and limitations in computer modelling

Guidelines for PIK projects

1) Research activities are evaluated according to
   - quality (scientific potential and results),
   - 'PIKuliarity' with respect to TOPIKs and TOOLS,
   - relevance of questions for stakeholders.
2) Accordingly, an activity
   - will become (part of) a regular PIK project,
   - will become a pilot project to check the scientific potential within one year,
   - will be upgraded to a regular or co-ordinating project,
   - will be continued where there is high yield, or otherwise stopped.
3) Generally, every externally funded activity must prove to be essentially in support of a PIK project.

Organization of Research in TOPIKs and PIK Projects

Corresponding to its main issues, every PIK project will belong to a specific TOPIK and will consist of different TOOL-oriented tasks, which may be funded either internally or externally. Tasks will be established and resources allocated for all projects in accordance with the table of TOPIKS and TOOLs (cf page 27).
A Steering Committee consisting of leading scientists from PIK (the heads of the departments plus director plus mentors specifically appointed for each TOPIK) has been set up to supervise the smooth functioning of the research programme and guarantee that guidelines are observed. The allocation of resources to the projects will be updated regularly.

A survey of the PIK projects assigned to the TOPIKs is given on the next page. There are three types of projects:
- regular projects (R),
- pilot projects (P), and
- co-ordinating projects (C), which include tasks which are linked to other projects.

When the total number of projects and resources allocated to them is looked at, the organizational structure of research activities will emerge as a matrix, with each scientist belonging to a department while at the same time engaged in one or several projects. Incidentally, this is how present industrial production has long been organized.

Table 3: TOPIKs and PIK projects

TOPIK 1	Nonlinear Dynamics of the Ecosphere	
QUEST	QUaternary Earth-system STability	C
BIS	Biosphere Interactions in the Earth System	R
EVITA	Exergy, Vegetation and Information: Thermodynamics Approach	R
CLIMBER-3	Earth System Model of Intermediate Complexity	R
TRIPEDES	Theoretical Research In Planetary Ecological Dynamical Earth Systems	R
TOPIK 2	Management of Singular Events	
EVA	Environmental Vulnerability Assessment	R
GRAIN	Guardrails and Indicators for Climate Protection	R
INTEGRATION	INTEGRAted Assessment of Changes in the Thermohaline CirculaTION	R
WADI	Management of Water-related Disasters	P
TOPIK 3	Socio-economic Causes of Global Change	
EUROPA	Modelling, Reflecting, Communicating Possible Futures of Europe in the Context of GC	C
BEAR	Biodiversity and Nature Protection Enhancement through Participatory Action Research	P
GLOREM	GLObal water Resources Modelling and Management	P
TOPIK 4	Emergence of a Global Subject	
PIAM	Potsdam Integrated Assessment Modules	C
GloGov	Global Governance - Policy Analysis for Earth System Management	P
GPP	The Geoscope Preparatory Project - Observing the Anthropocene for Sustainability Science	P
TOPIK 5	Regional Simulators	
BEST	Brandenburg Simulator of Environmental and Socioeconomic Transformations	R
ReCSim	Regional Climate Simulation Models	R
SYNAPSE	SYNdrome Assessment and Policy Strategy Evaluation	R
TOPIK 6	Sectoral Climate Sensitivity	
AIM	Agriculture emphasising Integrated Modelling (Focus: Morocco)	R
CLAWINE	Climate Adaptability of European Wine Industry	R
SAFE	Sensitivity and Adaptation of Forests in Europe under Global Change	R
TOPIK 7	PIKuliar Culture	
IMEQ	Integrating Models and Ensuring their Quality	C
PRUNE	Propagation of Uncertainties in Earth-System Models	R
PIRSIG	Pirsig's Quality	R
QUIS	Qualitative Intelligence Service	R
SIMENV	An Integrated Simulation Environment for Quality Assurance and Scenario Analyses	R

Catalogue of TOOLs

INTEGRATED SYSTEMS ANALYSIS

- Dynamical Systems Analysis
- Concepts of Integrated Modelling
- Soft and Set-based Modelling
- Assessing Uncertainty Implications
- Decision-Making Analysis

CLIMATE SYSTEM

- Meteorological Data Base
- Statistical Models
- Scenario Models
- Dynamical Regional Climate Models
- Ocean Models
- Climate System Models

GLOBAL CHANGE & NATURAL SYSTEMS

- Ecophysiological Simulation Models
- Hydrological Simulation Models
- Forest Dynamics Models
- Ecosystem Dynamics Model
- Data Retrieval Techniques

GLOBAL CHANGE & SOCIAL SYSTEMS

- Model of Endogenous Growth
- Multi-Sector Models
- Multi-Level Models
- Conceptual Analysis & Stakeholder Dialogue

DATA & COMPUTATION

- MODelling ENVironment (MODENV)
- Graphic Simulation Builder
- Parallelization Tools
- VISual ANAlysis (VISANA)
- Model Improvement Support
- Metadata Model and Interfaces

TOPIK 1 - Nonlinear Dynamics of the Ecosphere

The ecosphere is a complex dynamic system which encompasses the abiotic geosphere (mainly atmosphere, oceans, ice masses, the Earth interior) and the living world as composed of the terrestrial and marine biosphere; humankind is considered here as an external driver. This TOPIK explores the nonlinear behaviour of the ecosphere as well as its resilience to large-scale natural and anthropogenic perturbations. Examples of the latter are the continuing release of fossil fuel combustion products into the atmosphere, sub-continental changes in land cover, and variations in solar luminosity. Investigations include exploration of so-called switches and choke points in the ecosphere, i.e. regions in which slight external forcings/disturbances can trigger massive changes of climate and other vital Earth system elements.

QUEST
Quaternary Earth System Stability

Project speaker: Martin Claussen
PIK project members: Eva Bauer, Victor Brovkin, Reinhard Calov, Siegfried Franck, Andrey Ganopolski, Alexa Griesel, Matthias Hofmann, Anja Hünerbein, Claudia Kubatzki, Till Kuhlbrodt, Miguel Maqueda, Marisa Montoya, Vladimir Petoukhov, Stefan Rahmstorf, Yuri Szirezhev.
External project collaborators: Danish Centre for Earth System Science (Denmark), Dept. of Quaternary Geol./ Palaeoecology, Vrije Univ. Amsterdam (The Netherlands), Inst. d'Astronomie et de Géophy. Georges Lemaître: Univ. Catholique Louvain (Belgium), Inst. u. Museum f. Geol. u. Palöontologie, Univ. Tübingen (Germany), Laboratoire des Sciences du Climat et d' Environnement (France), Royal Netherlands Meteorological Institute (The Netherlands), KIHZ (Klima in histor. Zeiten) project partner (Germany).

Research Questions

Human interventions play a significant role in the Earth system. We are altering the character of the Earth at an increasing rate, and the present dynamic stability of the Earth system itself may be endangered. Therefore the QUEST project is designed to improve our understanding of the dynamics of the natural Earth system in its present geological epoch, the late Quaternary (the last several hundred thousand years). QUEST addresses the following questions:

(a) Can we identify the processes and feedbacks that have kept the natural Earth system within stable bounds during the last 400,000 years?

(b) Can we explain the abrupt climate changes found in records of the last glacial?

(c) How resilient is the natural Earth system in its present state to large-scale natural and anthropogenic perturbations?

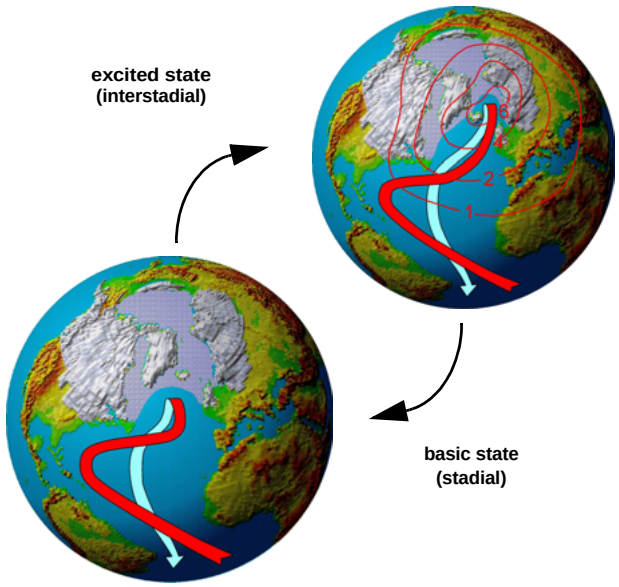


Fig. 1: Schematic of the two glacial climate states described in Ganopolski and Rahmstorf (Nature, 2001). Bottom: the stable "cold" or "stadial" mode. Top: the unstable "warm" or "interstadial" mode. Contours show the surface air temperature difference relative to the stable state. Ocean circulation is shown schematically, surface currents in red and deep currents in light blue. Continental ice sheets are based on the reconstruction of Peltier, prescribed in the simulations.

First Results

DANSGAARD OESCHGER CYCLES

Abrupt changes in climate, termed Dansgaard-Oeschger (D/O) and Heinrich (H) events, have punctuated the last glacial period (~100,000 - 10,000 years ago) but not the

Holocene (the past ~10,000 years). By using CLIMBER-2, Ganopolski and Rahmstorf (Nature, 2001) found that only one model of Atlantic Ocean circulation is stable in the glacial climate: a cold mode with deep water formation in the Atlantic Ocean south of Iceland. However, a 'warm' circulation mode similar to the present-day Atlantic Ocean is only marginally unstable, and temporary transitions to this warm mode can easily be triggered. This leads to abrupt warm events in the model which share many characteristics of the observed D/O events. For a large freshwater input (such as a large release of icebergs), the model's deep water formation is temporarily switched off, causing no strong cooling in Greenland but warming in Antarctica, as is observed for H events. This stability analysis provides an explanation of why glacial climate is much more variable than Holocene climate.

LARGE-SCALE LAND COVER CHANGE

Large-scale changes in land cover affect near-surface energy, moisture and momentum fluxes owing to changes in surface structure and the atmospheric CO_2 concentration caused by changes in biomass. For convenience, we call the former processes biogeophysical feedbacks, and the latter, biogeochemical feedbacks. Claussen et al. (Geophys. Rev. Lett., 2001) have quantified both the relative magnitude of these processes and their synergisms by using CLIMBER-2. Their sensitivity studies show that biogeochemical and biogeophysical processes triggered by large-scale land cover changes oppose each other on the global scale. Tropical deforestation tends to warm the planet because the increase in atmospheric CO_2, and hence atmospheric radiation, outweighs the biogeophysical effects. In mid and high northern latitudes, however, biogeophysical processes, mainly the snow-vegetation-albedo feedback through its synergism with the sea-ice-albedo feedback, win over biogeochemical processes, thereby eventually leading to a global cooling in the case of deforestation and to a global warming, in the case of afforestation.

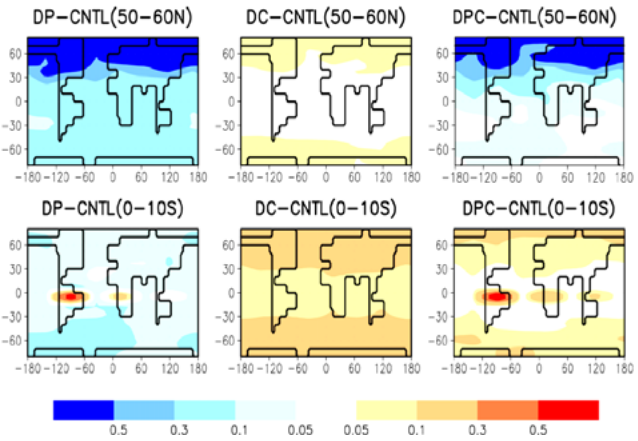


Fig. 2: Global pattern of temperature differences between three deforestation simulations (DP, DC, DPC) and the control climate (CNTL). In all deforestation simulations, deforestation is applied to boreal forests the zonal belt between 50°N and 60°N (labelled 50-60N) and to tropical forests in the belt between 0° and 10°S (0-10S). The control climate is computed for pre-industrial CO_2 concentration using a fully coupled atmosphere-ocean-vegetation model including terrestrial and oceanic carbon cycles. Vegetation is assumed to be in equilibrium with climate, hence no anthropogenic land cover change has been taken into account. The simulation DPC depicts the response of the fully coupled system. In DP, the carbon storages are fixed to values found in the control climate CNTL, i.e., DP reflects the effects of biogeophysical feedbacks only. In DC, near-surface energy, moisture and momentum fluxes are not directly affected by deforestation, but the carbon fluxes are allowed to change, i.e., DC shows the pure biogeochemical effect of deforestation.

This project is partly funded by BMBF, DFG, and the EU.

BIS
Biosphere Interactions in the Earth System

Project speaker: Stephen Sitch
PIK project members: Franz Badeck, Werner von Bloh, Alberte Bondeau, Victor Brovkin, Wolfgang Cramer, Dieter Gerten, Wolfgang Lucht, Tanja Rixecker, Sibyll Schaphoff, Birgit Schröder, Yuri Svirezhev, Kirsten Thonicke, Irina Venevskaia, Sergey Venevsky, Sönke Zähle.
External project collaborators: Centre for Geobiosphere Studies, Lund University (Sweden), Max Planck Institute for Biogeochemistry (Germany), Climate and Environmental Physics (Switzerland), Max Planck Institute for Meteorology (Germany), Laboratoire des Sciences du Climat et d' Environnement (France), Centre for Remote Sensing and Dept. of Geography, Boston University (USA), Dept. of Geography and Dept. of Geomatic Engineering, University College London (UK), Dept. of Geography, University of Jena (Germany).

Goal

To study the role of the land biosphere as a provider of the human environment and services and as part of the coupled physical and biogeochemical Earth system, on the time-scale of historic and future human intervention, i.e. years to a few centuries.

Research Questions

In this project, we address the following questions:
(a) What is the current and future structure and function of the land biosphere as a provider of the human environment and services?
(b) What is the current and future role of the land biosphere as part of the coupled Earth system on the ("human") time-scale of years to a few centuries?

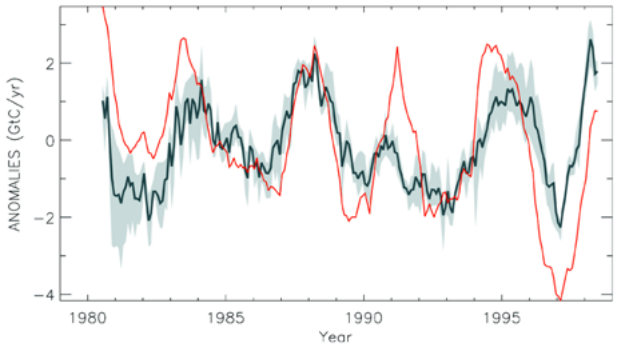


Fig. 3: Interannual Terrestrial carbon exchange anomalies (from the 1980-98 mean) using the bottom-up LPJ-DGVM approach (red), compared against top-down atmospheric inversion. Mean inversion is in black (Bousquet, Peylin, LSCE), the range of 20 inversions (grey).

Tools and development

The Lund-Potsdam-Jena Dynamic Global Vegetation Model (LPJ-DGVM) is one of the world's leading models of the global biospheric carbon cycle and of vegetation dynamics. Continued development of key components of the model, their validation with observed ecosystem data on several scales, and the study of the past and future of the global carbon cycle are the current focus of PIK's work using LPJ. E.g. inclusion of permafrost, a key influence on ecology in the boreal regions, into LPJ-DGVM led to a considerable increase in model performance. LPJ-DGVM representation of the hydrological cycle has been improved and successfully validated against seasonal, local- to global-scale data.

First Results

RECENT TERRESTRIAL CO_2 EXCHANGE

LPJ-DGVM seasonal carbon exchange has been compared over regions with those derived from atmospheric inversions. The importance of such work is first to locate the main source-sink regions, important for environmental policy (e.g. Kyoto debate), and second to identify, understand and model the underlying processes sensitive to current climatic variability, giving an insight into possible future environmental changes.

GREENING OF THE NORTHERN LATITUDES

Using time series of climate data, the LPJ-DGVM models an advance of spring in the last two decades and an increase of vegetation abundance in the global boreal zone. This is in excellent agreement with the observed trends found independently in satellite data. The model also reproduces the impact of atmospheric aerosols from the Mount Pinatubo volcanic eruption in 1991 on vegetation productivity and phenology in northern latitudes.

MODELLING OF REGIONAL FIRE PATTERNS

LPJ-DGVM simulates fire disturbance taking into account multiple natural and anthropogenic causes and processes such as fire spread. A regional version of this fire model adapted to the Iberian Peninsula, successfully reproduces both the number of fires occurring and the area burnt, factors that co-determine local ecosystems.

This project is partly funded by BMBF, DFG, and the EU.

EVITA
Exergy, Vegetation and Information: Thermodynamics Approach

Project speaker: Yuri Svireshev
PIK project members: W. Steinborn
External project collaborators: Kiel Ecology Centre

Goal

EVITA is a sub-project of BIS. EVITA aims to describe the state of vegetation by applying the concept of thermodynamics, in particular so-called exergy, to the observed spectra of the radiation balance.

Research Questions

- How do we define the *exergy* (one of the main thermodynamic characteristics of open systems far from equilibrium) of solar radiation interacting with vegetation?
- How do we use the exergy as an integrated index of the state and structure of vegetation under seasonal and annual variations of climate?
- How do we design experiments and observations in order to test our *minimax* hypothesis?
- What is the physical (biological) basis of the *minimax* principle?
- Can we use satellite monitoring data to calculate the exergy?

