

RESEARCH FOR EARTH AND ENVIRONMENT

 HELMHOLTZ
| GEMEINSCHAFT

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Cover:

Earth, air, water and life are the elements of the Earth system. Top left: "Potsdamer Kartoffel" showing the irregularities in the gravitational field of the Earth as measured by the GRACE satellite. Top right: Low pressure system as seen from outer space. Bottom left: A shoal of sardines in the ocean. Bottom right: Shoot culture of tomato plants.

FOREWORD



Prof. Dr. Jürgen Mlynek



Prof. Dr. Karin Lochte



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DEAR READERS,

Protecting the population against natural hazards, amelioration of climate change and preparing humanity for its consequences – these are key challenges of the 21st century. Overarching agreement exists on the fact that there are no patent remedies for these challenges.

Global change is a manifestation of the dynamic Earth system. Human activities are part of these dynamics and influence their course perceptibly. To ensure its existence on a sustainable basis, humanity has to adapt to the shifting conditions of this complex system. This requires a well-founded understanding of the Earth system.

The Helmholtz Association of German Research Centres tackles such existential challenges in the Research Field “Earth and Environment” on a wide scale and on an outstanding worldwide level. The focus here is not only on conducting basic research to gain an understanding of the interaction between animate and inanimate components, modeling climate development and making projections, but also on developing new technological approaches to improve observations and measurements. This includes finding very specialized and problem-oriented technological solutions, such as the setting up of early warning systems.

Scientists of the Helmholtz Association investigate a diverse array of natural processes, taking into account boundary conditions and concomitant circumstances such as climate impacts and environmental consequences as always linked to questions of human acceptance. Interactions with other sectors are considered, such as management of raw materials, energy supply and health. Earth and environmental research also seek industrial applications and is thus partnered with activities of application-oriented companies.

Federal and State Ministries in Germany and institutions of the European Union facilitate the research in “Earth and Environment” via funding. We are indebted to these institutions for their support.

This brochure provides insights into selected aspects of our work and an outlook on developments in the future. Our research is for you! It should be our common aim that life on planet Earth remains sustainable.

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THE CHANGING PLANET

The challenge

Global change poses great challenges for humankind. A profound understanding of the Earth system is necessary to ensure that the human bases of existence can be secured on a long-term and sustainable basis. It is important to describe the complex changes in the Earth and the environment in the best possible way. Only with this knowledge will politics and society will be able to make scientifically sound decisions.

The key questions

Climate models predict a warming of up to four degrees Celsius and an average rise in the sea level of around 60 centimetres by the year 2100. Climate change is expected to have a particularly pronounced impact on the Arctic. The world population will grow to about nine billion by 2050. That will aggravate conflicts over resources. There is competition between the cultivation of energy crops and the production of food. Agriculture and urban settlements compete for space. Many natural resources will therefore become scarce in the short or long run. An especially critical development is the increasing water shortage in numerous arid and semiarid areas that jeopardises the health of the population and may trigger political conflicts. Drastic consequences are expected for some regions.

In view of the scenario of global change, therefore, several key questions arise: What impacts can be expected? What avoidance and adaptation strategies can we develop at the regional level? How should sustainable land use be implemented? What changes can be expected in terms of the availability of water?





The three satellites of the SWARM mission are designed to measure the Earth's magnetic field starting in mid-2012.

The strategy

The research centres of the Helmholtz Research Field Earth and Environment want to analyse the already measurable impacts of global change within the next five years. Integrated model systems are aimed at simulating the future changes on a regional scale. Scientists observe, study and model the relevant processes. This makes it possible to assess the state of the Earth system and identify trends and changes.

As part of their extensive work on global change, the seven centres of the Research Field Earth and Environment have developed seven joint focal points that will be presented in the following:

- Earth system dynamics and risks
- Regional climate change
- Dynamics and services of ecosystems
- Efficient use and sustainable management of resources – water as an example
- Sustainable bioeconomy
- Earth System Knowledge Platform (ESKP)
- Infrastructure – observatories



Research vessel Polarstern: a key tool for German polar research (left).

The remotely operated vehicle (ROV) "KIEL 6000" after an operation in the deep sea. (right)



Earth system dynamics and risks

UNDERSTANDING NATURAL HAZARDS AND MITIGATING RISKS

Earthquakes, volcano eruptions, flooding and storms cause tremendous damage worldwide every year. Creeping threats like climate change also increasingly pose a risk for humankind. The objective of the work performed by the Research Field Earth and Environment of the Helmholtz Association is to gain a better understanding of natural hazards, analyse their risks and develop methods that provide protection against natural events.