TRIPEDES
Theoretical Research in Planetary Ecological Dynamical Earth Systems

Project speaker: Siegfried Franck
PIK project members: Werner von Bloh, Christine Bounama, Pavel Egorov, Antony Z. Owinoh, Hans Joachim Schellnhuber, Yuri Svirezhev, Sergey Venevski.
External project collaborators: Konrad J. Kossacki, Warsaw University (Poland), Timothy Lenton, Centre for Ecology and Hydrology (UK), Georg A. Zavarzin (Russian Academy of Sciences).

Goal and Principal Question

The aim of the TRIPEDES project is to develop and to analyse Earth system models for long time scales under changing internal and external forcing (Figure 4). TRIPEDES addresses the principal question: What are the limits to self-regulation in the process of co-evolution of the biosphere and the other components of the ecosphere?

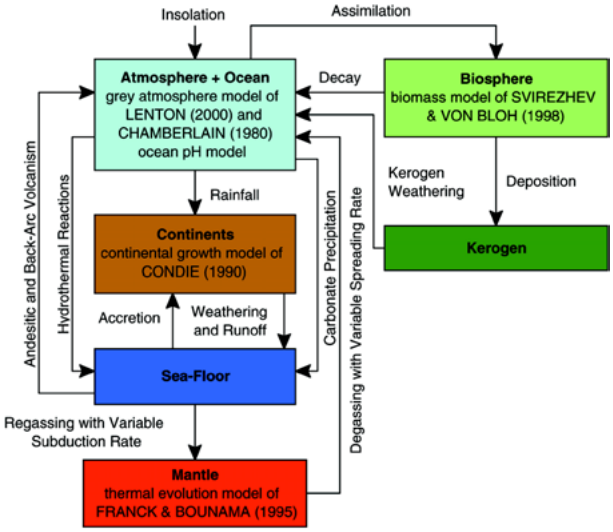


Fig. 4: Six-box model of the global carbon and water cycle. Special attention is given to the parameterization of the weathering process.

Historic Minimum of Surface Temperature

As shown in Figure 5, the present surface temperature of the Earth system is just at a point in its long-term evolution where external forcing of increasing insolation takes over the main influence from geodynamics. The present geological epoch is not only characterized by the lowest global mean surface temperature but also by remarkable biosphere cooling.

Habitable Zones

A simplified version of our integrated systems approach can be used to calculate the habitable zone (HZ) as the band of orbits around a central star where photosynthetic-based life can exist on an Earth-like planet (Figure 6).

Extrasolar Habitable Planets

The combination of our results for extrasolar HZs with new results for the formation rate of Earth-like planets allows us to determine the number of habitable planets in the Milky Way over cosmological time scales (Figure 7)

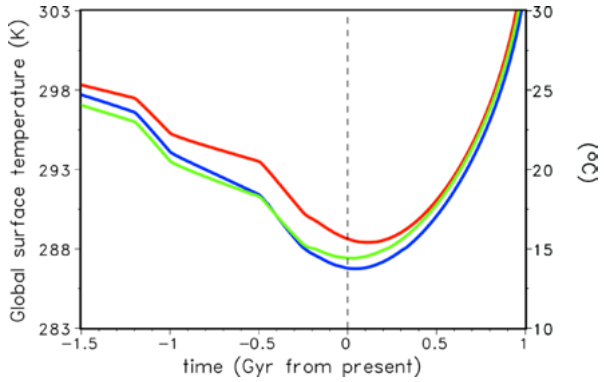


Fig. 5: Global surface temperature evolution. The red line denotes model results without biosphere, the blue line model results with biosphere but without kerogen, and the green one the full model.

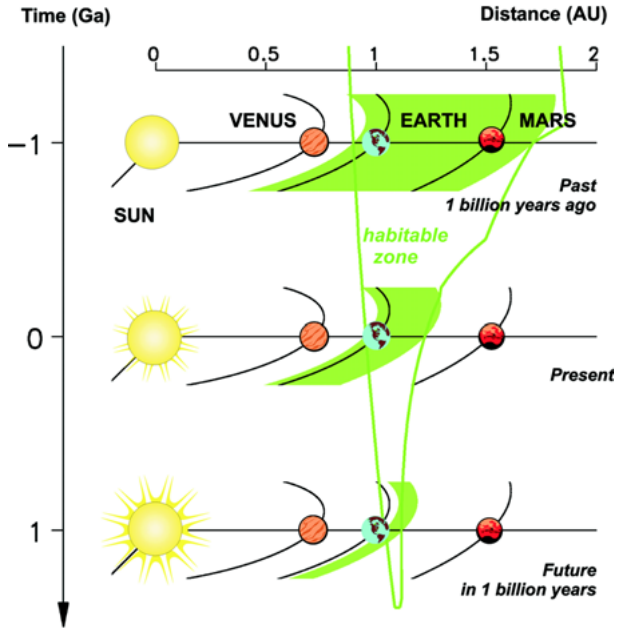


Fig. 6: The evolution of the solar system HZ.

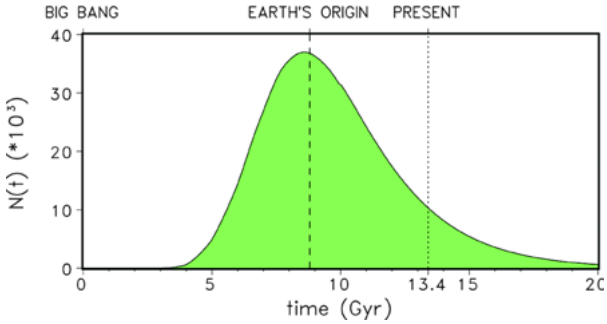


Fig. 7: Number of habitable planets N(t) in the Milky Way over cosmological time with a maximum at the time of Earth's origin.

This project is funded by HSPN and DFG.

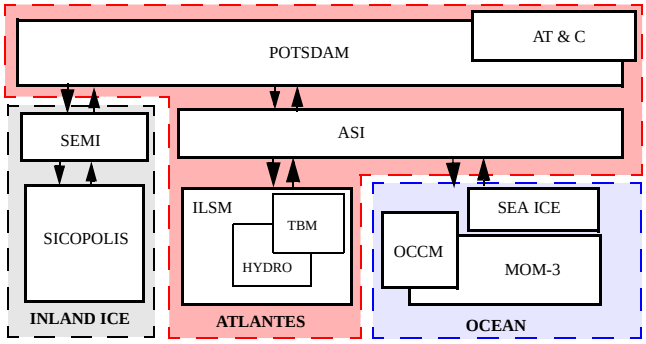
CLIMBER-3
Earth System Model of Intermediate Complexity

Project speaker: Andrey Ganopolski
PIK project members: Victor Brovkin, Reinhard Calov, Martin Claussen, Sergej Grafutko, Matthias Hofmann, Claudia Kubatzki, Miguel Morales Maqueda, Marisa Montoya, Vladimir Petoukhov, Stefan Rahmstorf, Stephen Sitch, Sergey Venevsky.
External project collaborators: Institute of Atmospheric Physics (Moscow).

Motivation

In order to understand the nonlinear dynamics of the Earth system, its past and future evolution, its stability and sensitivity, a new class of computer models is required - Earth System Models. The goal of the project is to develop an Earth System Model of the new generation: CLIMBER-3.

Compared to the CLIMBER-2 model (cf page 63) currently used at PIK for Earth system studies, the new model will be superior in the number of considered processes, degree of realism and spatial resolution. CLIMBER-3 will be used for millennial-scale simulations planned in QUEST (cf page 29) and other related projects.



ATLANTES (ATmosphere, LANd, Terrestrial ecosphere and Surface interface)
POTSDAM (POTsdam Statistical-Dynamical Atmosphere Model)
AT&C (Atmospheric Transport and Chemistry model
ASI (Atmosphere-Surface Interface) worker

ILSM (Integrated Land Surface Model)
TBM (Terrestrial Biosphere Model)

OCEAN
MOM-3 (Modular Ocean Model)
OCCM (Oceanic Carbon Cycle model)
SEA ICE model

INLAND ICE
SEMI (Surface Energy and Mass balance Integrator)
SICOPOLIS (SImulation COde for POLythermal Ice Sheets)

Fig. 8: Principal scheme and main components of the CLIMBER-3 model. Small boxes correspond to individual modules, coloured boxes represent macromodules.

Model Structure and Design

The design of CLIMBER-3 is based on the experience gained in the development and application of CLIMBER-2, as well as the experience of several contributing teams in different fields of the Earth sciences. Although the new model will employ more sophisticated components than CLIMBER-2, it still belongs to the class of Earth system models of intermediate complexity (EMICs). CLIMBER-3 is designed as a scientifically based, internally consistent, and flexible model. The essential features required of the model design are:

- Explicit description of the most important processes and feedbacks.
- Conservation of energy and other substances in the Earth system.
- Direct coupling of the modules without using flux correction and explicit empirical information.

This project is funded partly by DFG, the EU and the McDonnell Foundation.

TOPIK 2 - Management of Singular Events

This TOPIK is concerned with extreme events, such as severe storms, floods or droughts, and with abrupt changes in the Earth system, such as the break-up of a large ice sheet. Meteorite impacts or major volcanic eruptions are further examples of singular events. They are characterized by a major impact or change occurring over a relatively short time, in contrast to insidious trends. Singular events can have a particularly damaging effect on natural and socio-economic systems. This TOPIK aims at characterizing singular events with respect to their mechanisms and potential consequences, at defining and assessing associated risks, and at developing mitigation and adaptation strategies.

GRAIN
Guardrails and Indicators for Climate Protection

Project speaker: Elmar Kriegler
PIK project members: Nico Bauer, Ottmar Edenhofer, Hermann Held, Thomas Kleinen, Elmar Kriegler, Gerhard Petschel-Held.
External project collaborators: Thomas Bruckner, (Technical University Berlin).

Motivation

The GRAIN project addresses the issue of robust climate protection strategies under uncertainty and nonlinearity. How can we account for the large uncertainty about the complex human-environment system? How can we detect possible indicators of nonlinear thresholds? Which structural changes of the socio-economic system are needed to address climate change?

Decision under Uncertainty and Imprecision

The objective uncertainty about climate change can in many cases not be quantified by precise probabilities. Hence we are investigating theories which allow us to capture not only uncertainty, but also imprecision. We are particularly interested in the implications for decision-making; with imprecise information the decision-maker can adopt a range of equally rational attitudes ranging from a pessimist to an optimist perspective. Preliminary results show that the decision-making model behaves rather pessimistically, if there exists an intolerable domain of future developments which has to be strictly avoided.

Indicators of Critical Thresholds

Nonlinear effects, such as bifurcations and thresholds, can be very important for the behaviour of the climate system. As a prominent example we consider the North Atlantic thermohaline circulation (THC). The THC breaks down if the freshwater input into the North Atlantic basin reaches a critical value. This behaviour has been observed both in conceptual models and GCMs.

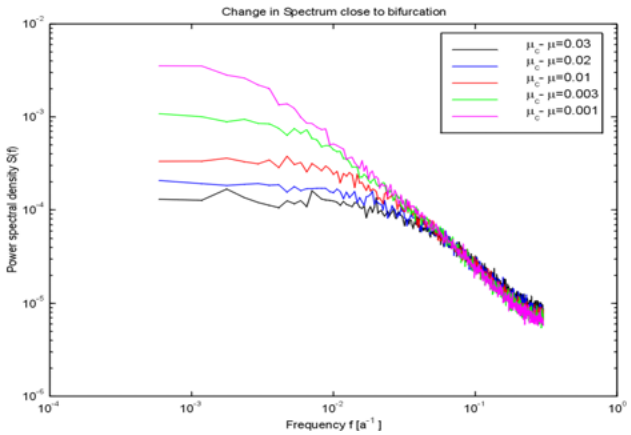


Fig. 1: The "typical" red spectrum becomes much "redder" close to the bifurcation and may even change to an algebraic relationship.

We are investigating the simplest model of the THC, the 2-box Stommel model. The model undergoes a bifurcation at a critical freshwater flux μ_c. We have added a stochastic freshwater flux with mean value μ. Figure 1 shows that the power spectral density of the circulation strength changes markedly when the system approaches the bifurcation. We are investigating whether this method can be applied to other systems and be used as an indicator for critical thresholds.

Technology and Investment

The energy system today is based on fossil fuels. To limit emissions we have three strategic options:
1) Efficiency: increasing the energy efficiency,
2) Substitution: conversion to renewable energy,
3) Sufficiency: stabilizing consumption.

We have built a module of investment and technological development (MIND) that relates technological change to investment in four ways: investment in fossil and renewable energy technologies, and investment in improving energy and labour productivity.

MIND indicates that we could limit climate change by increasing energy efficiency in the short term and substituting the energy system in the long run without excessive welfare losses. We will extend the model in terms of specific technologies and investment aspects.

This project is partly funded by the Volkswagen Foundation.

INTEGRATION
Integrated Assessment of Changes in the Thermohaline Circulation

Project speakers: Stefan Rahmstorf, Carlo C. Jaeger
PIK project members: Franz Badeck, Gerd Bürger, Wolfgang Cramer, Stefan Pohl, Frank Wechsung, Kirsten Zickfeld.
External collaborators: Alfred-Wegener Institut f. Polar- und Meeresforschung (Germany), Institute of Marine Research (Norway), ZMK, Univ. Hamburg (Germany).

Motivation

The risk of serious ocean circulation changes due to anthropogenic global warming has received much public attention in recent years, yet little scientific information exists on the likelihood or the possible consequences of such an event. A complete shutdown of the Atlantic thermohaline circulation would represent a major change in the heat budget of the Northern Hemisphere, as this circulation is believed to warm North-Western Europe by 5-10 °C in the present climate.

The INTEGRATION project aims to analyse uncertainties in projecting ocean circulation changes, as well as to make a first assessment of likely impacts on marine and terrestrial ecosystems and society.

Main Research Goals

The objective of this project is to investigate the risks and impacts of two types of ocean circulation change:

- A substantial weakening of the North Atlantic Current and deep convection by 20-50%, as simulated by most climate models for the coming 50-100 years.
- A (practically irreversible) complete shutdown of convection and the Atlantic thermohaline circulation, as simulated in some "pessimistic" model scenarios for the 22nd century.

Climate Scenarios

Identifying threshold values for a nonlinear change of the thermohaline circulation requires the investigation of a multitude of different multi-century radiative forcing scenarios accompanied by sensitivity studies with respect to major uncertain model parameters. Simulations both with CLIMBER-2 and CLIMBER-3 (cf page 33) will be used for this purpose. Statistical downscaling techniques are applied to define scenarios that are useful for impact assessments.

Impacts on Marine Ecosystems

The North Atlantic is the only high-latitude ocean which experiences an extensive spring diatom bloom which, in its eastern part, is followed by equally extensive blooms of coccolithophorids later in the season. A circulation reduction or collapse may cause alterations in the mixed layer depth and nutrient supply of the ocean and may change the structure of functional groups, and could ultimately lead to a considerable change in the CO_2 uptake by the ocean.

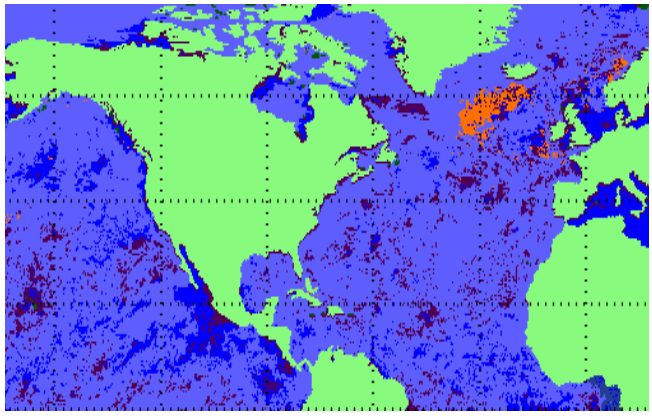


Fig. 2: Satellite-derived image of a plankton bloom in the North Atlantic. The high productivity of this region could be a consequence of the thermohaline circulation.

Large fish populations are adapted to large-scale features of the ocean circulation. Changes in the circulation pattern are likely to affect fish recruitment and population size.
To study these marine ecosystem impacts, models of the distribution of plankton and fish will be developed and applied in the project.

Impacts on Land Ecosystems and Agriculture
The sensitivity of European crop production to a climatic cooling will be explored for a set of major European crops. The investigation will focus on climate-related changes in crop suitability and yield.

Land ecosystems play an important role as providers of food and fibre, for recreation, as part of the hydrological cycle and for biodiversity. Rapid changes of land ecosystems triggered, for example, by rapid nonlinear climate changes could be detrimental for many ecosystem services. With the Lund-Potsdam-Jena DGVM (DGVM = Dynamic Global Vegetation Model) we will simulate the ecosystem structure and its dynamics at continental scale as well as the carbon- and water balance in the ecosystem.

Socio-economic Impacts
We use the integrated assessment model FUND to investigate the possible consequences of a major ocean circulation change. The model assesses monetary damages and simulates welfare changes, e.g., in the forestry, agricultural and water sectors due to ecosystem change.

The project will also determine guardrails for CO_2 emissions (safe corridors) that minimize the risk of major ocean circulation changes.

This project is partly funded by the German Ministry of Science.

WADI
Management of Water Related Disasters

Project speaker: Lucas Menzel
PIK project members: Friedrich-Wilhelm Gerstengarbe, Torsten Grothmann, Holger Hoff, Maarten Krol, Zbigniew Kundzewicz, Martin Welp, Peter C. Werner.
External collaborators: Humboldt University Berlin and the Universities of Potsdam, Marburg and Heidelberg (Germany).

Motivation
There are a number of indications of mankind's growing vulnerability to water-related disasters. The increasing exposure of a growing population settled in areas at risk, human-induced environmental degradation, loss of traditional adaptation strategies and changing lifestyles contribute to a steep rise in mortality and economic damage as a consequence of floods and droughts. Additionally, increasing climatic variability and climate change are expected to affect the frequency and severity of those events.

Scientific Concept
The guiding principle within WADI is the integration of selected branches of research into an inter-disciplinary approach. A first step towards this aim is the definition of common interfaces for data exchange and model coupling. The specific approaches from the individual disciplines will then be combined in an integrated model. This model includes a description of inter-relationships and feedbacks between relevant natural processes and human activities in view of extreme, water-related events. It serves as a tool for risk assessment before, during and after the occurrence of floods and droughts. The overall aim of the WADI project is the application of the integrated model as an expert system in support of risk management strategies in affected countries, jointly with international organizations.

Fig. 3: In December 1999, heavy rainstorms with debris flows and flash floods along Venezuela's coastal areas caused severe property destruction, and resulted in a death toll estimated at 19,000 people.

The implementation of this inter-disciplinary research approach includes the following disciplines: integration and risk analysis, climatology, hydrology and water resources management, ecology, agriculture, medicine, social sciences, economics and remote sensing. The WADI core group consists of a supra-regional research network of German competence centres, including PIK, the Humboldt University Berlin and the Universities of Potsdam, Marburg and Heidelberg.

Additional international partners, i.e. scientists and stakeholders from the case study regions, contribute to WADI through comprehensive assessments of local adaptation and mitigation practices to floods and droughts and the further development and adaptation of scientific methods for the integrated model. One of the case study regions will be in southern Africa, where both droughts and floods occur.

EVA
Environmental Vulnerability Assessment

Project speakers: Wolfgang Cramer, Richard Klein.
Project scientists: Lilibeth Acosta-Michlik, Anne de la Vega-Leinert, Thies Eggers, Markus Erhard, Hans-Martin Füssel, Torsten Grothmann, Jochen Hinkel, Fritz Reusswig, Dagmar Schröter, Frank Thomalla, Söhnke Zaehle.

The EVA Research Questions

The research questions addressed within EVA are those that stakeholders have indicated and will indicate as important. EVA takes a stakeholder approach to its work because it recognizes that science, policymakers, the private sector and the public need to work together to reduce vulnerability to global change.

Each project within EVA has its own set of research questions but the overarching research questions for EVA are as follows:

What will be the combined effects of global change on terrestrial and coastal ecosystems and the functions and services they provide to society?

- How will these changes affect social and economic processes in society and how will they interact with other ongoing developments?
- What capacity do ecosystems and society have to adapt to global change and what opportunities and constraints are there to increase this capacity?

The EVA Projects

EVA approaches these three research questions in the following collaborative, externally funded projects:

- *Advanced Terrestrial Ecosystem Analysis and Modelling (ATEAM)* - Assesses the vulnerability of European ecosystem services to environmental change, using numerical models of ecosystems, multiple scenarios of changing environmental forcings and explicit involvement of stakeholders.
- *Dynamic and Interactive Assessment of National, Regional and Global Vulnerability of Coastal Zones to Climate Change and Sea-Level Rise (DINAS-COAST)* - Develops a CD-Rom based model that allows users to analyse coastal vulnerability to climate change at various scales for a range of greenhouse-gas emission, sea-level rise, adaptation and other scenarios.
- *Socio-Economic Vulnerability to River Flood Events (SEVERE)* - Uses risk assessment and management techniques and takes a stakeholder approach to iden-

Welfare of human society depends on ecosystem services such as drought prevention and promotion of slope stability.

tify differential flood risks and risk perceptions in the lower Rhine Valley in Germany.

- *Security Diagrams: Improving a New Approach to Assessing the Risk of Extreme Climate Events on Society* - Develops a quantitative approach to evaluate the capacity of countries to cope with water crises. Includes a case study in India.
- *Climate Change Adaptation Strategies for Human Health (cCASHh)* - Identifies and evaluates climate change adaptation options for human health in Europe with regard to thermal stress, extreme weather events, vector-borne diseases and food- and water-borne diseases.
- *Indicators for Recent and Future Impacts of Anthropogenic Climate Change in Europe (WAKE)* - Defines indicators to characterize climate change and its impacts in the recent past, the present and the near future in Europe and its regions.

TOPIK 3 - Socio-economic Causes of Global Change

In this TOPIK, we study the human causes of global change. Global change results from the modern, planetary-scale interaction of the anthroposphere and the ecosphere. On the human side, proximate causes are visible, e.g., in the commercial energy system, in world-wide urban dynamics, in the transportation and traffic sector, and in the role of globalized capital and resource markets for overall economic development. Indirect causes may be found in institutional arrangements, in value orientations, and in patterns of knowledge. At present, global socio-economic dynamics are constrained to paths which are not sustainable. We investigate characteristics and causes of these constraints, possibilities for their future evolution, and opportunities to achieve a transition to sustainability.

EUROPA

Project speaker: Ottmar Edenhofer
PIK project members: Maren Ewald, Katrin Gerlinger, Armin Haas, Carlo Jaeger, Marian Leimbach, Ina Meyer, Fritz Reusswig, Detlef Sprinz, Martin Welp.

A Leading Role for Europe?
The EUROPA project addresses the main question: How can Europe take a leading role in global climate protection strategies, acting in an environmentally responsible and in an economically beneficial way at the same time? The European Union is already a key player in international climate policies, and has taken action within the UNFCCC framework. But in order to have a significant impact on the global climate, exclusively European protection strategies may not be effective. Thus it is necessary to think about allies in other regions and/or about the diffusion of effective European measures around the world. Usually, climate protection is seen as a burden, producing additional costs and hampering the economy. The project tries to take an innovation-oriented perspective, looking at economies from a dynamic perspective. It will be embedded in a continuous stakeholder dialogue (cf ECF on page 106) in order to be part of a mutual knowledge transfer to decision-makers in the European Union.

The Research Questions
Three research questions are focal points:
1) Which economic sectors and consumer lifestyle patterns can be identified as main drivers of CO_2 emissions?
2) Which socio-technical innovations and related diffusion processes can engender a substantial reduction of CO_2 emissions?
3) Can Europe play a pioneering role in bringing about such innovations?

These questions are answered by using a wide range of methodological tools from different social sciences. Economic modelling will play a key role, and it has to endogenize technological progress both in the fossil and the renewable energy sectors. Furthermore political and institutional factors that affect the innovative capacity of Europe and the rest of the world are included. Finally, the influence of lifestyles and lifestyle changes as well as their diffusion over the globe are part of the project. EUROPA follows a modelling philosophy that does not aim at one super-model but is based on a modular approach.

First Results
First results show that mitigation costs are exaggerated in conventional integrated assessment models because these models neglect technological change. Once technical change is taken into account, the standard trade-off between economy and ecology may vanish and give way to a world where economic prosperity and ecological stability are no longer contradictory. In particular, a transition of the energy system may even be economically superior to sticking to the present fossil base. If suitably managed, research and development dynamics may bring about this transition without energy prices rising.

In our stakeholder dialogue, it turned out that various business and industry players are well aware of such possibilities and are interested in using them profitably. They develop strategies for their future business and try to anticipate and influence the strategic measures taken by their business partners and competitors and by policy- makers.

A commonly held view is that environmental impacts of human economic activity follow an environmental Kus-

nets curve: with ongoing economic development the environmental impacts and damage increase in a first phase, peak at some time and decline thereafter due to gains in economic efficiency and an increased environmental awareness of consumers. This idea crucially depends on the evolution of lifestyles and the consumption patterns induced by them. Therefore, we consider the study of lifestyles an important step towards answering the research questions of the EUROPA project. To perform such an assessment, we plan, e.g., to model the dynamics of car passenger transport and car use induced by different scenarios of lifestyle patterns.

GLOREM
Global Water Resource Modelling and Managing

Project speaker: Uwe Haberlandt
PIK project members: Thomas Beckmann, Axel Bronstert, Andreas Güntner, Valentina Krysanova, Zbigniew Kundzewicz, Matthias Lüdeke, Lucas Menzel, Stephen Sitch, Martin Welp.

Population growth, the overall increase in water consumption, and climate change are some of the driving forces causing water stress. For these and other reasons, fresh water is becoming an ever-more limited, and sometimes even contested, global resource. In many climate models and climate impact studies the assessment of freshwater resources and their management by social actors and systems is an underdeveloped issue, however. The GLOREM pilot project was launched in order to close this gap.

It had three main purposes: (a) to review approaches for global freshwater resources modelling and management; (b) to define research requirements in the TOPIK framework related to global water; and (c) to develop a scientific concept and a specific proposal for a regular water project at PIK.

Sub-groups reviewed global water availability models, studies on global water use and different types of criticality measures in global water assessments. One sub-group systematized management options related to global water problems and further elaborated the link between the Syndrome approach (cf SYNAPSE in this report) and water management. The project identified crucial limitations and missing components in current modelling efforts, and the group suggested that future water-related research at PIK should in the first step focus on water for agriculture and the food trade, and the implications of land cover changes and human use on water resources.

BEAR
Biodiversitiy and Nature Protection Enhancement through Participatory Action Research

Project speaker: Susanne Stoll-Kleemann
PIK project members: Fritz Reusswig, Julia Schwarzkopf, Martin Welp, Volker Wenzel, Birgit Soete.

The biosphere is not only a bio-geophysical reality, it is a social reality as well. The BEAR project treats the biosphere and its protection from a social science viewpoint, following two major lines of research. First, we investigated nature conservation areas in Germany and South Africa as social settings, looking for organization-related and communication problems in protection strategies.
In a second line, we focused upon "nature" and "nature conservation" as social constructs and asked how these constructs are linked to different social groups within Germany. The lifestyle concept, common in sociology and marketing research, was used here in order to build a typology of eight lifestyle groups and to identify their different preferred views of nature and nature protection. The lifestyle research is funded by the German Federal Agency for Nature Conservation (Bundesamt für Naturschutz, BfN). We discovered a communication gap between conservationists and the general public. Conservationists - often natural scientists by training - tend to focus upon scientific and moral arguments when it comes to justifying the necessity for nature conservation, whereas society prefers a (cultural) identity and sustainable use point of view.

TOPIK 4 - Emergence of a Global Subject

The management of global change requires a subtle interplay between the most diverse political strategies and millions of "rational" everyday decisions. Out of this arises, through worldwide communication, something like a planetary will, which may be symbolized as a fictitious Global Subject. The interactions between very different actors play a decisive role in this, since, e.g., the effectiveness of climate protection programmes depends to a critical degree on the economic planning of politicians, multinational concerns and protagonists of the financial markets. The projects in this TOPIK investigate how the Global Subject may develop in order to increase, i.a., the efficiency of global environmental management. The tremendous progress made in all globalizing technologies such as the internet and air traffic will be the primary focus of attention here, but also of the growing number of global environmental institutions and organizations as well as the intensified dialogue between scientific communities and decision-makers.

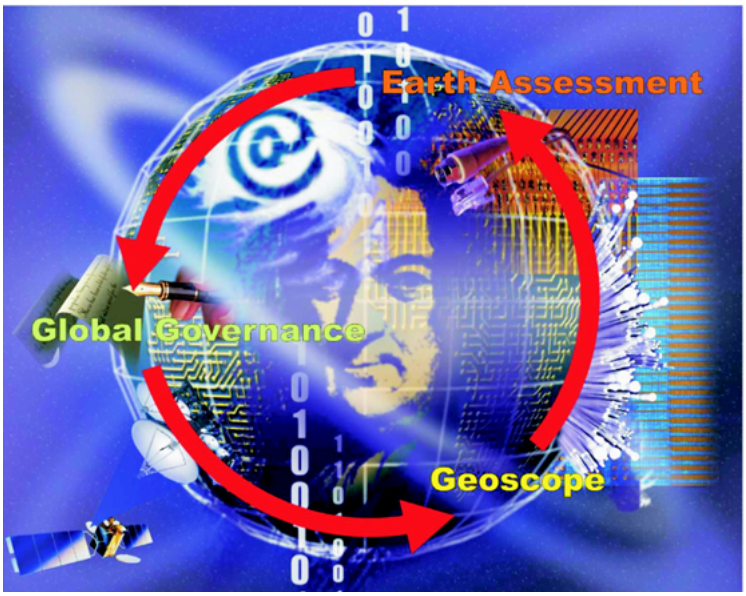


Fig. 1: Cartoon of the Global Subject as a trinity of scientific assessment, global governance and observation. Modern communication technologies, scientific understanding, and global co-operation might be seen as the neural system of the Global Subject.

PIAM
Potsdam Integrated Assessment Modules

Project speaker: Carlo C. Jaeger
PIK project members: Ottmar Edenhofer, Rupert Klein, Gerhard Petschel-Held.

Overview

The third generation of integrated assessments has to be organized as a modular process. Within this structure, modules are developed as separate units to be coupled in accordance with the questions raised by decision-makers. With well-defined interfaces between modules, a fruitful competition between different modules becomes possible. This is more productive than competition between monolithic integrated assessment models and it promotes co-operation between different disciplines and different institutions.

The Modular Approach

To assess problems of global environmental management, often rather complicated integrated assessment models are set up. Their features make them difficult to comprehend, thus limiting both their potential use by stakeholders and their further improvement by scientists. To tackle this problem, PIAM aims at integrating comprehensible modules in a comprehensible way.

PIAM has the potential to integrate different modelling activities emerging in different PIK projects. To operationalize its approach, PIAM has to tackle questions of interface support, modularization and coupling of existing modules. To accomplish its task, PIAM provides a software platform with the following characteristics:

Modularity

The different modules are exchangeable with different versions coming from different sources. The modules can be written in different programming languages. Figure 2 shows an example based on different versions for modelling the climate system, the biosphere, and the global economy.

Standardization of Interfaces

In order to integrate different modules, the interfaces between them must be well-defined. Every research group must comply to these interface definitions, but is free to design the internal structure of the module according to their specific modelling approach.

Mode of Interaction

The modules are integrated by an object-oriented platform which can operate both in simulation mode and in optimization mode.

Exploring Uncertainty

The PIAM concept allows us to explore uncertainties about the structure of its individual modules and helps us to assess parametric uncertainties in a standardized way.

Some of the modules are based on existing programs modified so as to fit the modular structure. Other, new modules are developed in cooperation with various PIK projects. As a rule, PIAM puts a strong emphasis on decision-making in the face of climatic risks.

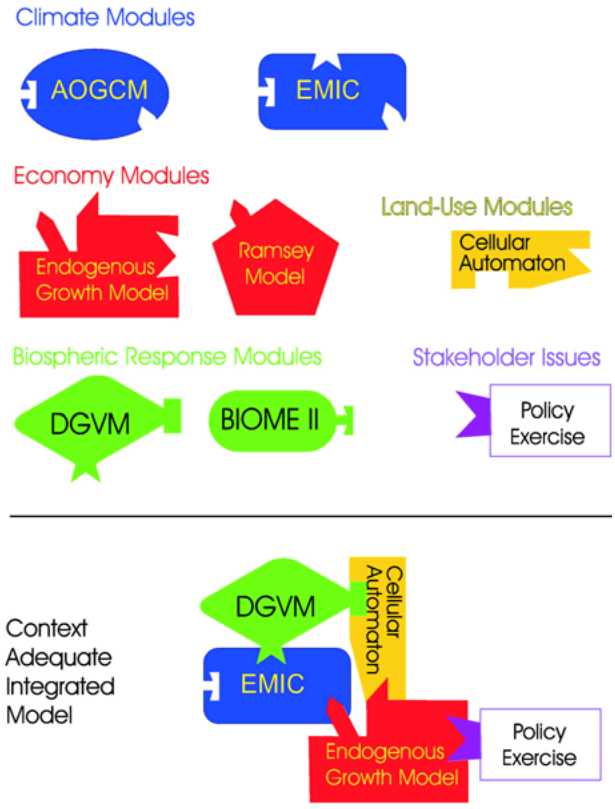


Fig. 2: Modularity represents the basic strategy of PIAM. By implementing an interface standard, it becomes possible to integrate modules for a specific context or policy question.

GloGov
Global Governance

Project speaker: Frank Biermann
PIK project members: Bernd Siebenhüner (deputy project leader), Aarti Gupta (visiting fellow, 2000/1), Lilibeth Acosta-Michlik, Torsten Grothmann, Richard Klein, Gerhard Petschel-Held.
External collaborators: Columbia University's Center for Science, Policy and Outcomes; Environmental Policy Research Unit of Free University of Berlin (Germany); Institute for Economic Research; Joint Global Change Research Institute of the Pacific, Northwest National Laboratory and the University of Maryland; Harrison Program on the Future Global Agenda of the University of Maryland at College Park; Harvard University; Oldenburg University.

Research Tasks

The Global Governance Project analyses international institutions, organizations, actors and political processes that influence the emerging system of global environmental governance. The focus is on questions of institutional and organizational effectiveness, learning processes in environmental policy, inter-linkages, and equity. Analytical tools are qualitative social science methods, like structured case studies, as well as legal analysis.

Subproject MANUS - "Managers of Global Change: Effectiveness and Learning of International Environmental Organizations"

Recent scholarship has questioned the adequacy of the organizational framework for global environmental governance. Some authors call for far-reaching reforms, including the establishment of a "world environment organization", while others argue in favour of an incremental improvement of decentralised systems. Little research, however, has yet been directed to an in-depth analysis of international environmental organizations. How effective are international environmental organizations, after all, and in what ways can they improve their effectiveness and "learn"? How can mathematical modelling techniques such as qualitative modelling help in understanding these processes? To explore these questions, the Global Governance Project has set up this new sub-project. The project will be supported by the Volkswagen Foundation under its transdisciplinary environmental research programme. MANUS is linked to the emerging political debate on the reform of international environmental governance and on strengthening the United Nations system in the field of sustainable development.

Subproject MOSAIC -"Multiple Options, Solutions and Approaches in Climate Policy"

In climate policy we observe the emergence of several parallel policy approaches that encompass equally important segments of international society and that may develop into parallel regulatory mechanisms and regimes. We are witnessing, in a sense, a 'mosaic' of different climate policies. This situation poses significant challenges. A lack of uniform approaches may jeopardise the success of the segmented policies adopted by individual coalitions, and the possibly strong economic implications of a stringent climate policy adopted by one coalition of states may have severe ramifications for other policy arenas, most notably the world trade regime that unites both the 'Kyoto coalition' and the 'anti-Kyoto coalition'. On the other hand, an international climate policy mosaic may have several advantages: it could allow, for example, for the testing of innovative policy instruments in some nations, with subsequent diffusion to other regions. Thus, an urgent need exists to explore the likely consequences of parallel approaches and regimes in climate policy and to analyse what response strategies policy-makers could avail of. To this end, the Global Governance Project is initiating this new sub-project.

Other Research Areas

- *Science and Global Governance:* Here we explore the interface of science and politics, for example regarding the "effectiveness" of the IPCC.
- *Environment and Security:* Several studies have suggested that environmental degradation will lead to an increase in the number of violent conflicts within and among states. Is that so? Apart from smaller studies on environmental security and migration, GLOGOV addresses these issues mainly in collaboration with the Security Diagram sub-project under EVA.
- *Power and Ecological Interdependence:* Traditional theory of international relations understands the power of nations in terms of material indicators, such as military might, industrial production, or population. The global environmental crisis, in particular climate change, forces a change in this traditional conception to include additional factors, such as "environmental power", in the equation.

GPP
The Geoscope Preparatory Project

Project speaker: Wolfgang Lucht
PIK project members: Carlo C. Jaeger, Hermann Lotze-Campen.

Research Aims: Observing the Anthropocene for Sustainability Science

Achieving a sustainability transition is a major challenge to global society. Meeting this challenge requires new theories and new data - data of a type that we currently do not have. This includes time series to monitor management and policy measures aiming at sustainability. It has to merge satellite data with on-the-ground social research and to look at the whole of the earth system, emphasizing the human dimension. It should be derived from theories that may guide economic development to sustainability and include data and theory capable of generating new images of our world in transition. In other words: a Geoscope.

A Sustainability Geoscope

Sustainability Geoscope is a national and international initiative co-ordinated at PIK for creating a multi-faceted instrument to serve as eyes for sustainability science. The instrument is to be designed to observe the world at the global scale, combining regional in-depth studies within a global theoretical, mental and methodological framework. The Geoscope is to observe the anthropocene: the rapidly approaching time period characterized by far-reaching fundamental interactions between the human and the natural systems of the planet, their variability and their change. To be based upon a large spatial sample and observed time series of key variables, and on a combination of satellite remote sensing with on-the-ground data, a Sustainability Geoscope is essential for constructing, validating and operating next-generation theories of sustainability in the world's economies and societies, for deciding between competing pools of current and future theories concerning the sustainability transition, and for integrating the human dimension into analyses of the variability and vulnerability of natural systems. It is to be built upon comparative regional studies of measures and actions affecting sustainability.

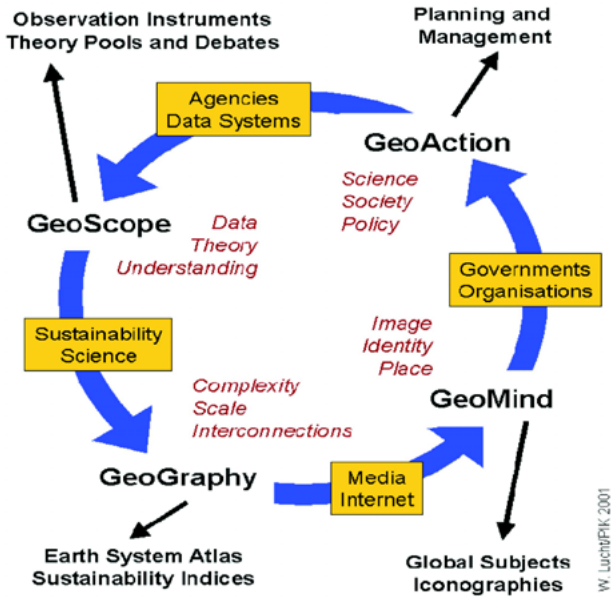


Fig. 3: Elements of a strategy for Sustainability Science. Activity in observational, analytical, mental and political categories is required to make the interplay between science and society successful. The Sustainability Geoscope is one element of this web of action and interaction. (Copyright W. Lucht, PIK, 2001).

First Steps Toward a Geoscope

A Sustainability Geoscope has to be built step by step. First steps are becoming a reality at PIK, on the national level, and internationally. On behalf of the National Committee on Global Change Research, a series of two national, one international and one mixed national/international workshops on the Sustainability Geoscope have been held in the year between November 2000 and November 2001. The three goals of these workshops were (1) to substantiate the structure and content of a Geoscope instrument, (2) to develop a research framework for a German Sustainability Geoscope research programme to be submitted in various parts to national funding agencies, and (3) to integrate the Geoscope initiative into the internationally emerging global change science focus on sustainability. These workshops were a great success, bringing together a diverse community in discussions of next-generation observation strategies, and establishing the Geoscope concept as part of the ongoing debate on next steps. At PIK, this effort is being co-ordinated while work has begun to investigate through basic research the following themes in the upcoming period with a view toward the Geoscope: interaction between the biospheric water cycle and human water demand, interaction between agricultural demand, the economic system and the global carbon cycle, and interaction between the biosphere, lifestyles and storylines of technological development (www.sustainability-geoscope.net).

This project has been funded by PIK and partially by the German Ministry for Education and Research under the "Climate, Vegetation and Carbon (CVECA)" project of the DEKLIM programme.

TOPIK 5 - Regional Simulators

Different regions are likely to face varying impacts of global change and are likely to respond differently to similar challenges. The vulnerability of a region and the people living there will depend on their ability to act and adapt to these challenges. This TOPIK aims at developing and applying region-specific models to simulate especially the consequences of planning decisions, their effectiveness and possible non-sustainable side effects. To achieve this goal, the relevant ecological, social and economic processes will be identified and assessed, appropriate sub-models will be selected or developed, and integrated. The resulting Regional Integrated Models are problem-oriented representations of the actual state of scientific knowledge. A Regional Simulator adds two further elements: one is the use of appropriate indicators to detect relevant deviations between real development and simulation. The other is an interface with users inducing feedback between simulation and real decision-making.

BEST
Brandenburg Simulator of Environmental and Societal Transformations

Project speaker: Frank Wechsung
PIK project members: Maarten Krol, Valentina Krysanova, Petra Lasch
External project collaborators: H. Rosé (FhG-FIRST).

Introduction

The State of Brandenburg, Germany, will undergo significant transformations in the coming decades, including those resulting from internal processes such as population ageing, and external drivers including climate change, globalization and extension of the EU. The general aim of BEST is to construct a regional simulator which makes possible the assessment of historic and plausible future long-term transformations in Brandenburg.

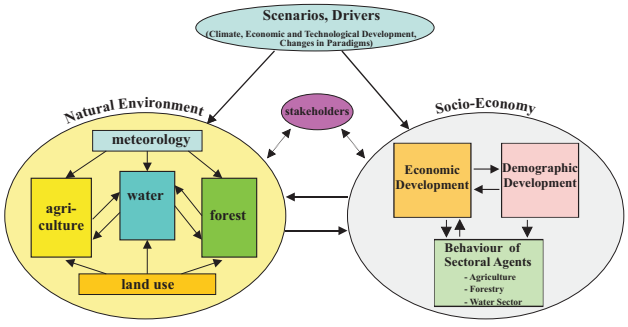


Fig. 1: Structure of the modelling approach.

Central foci of integration are water, the landscape and mankind's use of natural resources, in studying

- transformations of the landscape in Brandenburg as driven by international and national changes in the agricultural and forestry sector, or by changes in climate. These changes have impacts on ecosystem productivity, the water balance and carbon balance.
- effects of liberalization of agricultural markets and of EU policies, that could lead to a strong decrease in cropping area or cropping intensity.
- population dynamics in Brandenburg, characterized by a decrease and an ageing of population, leading to shifts in regional demand for natural resources, e.g. through impacts on settlement development.

Concept of the Regional Simulator

The natural environment is represented by spatially explicit models of the dynamics of the water cycle, agrosystems and forestry under climate and land use forcing. To describe the hydrological cycle, vegetation, soil erosion, and nutrient cycles at the river basin scale, the SWIM model is used. Forest succession, productivity and carbon balance are simulated using the forest model 4C. Socio-economic elements will be represented at the macro level (demography and economic growth). Agent-based models of agriculture, forestry, and the water sector will simulate decision-making on natural resource use. A demographic cohort model reflects socio-economic conditions affecting fertility and mortality. At the technical level, models are coupled in a scheme of open linkages, where the models can run in parallel with structured interfaces and centralized model control, developed in co-operation with the Fraunhofer-Institut für Rechnerarchitektur und Softwaretechnik.

Applications

Examples of the basic causal chains that will be studied in applications of the regional simulator are:

External drivers		Consequences		
climate change	⇒	water availability crop yield forest production carbon sequestration	⇒	sectoral economic output environmental quality tourism
globalisation/EU - effects on agricultural policy and markets	⇒	changes in intensity of agriculture	⇒	water quality water availability economic output
EU-extension	⇒	migration, population land use for settlement	⇒	water availability landscape attractiveness
decline in brown coal mining	⇒	water availability	⇒	water quality tourism

GLOWA-Elbe, funded by BMBF, and Grobraster, funded by the VW Foundation, are intensively intertwined with BEST.

Preliminary Results

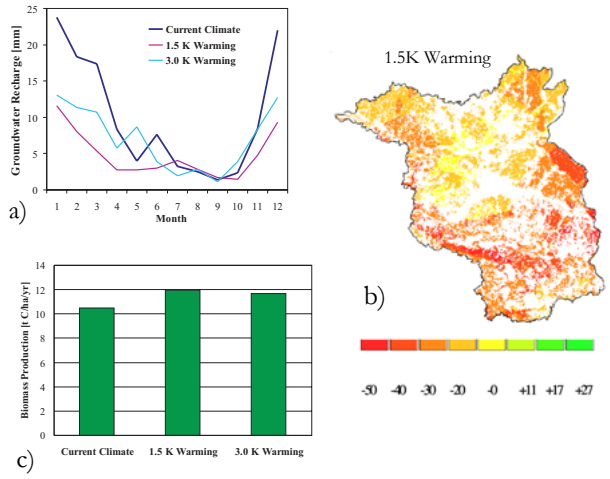


Fig. 2: Examples of climate change impacts on Brandenburg up to 2030: average groundwater recharge (a), percentage change in winter wheat yield (b), and mean annual biomass production of a pine forest stand (c).

SYNAPSE
Syndrome Assessment and Policy Strategy Evaluation

Project speaker: Gerhard Petschel-Held
PIK project members: Klaus Eisenack, Jürgen Kropp, Matthias Lüdeke, Fritz Reusswig
External project collaborators: Inst. for Geography, University of Marburg (Germany), Dept. of Economics, University of Oldenburg (Germany).

Rationale

Within the Syndrome Approach processes governing the dynamics of non-sustainable global change are decomposed into patterns of human-nature interactions. Syndromes emerge from incompatibilities of political and socio-economic processes of human use of nature on the one hand and natural processes of resilience, recovery, and renewal on the other. They are stabilized by internal interactions and represent entities of the coupled human-nature system.

Methodology

Pattern modelling requires a generalizing technique representing whole classes of (fictional) conventional regional models. There are, however, no such regional models and it might be misleading to assume there ever will be. Thus we need to define the classes by specifying the *common* properties without the models. This is done with help of qualitative differential equations (QDE, see QUIS), which characterize classes of functional relations in terms of monotonicity properties.

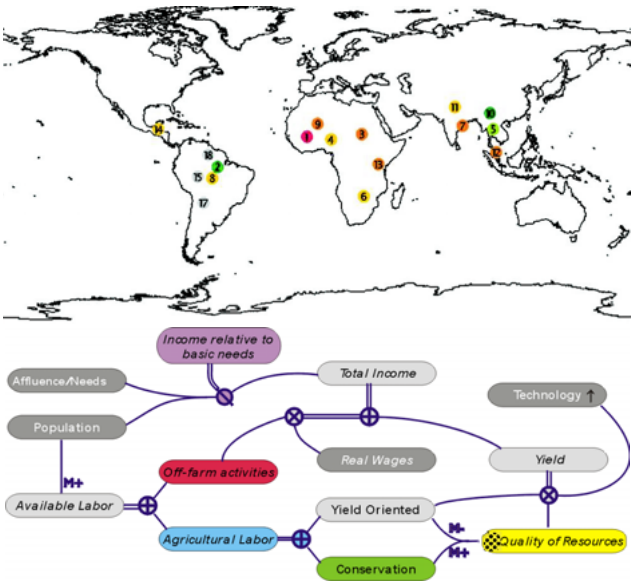


Fig. 3: Location of land-use case studies used so far (upper panel) and generalizing qualitative model (lower panel). The colour indicates the criticality of the region where red indicates high values and green low values.

Land-use Change in Developing Countries

Land-use change is particularly suited for pattern analysis. Work has focused on the syndrome-based analysis of deforestation on the one hand and the modelling of local decision-making of smallholders on the other. Based on a set of presently 15 case studies (see Figure 3), a qualitative model has been developed to integrate the case studies. The model exhibits the mechanism of the Sahel Syndrome (see SYNAPSE) to be related to the interplay between an *increasing* rate of soil degradation and a *limited* rate of yield increase due to social, economic and environmental circumstances.

Overexploitation of Marine Resources

The global pattern of overfishing has been examined with a focus on capital accumulation. Extending previous bio-economic models by QDEs, time series of resource use were reconstructed and general problems of fishery development identified (Figure 4). The generalized character of the model allows general conclusions for policy action. Model results show that a fishery needs perpetual adjustment, because the disaster case cannot be reliably avoided under the usual normative framework. Yet the adjustment should not be restricted to a single policy (e.g., catch quotas), but comprise a policy basket.

Further work will integrate alternative regulatory frameworks and improve the decision-making module. This will provide direct advice for the EU fisheries policy.

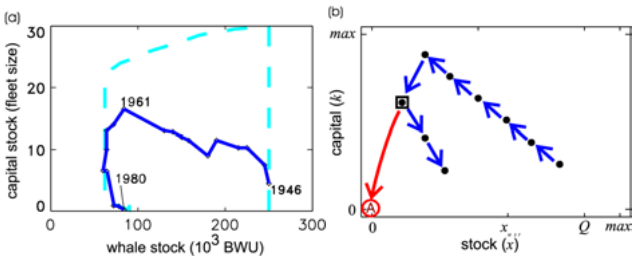


Fig. 4: Phase plot (a) of the development of the blue whale hunting industry (solid line), compared to results of former models (dashed line) and our qualitative model (b). The red arrow corresponds to the disaster case, emerging from the critical branching point.

Outlook

As well as further work in the two fields of syndrome analysis described here, a new focus will be on environmental issues of urban sprawl. This will be the subject of an EU project utilizing underlying case studies for which research is already ongoing.

ReCSim
Regional Climate Simulation Models

Project speaker: Rupert Klein
PIK project members: Nicola Botta, Friedrich-Wilhelm Gerstengarbe, Detlef Hauffe, Martin Kücken, Susanne Langenberg, Antony Owinoh.
External project collaborators: U. Böhm (Univ. Potsdam), G. Doms (DWD), U. Schättler (DWD), J. Steppeler (DWD), B. Rockel (GKSS), K. Keuler (BTU Cottbus).

The Climate-Limited Area Model CLM

Regional climate modelling refers to the practice of nesting a limited area model (LAM) in a general circulation model (GCM) to infer the combined impact of global driving fields and small-scale forcings on the climate of a region. This project will provide PIK with such a dynamic regionalization tool as a contribution to general integrated assessment technologies. PIK has joined the German climate research community in developing such a regional climate model (CLM) based on Deutscher Wetterdienst's Local Model (LM).

Operational Framework and Statistical Analysis

The first activity within ReCSim contributes an operational framework suitable for long-time computations and the associated data analysis, modern statistical and non-statistical validation schemes, and improved parameterizations. This is the basis for comprehensive model intercomparison and the validation of the new regional climate model against real data.

Figure 5 illustrates our new statistical cluster analysis tools by exhibiting the result of a spatial error estimation. The production of these results required the regional adaptation of the model, the development of software to drive the LAM with global analyses, as well as the incorporation of the group's statistical analysis tools within the CLM-operational framework.

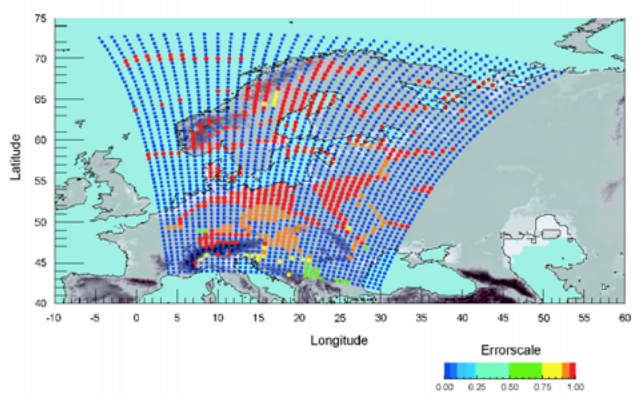


Fig. 5: Spatial error distribution of the comparison of the LM forecast version versus a three-month analysis period.

Numerics for Regional Climate Models

Regional climate models are often derived from numerical weather forecast models by extending and adjusting the parameterizations of unresolved processes to account for climatic scales. Although appealing, this approach has several shortcomings associated with the numerical and statistical methods used, and this is the focus of the second ReCSim activity. An example of our efforts concerns the elimination of the computationally expensive lateral and vertical sponge layers usually employed in LAM-GCM coupling. Figure 6 shows preliminary computations done with "spongeless" radiative boundary conditions. Our numerical flow solver requires a reference direction for evaluating numerical fluxes for mass, momentum, and energy. A directionally adaptive

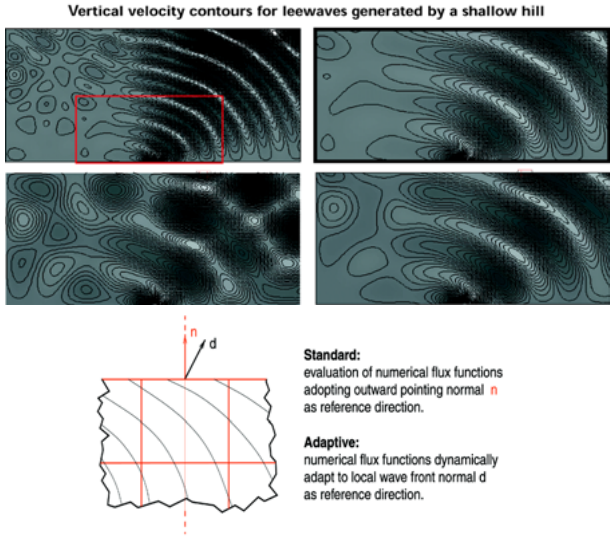


Fig. 6: Non-reflecting boundary conditions for non-hydrostatic compressible models based on rotated boundary Riemann problems.

flux computation is used near the boundaries aligning the reference direction with the gradient of vertical velocity. The result (lower right) is compared with the standard approach (lower left), and with the adaptive boundary condition on an enlarged domain (top pictures).

This project has been funded in part by the Deutsche Forschungsgemeinschaft, grant KL 611/6.

TOPIK 6 - Sectoral Climate Sensitivity

The projects within this TOPIK address the climate sensitivity of relevant ecological systems and economic sectors. Using special-purpose methods and models, the probable reactions of those exposure units to consistent global-change scenarios are quantitatively explored. The investigations focus on issues that have particular need of additional studies, such as the consequences of global warming for the European wine production and marketing system or the opportunities provided by alternative management strategies for temperate forests.

SAFE
Sensitivity and Adaptation of Forests in Europe under Global Change

Project speaker: Petra Lasch
PIK project members: Franz-W. Badeck, Thies Eggers, Ylva Hauf, Beate Klöcking, Marcus Lindner, Peter Mohr, Jörg Schaber, Felicitas Suckow.

Introduction

The overall objective of the project is the analysis of likely impacts of global change (CO_2 increase, nitrogen deposition, climate change and relevant socio-economic trends) on forests in Europe. Changes in growth and productivity of forest species may influence the competitive relationships among the species, the carbon sequestration, water budgets and biodiversity at local and regional scale. The project is focused on the integrated evaluation of the multi-functionality of natural and managed forests including economic and other social impacts of global change. Alternative management options are evaluated for different future scenarios.

Integrated Forest Sector Impact Assessment

An integrated impact assessment is based on linking:

- ecosystem dynamics,
- decision-making in forest management,
- wood production and socio-economic consequences,
- impacts of climate change and management on ecosystem services like carbon storage, water protection and yield, biodiversity, and recreation.

Using the physiology-based forest dynamics model 4C (Forest Ecosystems in a changing Environment) the effect of management intensity on carbon storage of forests in Germany was investigated. 4C was applied to 12 forest stands of pine, spruce, beech, oak and mixed spruce-pine in 6 forest growth regions. The application of three harvesting strategies leads to differences in total carbon storage over a period of 60 years. Current thinning practices (corresponding to the 5% scenario) do not strongly reduce the storage capacity (Figure 1).

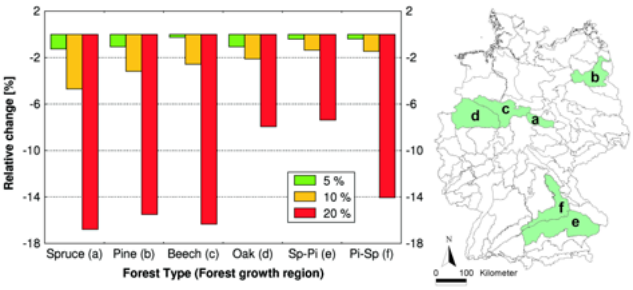


Fig. 1: The model stands are situated in 6 forest growth regions of Germany (map, right). Site data were provided by the BMBF project 'German Forest Sector under Global Change' (cf completed projects, CHIEF). Removing woody biomass by 5, 10, or 20% every five years resulted in reductions of total carbon storage (biomass, soil, removals) in comparison with carbon storage of an unthinned forest. In this case more carbon was stored than in any of the management scenarios.

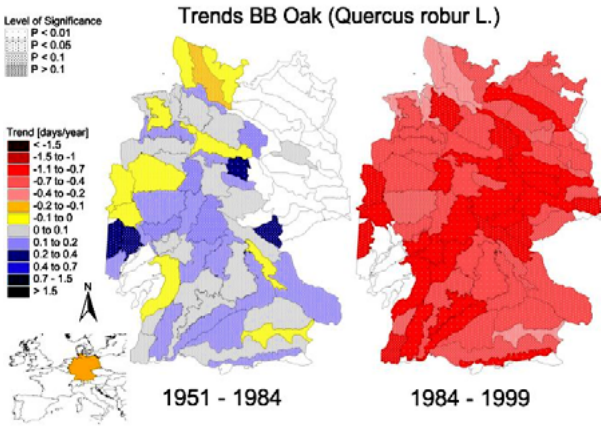


Fig. 2: Bud burst of oak at two periods in Germany.

Phenology

Growing season length and especially the start of the growing season marked by bud burst has substantial impact on the annual carbon balance of trees. Analysing records of bud burst in Germany from 1880-1999 showed that at the regional level the global warming sig-

nal is masked by multidecadal climate fluctuations. Consistent cooling trends of April temperatures in Germany between 1951 and 1984 and a warming from 1984 to 1999 led to both a delay and an advancement of bud burst for trees with bud burst in late spring (Figure 2). Early flushing trees showed an increasingly advanced budburst leading to a possible competitional advantage over late flushing spring trees. Models of bud burst were developed to incorporate this important aspect into simulations of ecosystem dynamics and carbon balance.

This project has been partly funded by BMBF and the EU.

CLAWINE
Climate Adaptability of European Wine Production

Project speaker: Manfred Stock
PIK project members: Wilfried Ahrens, Franz Badeck, Antonella Battaglini, Friedrich-Wilhelm Gerstengarbe, Peggy Gräfe, Thomas Kartschall, Gerhard Petschel-Held.
External collaborators: DWD-Geisenheim, Schloß Johannisberg (partners 2-25 cf Figure 3).

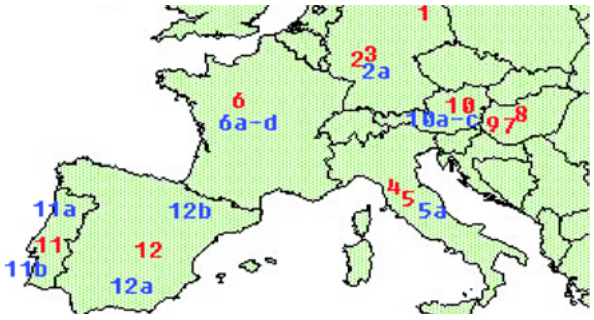


Fig. 3: Location of project partners, with 12 scientific and 14 producing partners.

Objectives

The overall objective of CLAWINE is to the evaluate the role and potential of European wine production in the context of climate change. Wine plays a key role for the economy of several regions. Grapevine is grown under conditions often termed marginal for agriculture, thus it is vulnerable to climate change. CLAWINE will develop and evaluate necessary adaptation measures by:

- correlating grape yield/quality and environment,
- downscaling climate scenarios for selected regions,
- assessing risks,
- estimating necessary adaptation costs.

The main goal is a grapevine decision support system. The work will be done within five work packages (Figure 4). It is planned to disseminate the results to policy-makers, advisors, organizations and wine producers through involvement in the project and knowledge transfer.

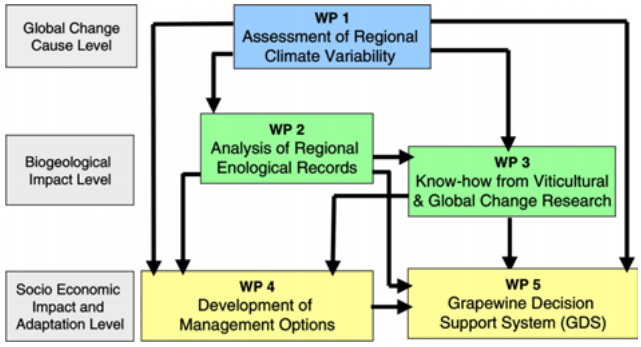


Fig. 4: Information flow chart from climate change to phenological and socio-economic impacts and management decisions.

Results in 2000 and 2001

1) A climate scenario (period 2001-2050) for the Rheingau region based on weather records from 1951-2000 was generated and distributed to the partners.
2) Using this scenario, impact studies on phenological development for *Riesling* have been conducted. They indicated an acceleration of phenology by 10-14 days. This tendency is also visible in harvest data from 1950-2000 (Figure 5). Such a shift is capable of endangering the typical character of the Rheingau Riesling, because of:
   - early maturity, shifting vintage to mid September; and ripening under higher night-time temperatures,

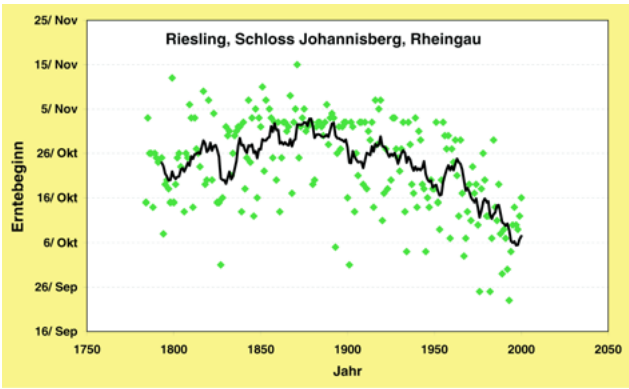


Fig. 5: Effect of climate change on start of harvest in the Rheingau.

resulting in unbalanced sugar/acid ratio and flavour contents.

3) A preliminary study on conceptual basics for the Grapevine Decision Support System was conducted.

Outlook for 2002 and 2003

Homogenous data sets/climate scenarios for all included regions will be built up. Analogous studies of impact on phenology for the typical varieties in these viticultural areas will be conducted. A socio-economic/management questionnaire will be developed, distributed and evaluated. Existing grapevine and physiological submodels will be integrated for detailed impact studies.

AIM
Agriculture emphasising Integrated Modelling for Morocco

Project speaker: Gerd Bruschek
PIK project members: Gerd Bruschek, Ylva Hauf, Frank Wechsung.

Introduction

AIM translates weather extremes and climate shifts into changes of agricultural production and assesses the combined effects of these. Integrated assessments include here second order effects of changes in agricultural productivity on the economic sector on the micro- and macro-scales, and the ecological consequences related to the changed extent and intensity of agricultural production. In the case of Morocco, we take the example of an extremely marginal situation for both climate and society to explore climate-related response patterns in the economic and social spheres of regions which strongly depend on agricultural production. We explore not only the current nature of the problem but also attempt to improve the ability to adapt to year-to-year climate fluctuations by improved medium-term precipitation and yield predictions.

Morocco

38.6% of Morocco's population depend directly on agriculture for their livelihood. The mean agricultural share of the Gross Domestic Product (GDP) amounts to 16.6%. 21.5% of the total land area can be used for arable and permanent crops. The cropping season for the two major cereals, wheat and barley, lasts from December to May in a sub-humid to arid climate. Morocco maintains one of the world's highest wheat consumption rates per capita for food supply (202 kg/yr in 1996). Self-sufficiency in wheat (ratio of production to domestic demand) fluctuated between 111% in 1968 and only 19% in 1995. The variability in wheat yield explains almost all of the year-to-year fluctuation of the wheat self-sufficiency rate during recent years.

Research Tasks

- Integration of empirical relationships between climate modes and precipitation, crop yields and other second order effects (i.e. year-to-year fluctuation in water storage and availability, hydro-energy production, irrigation, food imports, port capacity requests, unemployment rate, disposable income, gross domestic product) based on teleconnections.
- Identification of typical qualitative response patterns to climate-related shifts in precipitation and crop production potential for marginal developing countries, in particular at semi-arid sites.
- Regular prediction of year-to-year fluctuations in Morocco's precipitation, cereal yields and related second order effects.
- Monitoring the reliability of predictions and the effect of those predictions on adaptation measures.

Results

A system of prediction measures was developed which delivers estimates of changes in cereal yields (wheat, barley) in comparison to the previous cropping season for

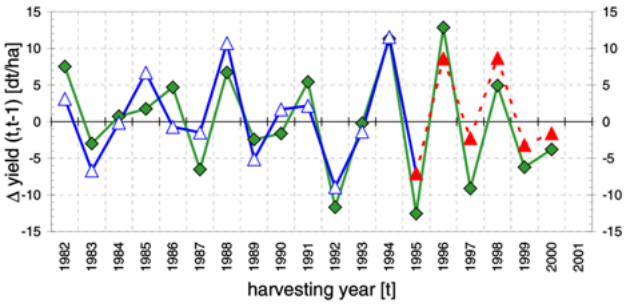


Fig. 6: Comparing year-to-year changes in Moroccan national observed wheat yield (filled rhombus) for 1982-2000 with simulated changes using MID a) in 1982-95 (open triangle), the period the model was calibrated to; and b) in 1996-2000 (filled triangle), when the model was run in a predictive mode.

the coming harvest. Predictions will be supplied for the crops wheat and barley and for the mean cereal yield before planting, shortly after planting and at mid-season by the statistical models PRE, POST and MID. PRE is based on correlations between pre-planting Atlantic sea surface temperatures (SST) and yield, POST uses correlations between the NAO (North Atlantic Oscillation) at planting time and local precipitation to calculate first the change in precipitation, and from that the alteration of yield, and MID (Figure 6) derives a yield change estimate from the NAO between planting time and mid-season.

TOPIK 7 - PIKuliar Culture

PIK operates in a vast scientific field - global change and Earth system analysis - that is as yet largely unexplored. Serious challenges arise from the complexity of the systems considered, from the necessity for truly interdisciplinary research which they imply, from the absence of a comprehensive data base, and from the fact that most of the pursued research activities rely heavily on computational modelling. In response, within "PIKuliar Culture", PIK intends to establish a functioning interdisciplinary dialogue, to reflect the philosophical background of its research, to develop common priorities and standards of quality, and to synchronize and, if necessary, extend existing disciplinary scientific procedures.

IMEQ
Integrating Models and Ensuring their Quality

Project speaker: Gerhard Petschel-Held
PIK project members: Nicola Botta, Hermann Held, Cezar Ionescu, Rupert Klein.

Research Questions

IMEQ's goal is to develop principles of high-quality integrated modelling and strategies for implementing them. Particular emphasis was to be given to the coupling of models with the aim of answering specific research questions. In this context, the following issues were raised:

- How can individual models in global change research be classified to pave the way for integration and quality assurance? Which categories are helpful with respect to a model's object (atmosphere, ocean, economics etc.), structure, scales, implementation, capacity for coupling, and integration? Which categories relate to each model's aims, i.e., the questions each model is supposed to answer, and the questions it is capable of answering?
- How can we classify "integrated" research questions, i.e., questions that can be answered by coupling individual models? How is such a classification related to the classification of individual models? Can we develop a joint classification scheme for models and questions which would allow us to deduce which models need to be coupled in which way in order to obtain answers to specific types of integrated research questions?
- How does uncertainty assessment, including intrinsic model limitation assessment and error estimation, relate to quality assurance in integrated models?
- What do model interfaces (both in a model-inherent disciplinary, and in a software-technological sense) look like? How general a definition can be found for interfaces and how flexible do they have to be?

State of Work and the Project's Future

There are basically two complementary approaches to tackle the questions raised:

- Analyse and categorize existing models along internal specifics and categories like physiological/functional/statistical or numerical/symbolic. This might be called a bottom-up approach.
- Starting from a set of requirements on quality of individual and integrated models, set up a catalogue of criteria and standards to be used as a guideline for the models and coupling procedures.

The project's first target was the organization of the mathematically oriented symposium in the framework of the First Sustainability Days. From its sessions the following conclusions were drawn:

- Concepts used in applied mathematics and computing science offer significant potential for improvement of current models in sustainability science and for their quantitative assessment.
- Modern software engineering is at the core of recent developments of model coupling technologies aiming at the much-desired modularity of applications.
- There is a range of different uncertainty types which might be classified according to the language used (e.g. the temperature is 15.0 °C vs. it is warm) and the measures quantifying the degree of uncertainties (e.g. probability vs. possibility).
- Hybrid modelling has been advanced considerably, combining quantitative with qualitative information.

Despite a general feeling that the conceptual work within IMEQ is greatly needed to achieve PIK's ambitious goals, the project's activities have been regrouped under two other related PIK projects: PIAM and PIRSIQ. PIAM (cf page42) focuses on practical implementations

of a flexible, modular model coupling technology, thereby challenging IMEQ's conceptual thread. PIRSIQ will now incorporate some of the practical aspects of quality assurance previously pursued within IMEQ.

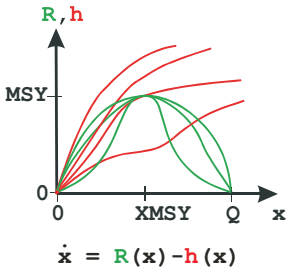
QUIS
Qualitative Intelligence Service

Project speaker: Matthias Lüdeke
PIK project members: Klaus Eisenack, Jürgen Kropp, Gerhard Petschel-Held.
External project collaborators: B. Kuipers (Univ. Texas), J.-P. Aubin (Univ. Paris-Dauph.).

Task

QUIS aims at building a bridge between quantitative and semi-quantitative and qualitative modelling techniques, e.g. qualitative differential equations (theory of classes of ODEs where the right-hand values are largely characterized by their monotony characteristics) or differential inclusions (r.h.s. are set-valued functions). The application of these methods allows an adequate representation of uncertain quantitative knowledge and intrinsically qualitative relations in dynamic models. It also enables the sound generalization of quantitative or qualitative knowledge on relations as derived from a large number of different case studies. The findings will be used in particular, i.a., in SYNAPSE and GlobGov, to describe man-environment interactions and heterogeneous or weakly defined systems.

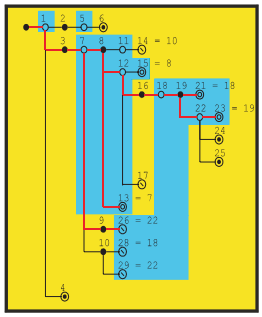
Fig. 1: Simple example of a qualitative model: a single fish stock x with logistic growth function R and a harvest function h depending on x. R and h are only defined by their monotony properties and the existence of the landmarks MSY, (denoting the unknown maximal growth), XMSY and Q (the carrying capacity).



Qualitative Models

Qualitative differential equations (QDE) were introduced by Kuipers (1994). Improvements in techniques for the simplification and analysis of solutions of QDEs are illustrated by a simple bioeconomic model of resource exploitation (cf Figure 1). Its evaluation with the basic QSIM algorithm is shown in Figure 2.

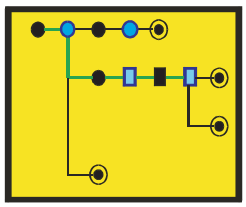
Fig. 2: All solutions consistent with Figure 1. Each symbol denotes a qualitative state characterized by the direction of change and the relation of the variables to landmark values. Each branch of the tree denotes a qualitative trajectory, starting with the initial state in the upper left corner. Circles with dots denote steady states, double circles stand for cycles, double state numbering for continuation at the respective state.



Chatter Box Abstraction

This technique simplifies the solution tree by making irrelevant distinctions invisible (Clancy 1997). It was improved and reimplemented as part of a new C version of the QSIM algorithm. States which exhibit so-called chatter (changes in derivatives without feedback on other variables) are combined to abstract states - in our example this leads to a remarkable reduction of the number of trajectories (13 -> 4, cf Figure 3).

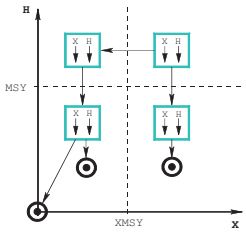
Fig. 3: Simplified or "abstracted" behaviour tree (blue symbols stand for the blue "chatter" areas in Figure 2). The four resulting "relevant" trajectories describe the ways to the stable equilibria "extinction", "low and high equilibrium" and the - rather improbable - MSY saddle point.



Focus Graphs

The representation of the solution as a tree often obscures qualitative values of the variables and important transitions. Moreover, some states and variables may be of limited interest. Thus an alternative representation, the focus graph, was developed (cf Figure 4). It is a projection of the solution onto the subspace spanned by the important variables, enabling a "gestalt view" of the system dynamics.

Fig. 4: Focus graph for the example model enabling an effective overview ("gestalt view"): the state in the upper right corner denotes a bifurcation, irreversibly leading either to the high equilibrium or the low equilibrium/extinction path.



Next Steps

Further work will profit from graph theoretical algorithms to investigate, i.a., viability domains in complex behaviour trees and properties of coupled systems. Another activity will address the integration of differential inclusions to a hybrid systems approach.

PIRSIQ
Pirsig's Quality

Project speaker: Rupert Klein
PIK project members: Cezar Ionescu, PIK staff at large.

Motivation

PIK's interdisciplinary research goals necessitate a conscious activity aiming at the development of a joint "PIKuliar sense of quality". PIRSIQ supports this development by initiating cross-disciplinary discussions and philosophical reflections on our research work.

Interdisciplinary Research

Our objects of study are generally quite complex and inhomogeneous in terms of the involved disciplines, and thus provide inherent difficulties for any of our research projects. These *inherent* difficulties, while also at the core of the PIKuliar Culture TOPIK, are *not* central to PIRSIQ. In contrast, we focus here on *contingent* complexity due to, i.a., different languages, metaphysical concepts, sets of priorities, educational backgrounds, etc.. But this troublesome diversity is actually one of PIK's most important assets and the very basis of the PIRSIQ project.

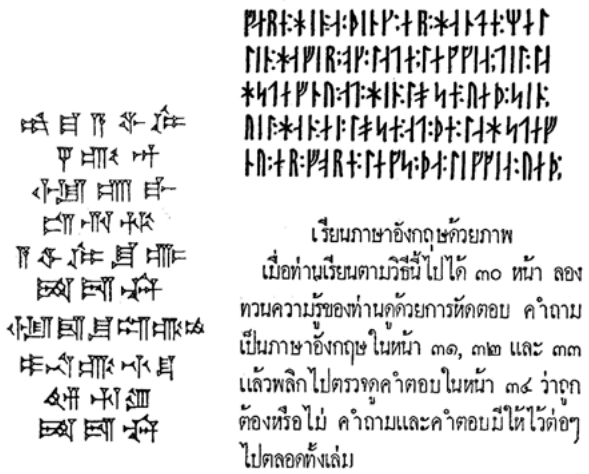


Fig. 5: Contingent Complexity, Inherent Beauty.

Pirsig's Quality

In "Zen and the Art of Motorcycle Maintenance" Robert Pirsig develops a fascinating vision that unifies what he calls the "classic" and the "romantic" views of the world. His notion of the "classic" approach is closely related to the natural sciences, abstract rational thinking, and pure reason. The "romantic" approach is related to an artist's view, to feelings, intuition, the free will, and aesthetics. Pirsig identifies in the concept of Quality the bridge between these two points of view.

One of the most demanding challenges PIK is facing at this point is the integration of socio-economic and natural sciences. This problem is in many ways analogous to the integration of the romantic and classic world views, for which the concept of Quality proved essential. It is reasonable to expect that this concept will also prove useful to our task.

Activities

The project has invited all PIK members to join an electronic discussion forum, designed as an open platform for exchanges on our scientific activities. We have

Fig. 6: Robert Pirsig and his son Chris on "roads less travelled by".

started by focusing on the issue of modelling, challenging contributors to comment on questions such as "What is a model?", "When is a model scientific?", or "Is the computer useful for modelling?"

Also, we intend to set up a guest programme. A guest is invited to visit the institute for a period of days, weeks, or even months. This person would observe our everyday life and research, participate in the PIRSIQ discussions, and would be specifically encouraged to be openly critical and to challenge us in every possible constructive way.

In parallel we hold non-electronic meetings including joint reading sessions, seminars, and panel discussions to crystallize controversial issues and develop common philosophical foundations.

This project is supported through PIK's regular funds.

PRUNE
Propagation of Uncertainties in Earth System Models

Project speaker: Hermann Held
PIK project members: Brigitte Knopf, Thomas Schneider von Deimling, Hans Joachim Schellnhuber.

Introduction
The issue of uncertainty in Earth system modelling becomes increasingly important for the assessment of global change. In this project, uncertainty is analysed in a two-fold way. A conceptually oriented branch addresses a particular yet crucial type of uncertainty which arises from the possibility of abrupt changes. Such changes are caused by bifurcations rooted in the existence of nonlinear feedbacks. We ask how the successive coupling of modules which characterizes current Earth system modelling practice would change bifurcation diagrams and stability properties of dynamical equilibria. Such a conceptual analysis serves as prerequisite for a guided investigation of complex models. A more practically oriented branch of the project aims at a "complete" uncertainty analysis of CLIMBER-2 (cf page 63), PIK's climate model of intermediate complexity. The analysis is optimized according to the needs of an integrated assessment of future climate change.

Uncertainty Analysis of Model Coupling
In the climate system, nonlinear phenomena like transitions from one equilibrium to another or thresholds caused by bifurcations in the underlying dynamics can be observed. Any sensible assessment of future behaviour utilizing climate models has to take into account the existence of nonlinearities.

The Earth system is often modelled by coupling several nonlinear submodules. For predicting the climate with these models the following uncertainties play an essential role: parameter uncertainty, uncertainty in initial conditions or model uncertainty. As the process of coupling is an important part of modelling, one main aspect of this project is the investigation of uncertainties that are due to the coupling process.

For this study we use conceptual models which, compared to General Circulation Models (GCMs), have the advantage that the model can be treated in a mathematically elaborated way. As the time for executing the model is much shorter, it is also possible to perform longest runs on palaeo time scale. Palaeodata provide a very important resource for validation, because they show abrupt changes that mostly have not been predicted by GCMs. In consideration of these facts it appears attractive and feasible to analyse the whole phase space of the conceptual model.

The process of coupling is investigated by using different methods of examining (successively) coupled systems including continuation techniques. Finally, we propose to construct a "toy model" to represent all the different aspects of coupling and of uncertainty. This toy model should be a representation of key aspects of the whole Earth system.

Uncertainty Analysis of CLIMBER-2
One of the major challenges of climate prediction is the estimation of uncertainties related to the modelling results. Various assumptions on model structure and different settings of parameters and initial conditions can alter the model output crucially - especially in the case of model-inherent thresholds and the existence of nonlinearities within the model equations. A multi-run experiment (e.g. Monte Carlo Simulation) can serve as a tool to

investigate the effect of uncertainty in model parameters. Due to limited computer power this method fails for complex models like PIK's fully coupled atmosphere-ocean-vegetation model CLIMBER-2. To circumvent this problem we are constructing a reduced model to emulate the behaviour of the original code. We have chosen the polynomial chaos expansion/probabilistic collocation method (Webster and Sokolov, Climatic Change, 2000) for this.

By means of the computationally efficient reduced model, extensive uncertainty analyses become feasible for various parameters of interest. This procedure yields far more information on the uncertainty of the model result than sensitivity analyses of single parameters (as often presented). Comparison of the model output of the 2.5D atmosphere and the 2D zonally averaged ocean with observational data will strongly constrain and correlate multiple parameters. It is planned to illustrate how the characteristics of input probability density functions are constrained and transformed by such a state-of-the-art climate model which displays pronounced nonlinearities like a possible breakdown of the thermohaline circulation. Bayesian belief networks will serve here as a versatile tool for a unifying representation of uncertainties stemming from experimental data and model parameters.

The investigations aim at qualitatively improved estimates of the uncertainties in climate change projections.

SIMENV
An Integrated Simulation Environment for Quality Assurance and Scenario Analyses

Project speaker: Michael Flechsig
PIK project members: Uwe Böhm, Arnulf Günther, Jochen Hinkel, Cezar Ionescu, Ciaron Linstead, Claus Rachimow, Markus Wrobel.

Aim
Simulation is one of the cornerstones of research in global change. The goal of the SIMENV project is to develop a toolbox-oriented simulation environment that enables the modeller to deal with model-related quality assurance matters and scenario analyses. Both research foci require complex simulation experiments for model inspection, validation and control design without changing the model in general.

Approach
SIMENV aims at model evaluation by performing ensembles of simulation runs in a co-ordinated manner. Co-ordination is achieved by pre-defined experiment types representing typical multi-run simulation tasks.

According to the strategy of a selected experiment type a model M is re-adjusted numerically (mainly by a subset p of model drivers, parameters, boundary and initial values) before each single simulation run. Each experiment type results in a sequence of model outputs over the single runs for the state variables z which can be post-processed specifically.

The following experiment types form the base of the SIMENV multi-run facility, other types may be identified for implementation by PRUNE and SAFE - the co-operating TOPIK2k projects - during the course of the project:

- Behavioural analysis: Inspection of the model's behaviour in a space spanned from p with discrete numerical adjustments and a flexible inspection strategy for the whole space.
  Used in: model verification, numerical validation, deterministic error analysis, deterministic control design, scenario analysis and spatial patch model applications.
- Sensitivity analysis: Determination of model (state variables) sensitivity to p. Can be performed either by finite difference derivative approximations from M or more accurately and stably by an algorithmically generated code of the tangent linear model to M.
  Used in: numerical validation purposes, model analysis, sub-model sensitivity.
- Monte Carlo and stochastic analysis: Perturbation of p according to probability density functions pdf; determination of moments, confidence intervals and heuristic pdf for z.
  Used in: error analysis, uncertainty analysis, verification and validation of deterministic models.
- Optimization: Iterative determination of an optimal value of p for mono- or multi-criterial cost functions derived from z of the model M or its adjoint model.

Used in: model validation (system - model comparison), control design, decision-making.

General System Design

SIMENV makes use of modern IT concepts. Figure 7 shows the main pathways from the original model to experiment evaluation and finally model update.

To interface a model with SIMENV the source code of the original model is transformed by implementing SIMENV function calls for adjustments of p and for model output. XML descriptions of adjustments and model output are generated semi-automatically. Both XML descriptions and transformation functions are adapted from the Typed Data Transfer approach TDT of the MODENV project at PIK.

Experiment performance supports local, remote, distributed and parallel architectures.

Experiment-specific result postprocessing enables navigation in the experiment - model output space and interactive filtering of model output and reference data by statistical operators. Result evaluation will be dominated by application of pre-formed visualization modules and will offer data interfaces for a more detailed result processing outside SIMENV.

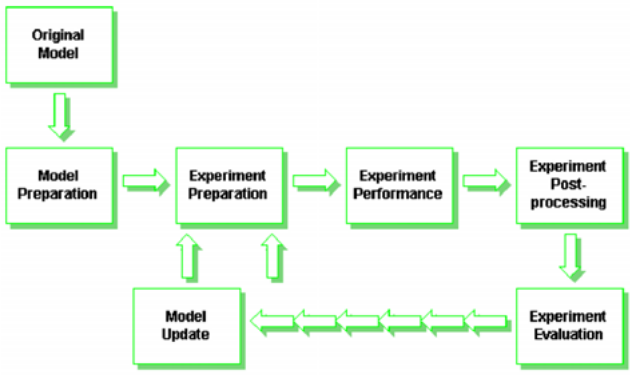


Fig. 7: SIMENV system design.

Completed Projects

QUESTIONS
Qualitative Dynamics of Syndromes and Transition to Sustainability

Project leader: Gerhard Petschel-Held
PIK project members: Martin Cassel-Gintz, Matthias Lüdeke, Fritz Reusswig, Hans Joachim Schellnhuber.

Rationale

Global change results from a manifold of processes, ranging from climate change on the global scale to local processes like land-use decisions or community policies. Within the syndromes approach this variety of processes is clustered into patterns which represent new entities for analysing global change (Figure 1)..

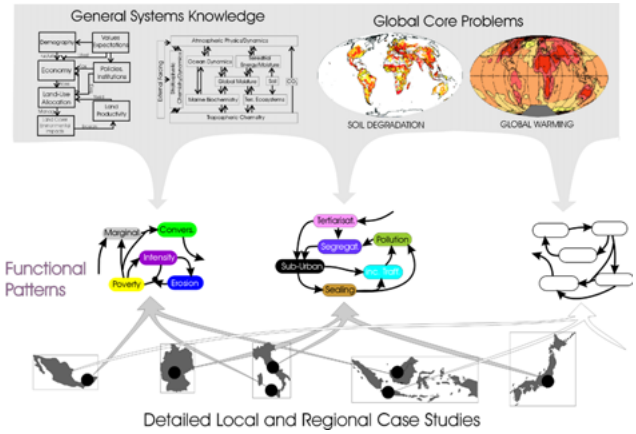


Fig. 1: Syndrome approach: global and local processes of global change are clustered into typical functional patterns.

Syndrome Diagnosis

In 1996 the German Advisory Council on Global Change (WBGU) proposed a set of 16 syndromes. This set represented the basis for the work within the QUESTIONS project, seven syndromes being analysed in greater detail. One example, the analysis of the FAVELA SYNDROME, is depicted in Figure 2.

Syndrome Coupling

Individual syndromes describe major processes of Global Change. Yet the processes of each syndrome might induce or reinforce each other. Deforestation, for example, is often initiated by profit-oriented timber exploitation (OVEREXPLOITATION SYNDROME) which opens up the forest and entails in-migration of farmers (SAHEL and DUST-BOWL SYNDROME). This leads to an enhanced endangerment of forests, the assessment of which is depicted in Figure 3.

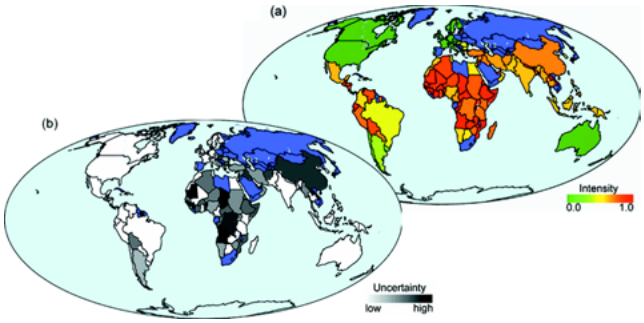


Fig. 2: The FAVELA SYNDROME describes the socio-ecological degradation through uncontrolled urban growth and development. Map (a) in the central panel shows the countries where the syndrome occurred during the 1980s and early 1990s. Due to data gaps, however, high uncertainties exist. These are mapped out in bottom panel. For countries coloured in blue no data exist.

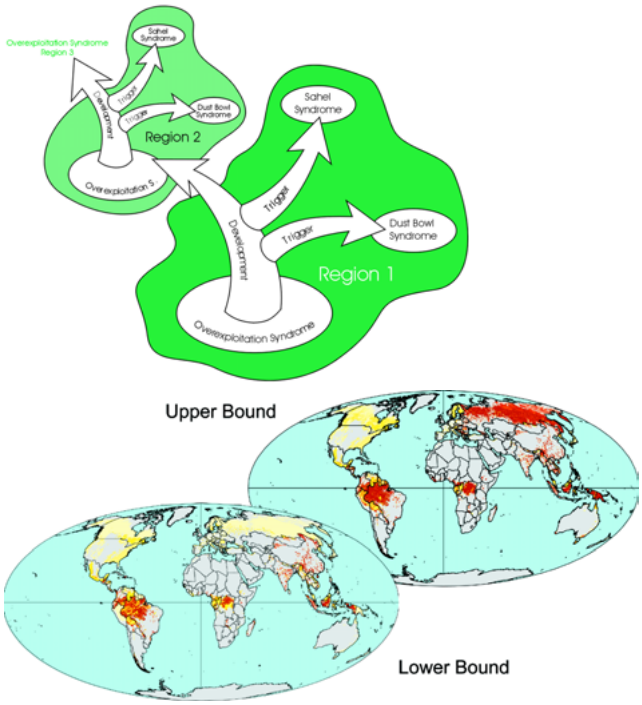


Fig. 3: Threat to the world's forests through syndrome coupling as sketched by the successor graph. The assessments of the intensity and disposition of the syndromes involved are combined to compute an upper and a lower bound for the threat by coupled processes of land-use change (yellow: low threat; red: high threat).

ICLIPS
Integrated Assessment of Climate Protection Strategies

Project speaker: Ferenc Toth
PIK project members: Hans-Martin Füssel, Marian Leimbach, Gerhard Petschel-Held, Hans Joachim Schellnhuber, Eva Tothne-Hizsnyik.
External project collaborators: Thomas Bruckner (Inst. for Energy Engineering, Technical University of Berlin).

Main Goals

The ICLIPS project represented an international and interdisciplinary research activity whose aim was to provide an Integrated Assessment of Climate Protection Strategies. This assessment is intended to support the decision-making community in realizing the United Nations Framework Convention on Climate Change (Article 2: "prevent dangerous anthropogenic interference with the climate system"). This calls for an inverse approach that provides information about possible emission strategies subject to specified environmental and economic constraints. Early attempts by scientists depicted emission paths with respect to given concentration targets. Subsequent work took climatic attributes (change in global mean temperature) or geophysical consequences (sea level rise) as environmental targets. While these analyses provide useful insights into the stabilization issue, they are only remotely related to the ultimate concerns about climate change, its possible adverse effects. The main research objective was to develop an Integrated Assessment model (IAM) that extends the inverse approach to address this ultimate concern.

Methods and Models

The inverse approach is formulated as a kind of generalized cost-benefit analysis for which two types of normative inputs are required. The first type is based on the use of climate impact response functions (CIRFs) that depict reactions of climate-sensitive socioeconomic and natural systems to climate change forcing. As users of the ICLIPS model, social actors can specify their willingness to accept a certain amount of climate change impacts in their own jurisdiction. The same social actors can reveal their perceptions about their society's willingness to pay for climate change mitigation and about acceptable international burden-sharing principles which represent the second type of normative input. The ICLIPS IAM then determines whether there exists a corridor of emission paths that keeps the climate system within the permitted domain without exceeding the specified social costs.
The ICLIPS IAM is a tightly interconnected system of models built on a platform of carefully harmonized assumptions. The core of the model system is a fully integrated climate-economy model. It is linked to an impact module that consists of a comprehensive set of global and regional CIRFs.

Main Results

After developing and integrating the different modules of the ICLIPS framework, applications and policy analyses were performed in different ways. The results reveal the strong nonlinearity and sensitivity of the climate policy space to impact constraints.

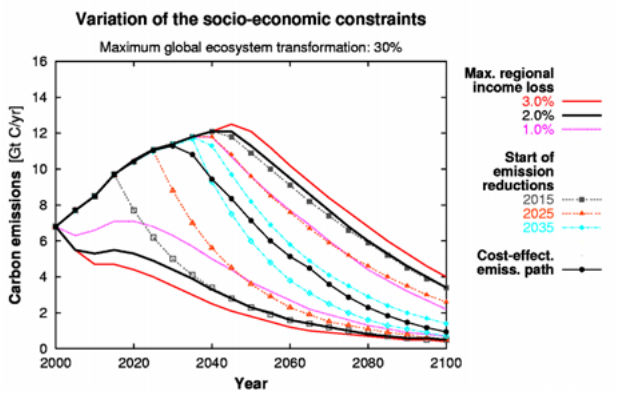


Fig. 1: Corridor for energy-related CO_2 emissions in the 21st Century.

Figure 1 shows an explanatory result. The carbon emission corridor is based on an assumed policy agreement that transforming more than 30% of the Earth's ecosystems would constitute a dangerous climate change impact. The sensitivity of the emission corridor is analysed by varying the mitigation cost limit and the starting year of emission reductions. It requires at least about 1% of per capita consumption in at least one region in at least one period to have an open corridor. If effective reductions are postponed until 2015, 2025, and 2035, the resulting corridors become increasingly narrower. The emission corridor widens when the impact threshold is relaxed to 35%. Due to the emissions already in the atmosphere and the inertia of the Earth system, it is not possible, however, to constrain the transformation of ecosystems to significantly less than 30% on the global scale by reducing carbon emissions alone.

A major part of the project has been funded by BMBF and BMU.

POEM
Potsdam Earth System Modelling

Project convenor: Hans Joachim Schellnhuber
Project speakers: Martin Claussen (CLIMBER), Wolfgang Cramer (DGVM), Yuri Svireshev (COEM).

POEM Components

The focus of POEM was the problem of Earth system stability by analysing (i) the land biosphere and its feedbacks to the atmosphere, (ii) the interactions between all major components of the Earth system (atmosphere, ocean, biosphere, ice masses), and (iii) the long-term evolutionary dynamics of the geophysical Earth system. Accordingly, three main POEM components were set up to focus on the particular processes of geosphere-biosphere interactions. The resulting models were used to study the stability of the Earth system under a broad range of scenarios for modified boundary conditions.

- The short-term (days to centuries) atmosphere-biosphere interactions and vegetation dynamics were addressed by the development of a Dynamic Global Vegetation Model (LPJ-DGVM), incorporating plant physiology and vegetation dynamics (including disturbances).
- At the time scales of centuries to millennia the feedback between atmosphere, ocean, vegetation and inland ice becomes important. This is described by the CLIMBER (CLIMate and BiosphERe) model. This activity has received international attention since it served as the nucleus for EMIC (Earth system Models of Intermediate Complexity) research, e.g. in the IGBP.
- The long-term evolution and development of the biogeochemical cycles is influenced by variations in the luminosity of the sun, plate tectonics, and changes in the geosphere, which is the focus of the CO-Evolutionary biosphere and geosphere Model (COEM).

Progress and Perspective

DGVM

The POEM DGVM group is the core of an international team that develops the Lund-Potsdam-Jena Dynamic Global Vegetation Model (LPJ). LPJ simulates plant functional types (PFTs) performance as a function of ambient temperature, water availability, CO_2 and radiation. Canopy structure and soil carbon dynamics are modelled with realistic inertia and rapid (disturbance-related) short-term changes.
Recent developments include a realistic fire dynamics model, a permafrost routine and successful validation against satellite remote sensing data.
From 2001, the DGVM project has been continued under the project name BIS (cf page 30).

CLIMBER

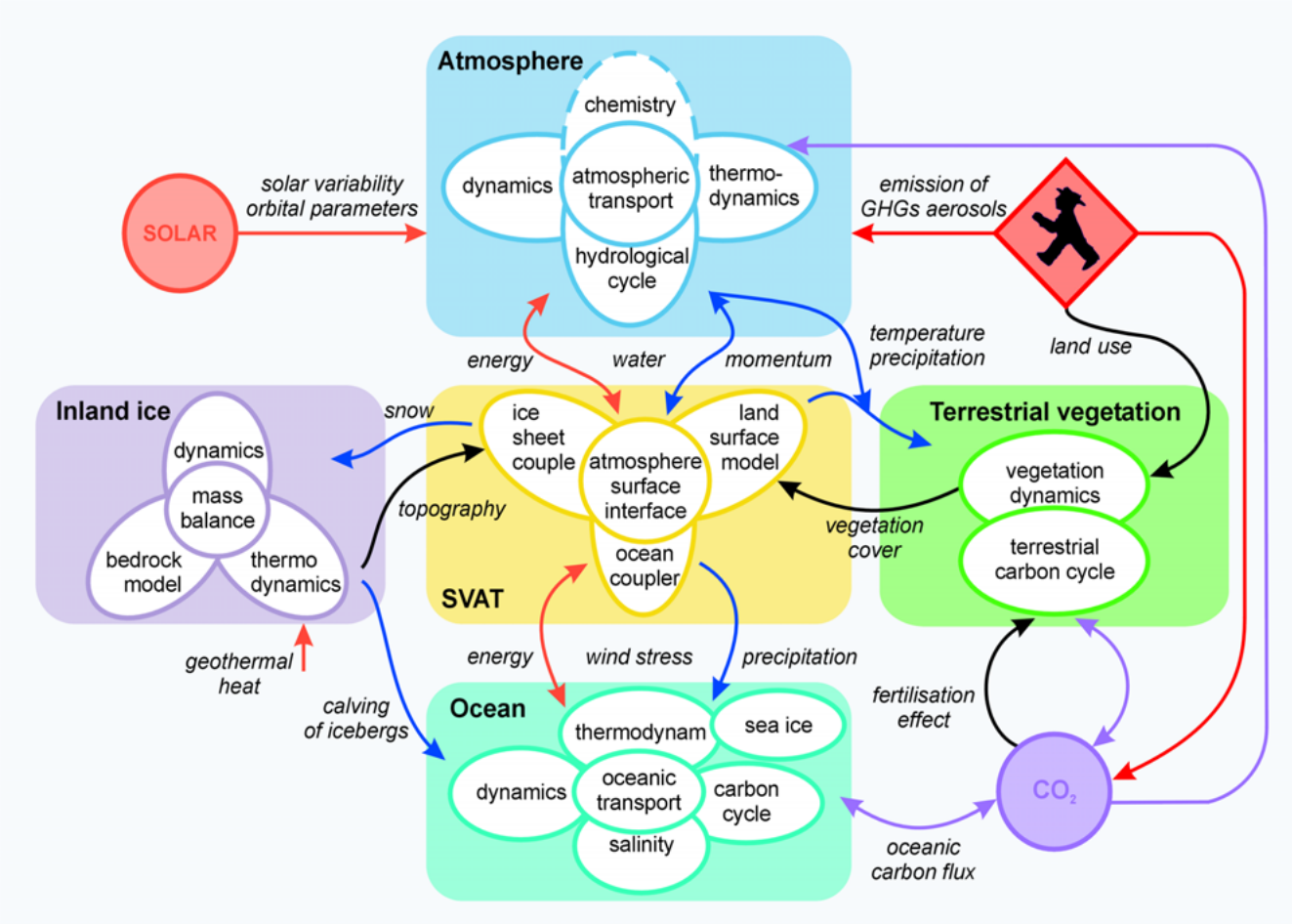
A model of oceanic biogeochemistry and the inland-ice model SICOPOLIS (Simulation code for polythermal ice sheets) were successfully implemented into the new version CLIMBER-2 (cf next page). Using CLIMBER-2 fully coupled simulations of the last glacial inceptions (which occurred some 115,000 years ago) as well as simulations of the present interglacial (the last ~10,000 years), including the terrestrial and oceanic carbon changes, are under way.
In 2001, the CLIMBER activities were merged into the new project named QUEST. Construction of a high-resolution Earth system model is the focus of the new CLIMBER-3 project.

COEM

The fate of the Earth´s ocean was investigated. It was shown that about 25% of contemporary ocean will be subducted by the Earth`s mantle in the next 1 billion years. Furthermore a model, which describes the intensification of chemical weathering by terrestrial ecosystems, intercontinental and epicontinental seas, has been developed. It allows estimation of the role of the biosphere in carbon uptake from the atmosphere in different geological epochs. In 2001, the COEM project was merged into the new project TRIPEDES.

POEM was funded in part by the EU, BMBF, and DFG.

Fig. 1: Structure of CLIMBER-2. The climate system model CLIMBER-2 consists of four modules which describe the dynamics of the climate components: atmosphere, ocean, terrestrial vegetation, and inland ice. These components interact via fluxes of energy, momentum (e.g. wind stress on the ocean), water (e.g. precipitation, snow and evaporation) and carbon. Also the land-surface structure is allowed to change in the case of changes in vegetation cover or the emergence and melting of inland ice masses, for example. The interaction between climate components is described in a so-called Soil Vegetation Atmosphere Transfer Scheme (SVAT). CLIMBER-2 is driven by insolation (which can vary owing to changes in the Earth orbit or in the solar energy flux), by the geothermal heat flux (which is very small, but important in the long run for inland ice dynamics), and by changes imposed on the climate system by human activities (such as land use or emission of greenhouse gases (GHG) and aerosols).



RAGTIME
Regional Assessment of Global Change Impacts Through Integrated Modelling in European River Basins

Project speaker: Alfred Becker
PIK project members: Werner Lahmer, Valentina Krysanova, Beate Klöcking.

RAGTIME covered a variety of projects for the regional modelling of global change impacts. Some of the topics were finished in 2001, others are being continued within the new BMBF-funded project "Integrated Analysis of Global Change Impacts on the Environment and the Society in the Elbe River Basin" (GLOWA-ELBE) and the "Brandenburg Simulator of Environmental and Socio-oeconomic Transformations in the context of Global Change" (BEST, cf TOPIK 5, page 46).

RAGTIME Deliverables

Results from RAGTIME research were primarily provided within externally funded projects, in particularly "Impacts of landuse on the water and nutrient balance in the Elbe river basin" (Elbe Ecology, BMBF) and "Water and material retention in the Elbe river lowland" (WaStor, BMBF).

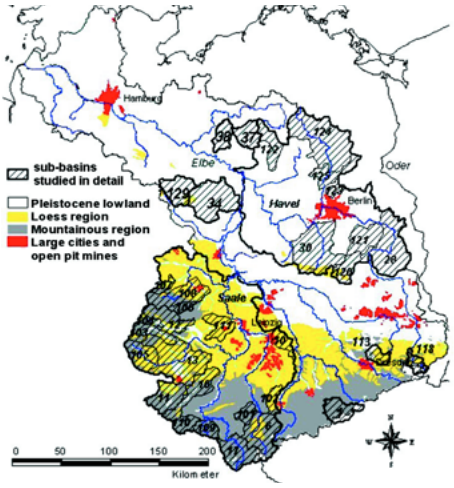


Fig. 1: German part of the Elbe basin including its natural structure and the sub-basins in the Saale and Havel basins studied in detail.

Methods and program systems (ArcEGMO, SWIM) have been developed and applied to calculate aerial distribution patterns of water balance components, including three runoff components and associated nutrient flows in dependence on climate and land-use characteristics, and changes in these. Figure 1 gives an overview of major natural regions of the Elbe basin and on the sub-basins studied in detail. The results of both projects will be published in separate books.

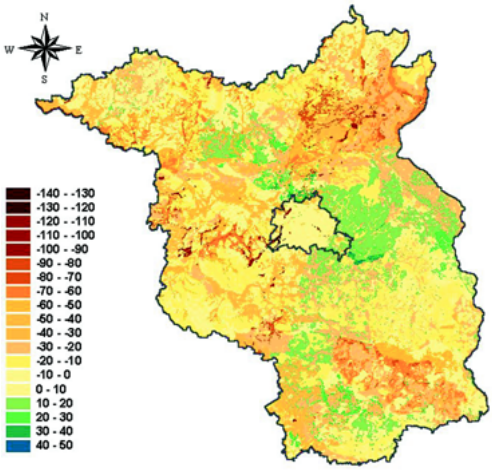


Fig. 2: Absolute changes of percolation calculated for the State of Brandenburg in the period 1961-1998 (in mm/year).

Two studies were performed in collaboration with the Environmental Protection Agency Brandenburg, which provide basic input for water management activities in the State of Brandenburg. In addition to the spatially distributed modelling of water balance components, trend analyses of percolation have been performed, which indicate considerable changes already under the current climate. The absolute changes of percolation in the period 1961-1998 given in Figure 2 show reductions in about 75% of the total area. Impacts of climate change on the water balance were also studied in Brandenburg and some other regions. Some of the results are summarized within the project KLIMOSTAT, funded by the German Foundation for the Environment (DBU).

Perspectives

The European Water Framework Directive aims at a general improvement of water quality in European river basins. As a contribution to this directive, two research projects funded by BMBF started in 2001, one in the Unstrut and the other in the Havel basin. Both projects are closely linked to GLOWA-ELBE and also form an integral part of BEST.

WAVES
Water Availability, Vulnerability of Ecosystems and Society in the Northeast of Brazil

Project speaker: Friedrich-Wilhelm Gerstengarbe
PIK project members: Uwe Böhm, Axel Bronstert, Andreas Güntner, Detlef Hauffe, Annekathrin Jaeger, Maarten Krol, Martin Kücken, Hermann Österle, Peter C. Werner, Ursula Werner, Martin Wodinski.
External project collaborators: Technische Universität München-Weihenstephan, Universität Stuttgart-Hohenheim, Universität Köln, Gesamthochschule-Universität Kassel, Hydroisotop Schweitenkirchen, Universidade Federal do Ceará, Fortaleza, Universidade Federal do Piauí, Teresina, Fundacao Cearense de Meteorologia e Recursos Hídricos, Fortaleza.

Final Summary

The population of semi-arid regions, in particular in developing countries, is extremely vulnerable to global climate change. Therefore tools for a sustainable water and land-use management under climate change conditions have been developed. As a case study, the Brazilian states Piauí and Ceará were chosen. Integrated regional scenarios have been elaborated in close co-operation with Brazilian partners, in particular with local government and scientific institutions. This co-operation guaranteed interdisciplinary communication between scientists of different backgrounds and between scientists and stakeholders. As a main result of the WAVES project a number of methods and tools - listed below - are now available to Brazilian scientists and authorities to develop future strategies in water and land-use management. In this way it is possible to supply semi-arid regions of Brazil with water of sufficient quality and quantity in a sustainable way. A comprehensive report discussing the major results and its potential applications achieved in the WAVES project is in press (PIK, 2002).

Fig. 1: Investigation area, Piauí and Ceará in Brazil.

	Achievements	Potential Application
MACROSCALE	Semiarid Integrated Model	Long-term strategic planning of sustainable development of land use and water management
	Climate scenarios	Long-term planning for the period of 2000-2050
	Soil and Land Resource Information System	• Data base of soils and land resources • Large-scale agro-ecological zoning • Identification of areas with high production potential or high erosion risk in relation to climate, soil and management
	Model of Water Availability in Semiarid Environments	• Simulation of natural water availability in surface waters and dams • Simulation of the effects of investments in the water storage or water transposition on availability of water in the individual municipalities and river catchments
	Nordeste Water Use Model	• Estimation of water demand per municipality as a function of population growth, infrastructure, water pricing and irrigated areas
	Hydro-sedimentation	Calculation of sedimentation in large water reservoirs
	Data base of water costs	Estimating the costs for the supply of water as a function of water extraction technologies
	Regional Agricultural Sector Model of Ceará and Piauí	• Spatial distribution of water demand in the agricultural sector, in relation to farm size and farm technology level • Income structure according to the regional availability of resources
	Migration Flow	• Estimation of changes in life quality per municipality • Estimation of net migration rates
MESOSCALE	Model for sustainable development of land use	Medium-term strategic planning of sustainable development of land use and water management
	Soil and Land Resource Information System	• Soil database • Estimation of yield losses
	Modeling of Water Availability and Quality in Rio Guaribas Basin	Estimation of water availability in surface and ground waters
	Survey of water quality and water infrastructure in the municipalites of Picos and Tauá	• Recommendations for improving drinking water supply and suitability of waters for irrigation
MICROSCALE	Erosion Productivity Impact Calculator	Identification of optimal crop management (fertilization, irrigation) in relation to soil, weather conditions and crop
	Testing of crop management options in maize and cowpea cropping systems	Management recommendations for agricultural extension services
	Assessment of soil water balance as a function of weather conditions, soil and vegetation	Calculation of irrigation requirements
	Botanical survey in Caatinga vegetation	Identification of genetic resources for potential economic use

Fig. 2: Models and scenarios for the investigation area in co-operation with stakeholders.

The WAVES project was mainly funded by the German Ministry of Education and Research (BMBF) and by the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) of Brazil.

EUROPA
European Network Activities on Global Change

Project leader: Manfred Stock

Overview

A number of project activities at PIK, most of them financed externally by the European Union, were bound together to a kind of 'concerted action' named EUROPA, to support internal and external scientific co-operation and exchange. Most of the topics and results are closely connected to the other core projects and these are included elsewhere (see table below).

Project Activities and Concerted Actions

ACACIA

The final report, published Nov. 2000, two weeks before the climate conference in The Hague and in the wake of disastrous floods in southern England and the Alps, reveals that parts of Europe can expect more flooding, but may reap some benefits from climate change, reducing energy needs for heating and increasing potential for forestry and some types of agriculture. More important, the project team with members from PIK and headed by Martin Parry, concludes that adverse effects of climate change will be greater in southern than in northern Europe, with increased desertification, water shortage and forest fires in the Mediterranean region. This has major implications for environmental policy in the EU. The report gives almost 50 recommendations for policy and research (www.jei.uea.ac.uk/acacia_report.html).

CLIMPACT

The European Arctic is a particularly sensitive part of the global system. Through a series of three workshops, this ESF network brought together two important research communities, regional climate modellers and impact researchers. With participation from PIK it has helped to enhance Europe's capacity to carry out regional integrated impact studies, combining both the natural and the socio-economic aspects of global change impacts on a regional level.

Outlook

This core project ended in 2000. In the new research programme TOPIK, starting 2001, another project also named EUROPA adopted parts of this network activities, by modelling, reflecting and communicating possible futures of Europe in the context of global change. Other European activities are associated to respective PIK projects according to their subjects.

The project activities in EUROPA were funded by the EU.

Table 1: List of project activities under **EUROPA** and other projects.

Acronym	European Network Activity	see project (end of act.)
ACACIA	A Concerted Action Towards a Comprehensive Climate Impacts and Adaptation Assessment for the EU)	(Report: 02.11.2000)
CLD	Modelling the Effect of Land Degradation on Climate	POEM (30.04.2001)
CLIMPACT	Regional Climate Modelling and Integrated Global Change Impact Studies in the European Arctic (Concerted Action)	(30.09.2000)
DART	Dynamic Response of the Forest-Tundra Ecotone to Environmental Change	CHIEF (31.03.2001)
EUROTAS	European River Flood Occurrence and Total Risk Assessment System	RAGTIME (31.12.2000)
LTEEF-II	Long-Term Regional Effects of Climate Change on European Forests: Impact Assessment and Consequences of the Carbon Budget	CHIEF (30.06.2000)
MAGEC	Modelling Agroecosystems Under Global Environmental Change	AGREC (30.03.2001)
RICAMARE	Research In Global Change in the Mediterranean: A Regional Network (Concerted Action)	RESOURCE **(**in **2002)**

AGREC
Assessment of Agro-Economic Impacts of Climate Change

Project speaker: Frank Wechsung
PIK project members: Gerd Bruschek, V. Krysanova.

Introduction

The AGREC project mainly focused on simulation studies on the impact of climate change on regional crop production. In addition, the statistical modelling of Morocco's wheat yield fluctuation using teleconnections and circulation measures was continued (cf AIM p. 52). Below, we give an example of a regional crop yield study carried out for the State of Brandenburg.

Brandenburg Crop Study

Regional simulations of crop yield have been carried out for present-day climate and a series of climate change scenarios using the eco-hydrological model SWIM. The crop spectrum was restricted to the three crops winter barley, winter wheat and silage maize. The model SWIM was run under present-day climate conditions around 1951-1990 (referred to as period A) and under altered climates referred to as periods B and C. The dates of sowing and harvesting were the same for the control period and for the climate scenarios. The atmospheric CO_2 concentrations for the control period A and the two scenario periods B and C were set to 346, 406 and 436 ppm, respectively. Higher CO_2 is likely to stimulate photosynthesis and to decrease transpiration per unit leaf area. However, the real extent of these effects at the regional scale is still in question. Therefore, we considered three cases (C0, C+, C++) reflecting the impact of elevated CO_2 concentrations on crop yield. In the case C0, the CO_2 impact was neglected. The CO_2 effect on photosynthesis was only taken into account in the variant C+, and in the case C++, CO_2 was allowed to affect both photosynthesis and transpiration.

Climatic Sensitivity of Brandenburg's Wheat, Barley and Silage Maize Yields

The correlation between temperature change and yield fluctuation was negligible for all crops. Results of regression analysis indicate that wheat is most sensitive and silage maize least sensitive to decreasing precipitation. The sensitivity decreases from C0 to C++, which relates to the effects of higher CO_2 on photosynthesis and transpiration. In conclusion, crop production in the State of Brandenburg appears more sensitive to precipitation than to temperature changes. Expansion of maize cropping can be expected under drier climate conditions, because it decreases the vulnerability of Brandenburg's fodder production to drought.

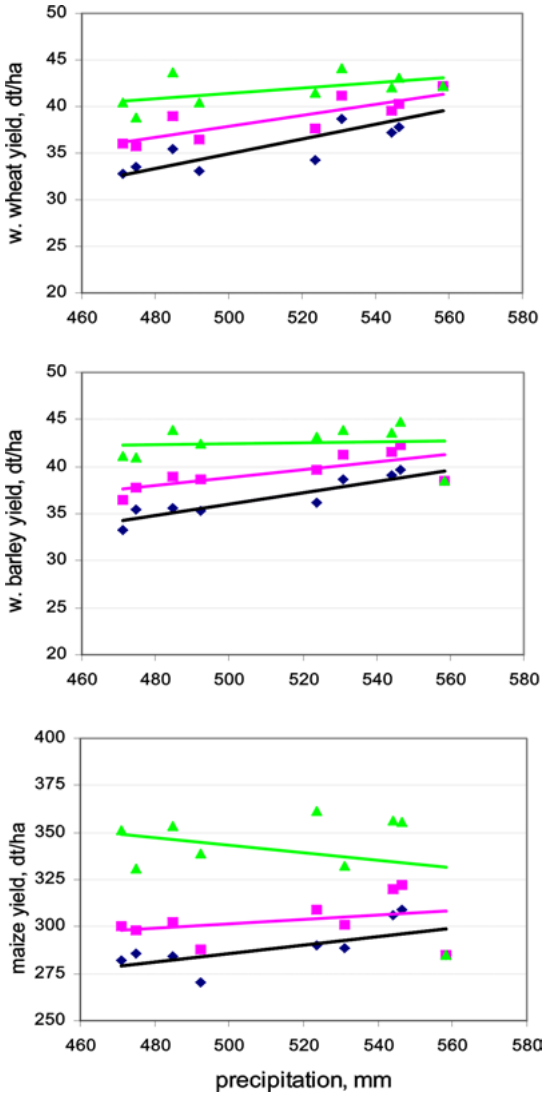


Fig. 1: Regression lines showing the dependence between crop yield and precipitation. Depicted are the results for winter wheat (top), winter barley (middle), and silage maize (bottom). The results are based on simulated regional means for the reference climate and eight climate scenarios, and for three cases of varying sensitivity of crops to atmospheric CO_2 concentrations: 'CO' (black), 'C+' (pink) and 'C++' (green).

AGREC was partly funded by BMBF.

CHIEF
Global Change Impacts on European Forests

Project speaker: Petra Lasch
PIK project members: Franz -W. Badeck, Markus Erhard, Ylva Hauf, Markus Lindner, Jörg Schaber, Felicitas Suckow.

Introduction

The project CHIEF aimed at the assessment of possible impacts of global environmental change on forests in Europe with main emphasis on

- forest growth and carbon storage,
- species composition,
- economic consequences,
- secondary functions of forests,
- interaction with hydrology.

Analyses and impact studies were focused on different levels of spatial and temporal resolution with special emphasis on the regional scale.

German Forest Sector under Global Change

In the 'German Forest Sector under Global Change' (GFS) study, an interdisciplinary team of forest scientists investigated impacts of climate change on forest succession, growth and yield projections, decision-making in forest management, and forest economics. The projected impacts of climate change on the German forest sector are very sensitive to the amount and annual distribution of precipitation in the future climate. Especially spruce and beech may suffer from increased drought stress. Significant negative ecological and socio-economic impacts are possible in regions with warm and dry site conditions. However, the overall conclusion was that climate change constitutes a manageable risk to the national forest sector.

The GFS study was the first integrated climate impact assessment study for the German forest sector and it covered a broad range of disciplinary simulation approaches that is unparalleled in current forest impact studies. The results underlined the importance of considering both the ecological and economic impacts of climate change.

Analysis of Hydrological Fluxes of Forest Stands

At six sites of the Pan-European Programme for Intensive and Continuous Monitoring of Forest Ecosystems (Level II) with managed pine forest stands in Brandenburg, Germany (see Figure 2, right), the forest model 4C (FORESt Ecosystems in a changing Environment) was applied to investigate the sensitivity of the forest water budget to climate change.

Two simulations were carried out with current climate (1996-1999) and a climate scenario with a 20% reduction in precipitation at all sites. The comparison of results showed that under dryer conditions the percolation from the rooting zone of soil declined for all stands. Additionally, the share of percolation in the total water budget decreased by about 7% and the share of interception and transpiration increased by 3-4% (see Figure 2,). This underlines that groundwater recharge was most affected by reduced precipitation.

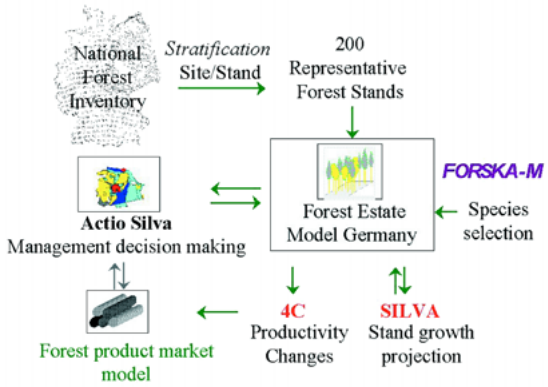


Fig. 1: Components of the GFS study: Several simulation models were linked to a forest estate model representing the most important forest types of German forests. Different management strategies were investigated under current and future climate scenarios.

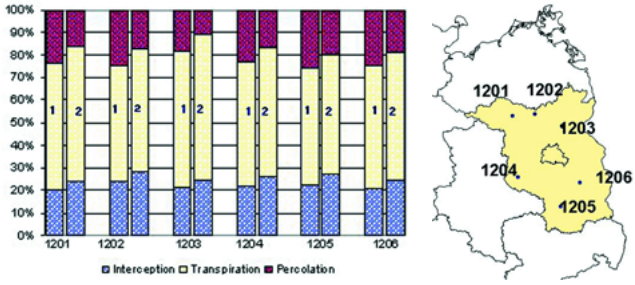


Fig. 2: Left - Shares of simulated yearly water budget (mean of period 1996 - 1999) [1] with measured meteorological data [2] climate change scenario with percolation reduction (20%).
Right - Map of Level II monitoring sites in Brandenburg: 1201 Natteheide, 1202 Beerenbusch, 1203 Kienhorst, 1204 Weizgrund, 1205 Neusorgefeld, 1206 Schwenow.

This project was partly funded by BMBF and the European Commission.

RESOURCE
Social Dimensions of Resource Use

Project speaker: Manfred Stock
PIK project members: Holger Hoff, Friedrich-Wilhelm Gerstengarbe, Richard Klein, Lucas Menzel.

Rationale
In RESOURCE we investigated socio-economic factors and processes concerning use of fresh water under global change and the way these interacted with natural processes. The Mediterranean was identified as a suitable study region to investigate how adaptation and sustainable management options could serve to reduce vulnerability of water resources to climate change. The report for 2000 and 2001 concentrates on two project activities, a joint European project and a German-Israeli co-operation.

RICAMARE - Research In global ChAnge in the Mediterranean: A REgional network
RICAMARE was a concerted action which ran for three years and organized several courses and workshops on different issues of global change (see http://medias.obs-mip.fr/ricamare/). The goals were capacity building and identification of research needs. PIK was involved in the steering committee and contributed mainly to two workshops:

- Assessment of the costs of global change in the Mediterranean, 18-19 February 2001, Milan,
- Assessment assimilation, and validation of data for global change related research, 21-24 February 2001, Casablanca.

RICAMARE ended in 2001 having established a network and an action plan recommending further research activities ('The RICAMARE Manifesto').

German-Israeli Co-operation: GLOWA Jordan River
PIK has established a collaborative project with partners from the eastern Mediterranean region. The project aims to carry out an integrated assessment of global change impacts on water resources and develop strategies for sustainable management of water resources. A research network with partners in Israel, Jordan and the Palestinian Authority was initiated through:

- a visit of PIK scientists to the region, July 2000, and
- the BMBF-funded GLOWA Jordan River project, with a meeting in the region in November 2001.

PIK is engaged in the co-ordination of the GLOWA Jordan river project together with the University of Potsdam. Further contributions by PIK are:

- nested regional climate modelling for the eastern Mediterranean,
- development of a catalogue of regional climate change scenarios,
- land-use and land-cover scenarios and derived land-surface parameters,
- effects of changing water availability on agricultural vegetation,
- modelling agricultural productivity, water-use efficiencies, and bi-directional vegetation-atmosphere interactions,
- basin-wide vulnerability assessment and integrated river basin management,
- stakeholder participation.

In 2001 the activities became part of the project WADI.

GLOWA Jordan River Project - Work Packages (WP):

WP I Global change scenarios of climate and land use
WP II Water resources: changes of water availability and demand
WP III Water in (semi-)natural ecosystems: interaction & management
WP IV Water and agriculture: interaction & management
WP V Integration and stakeholder participation: risk perception in regional land & water management

Fig. 1: Map of Israel and the river Jordan valley and list of work packages in the GLOWA Jordan River project.

RICAMARE was financed by the European Commission as part of ENRICH (European Network for Research into Global Change). GLOWA Jordan River is partly funded by the BMBF.