Damage due to natural hazards has been rising continuously for decades. There are various reasons for this trend. On the one hand, as a result of globalisation, economic systems are more and more tightly intermeshed. Thus, every disaster has worldwide consequences. On the other hand, a rising number of people live in extreme urban agglomerations. Many of these megacities are located near coasts or geologically active zones. Earthquakes, tsunamis, storms and floods may cause greater damage there than in thinly settled areas of the globe. For these reasons vulnerability rises: humankind becomes increasingly prone to natural disasters.

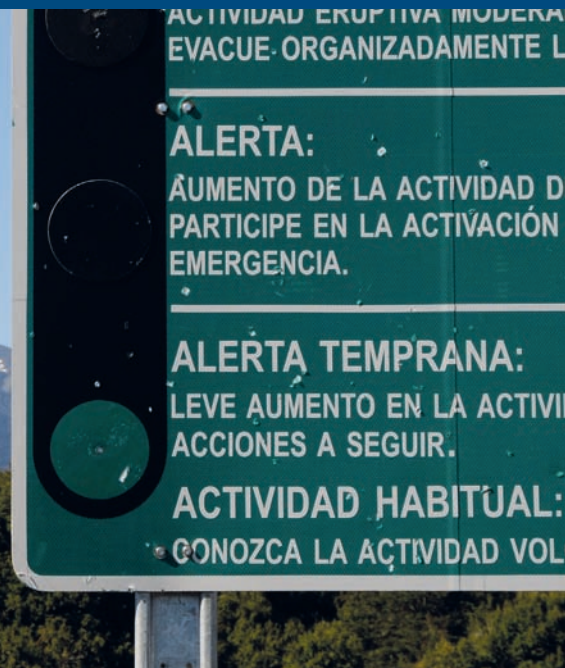
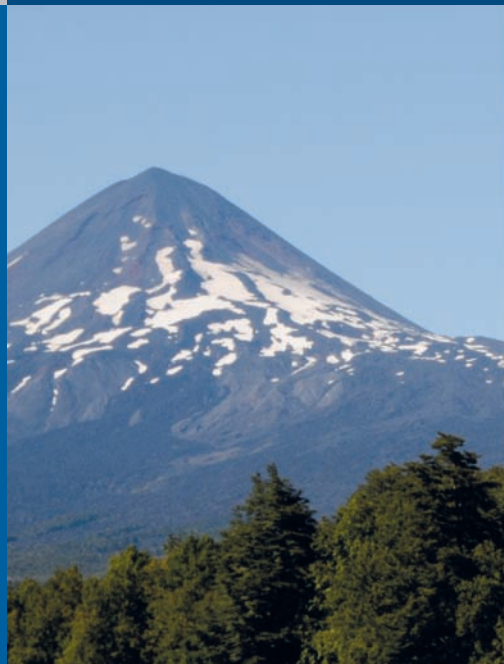
Many natural disasters have a sudden and direct impact. They may devastate entire regions within a short time. Gradual changes like desertification, erosion and accumulation of contaminants are less conspicuous, but they change the environment just as drastically in the long run. As a result of these challenges, humankind faces pressing questions:

- What dangers do we have to take into account in future?
- How great is the respective risk potential and how does it change over time?
- How can we protect ourselves against extreme natural events?
- To what inevitable risks do we have to adapt ourselves?
- What harbingers foreshadow an extreme event?

The researchers of the Helmholtz Association develop new approaches to answer these questions. They want to understand the causes of natural hazards and their impacts, assess risks more precisely and make forecasts according to need. They endeavour to offer solutions to prepare society for imminent hazards. Their work essentially involves monitoring the processes on the Earth using state-of-the-art technology, developing precise models from the data obtained and utilising these models for forecasts. A natural science approach is frequently not enough to mitigate the consequences of natural disasters. Therefore, technical and social expertise is also integrated into research activities.

Flooding in Offenau on the Neckar: How can we better forecast heavy rain (left)?

Warning signs indicate activity of Llaima volcano in Chile (right).



Early warning systems

Natural disasters cause less damage if a society is well prepared. Early warning systems can make a major contribution in this regard. They first have to identify critical developments, such as cyclones, severe earthquakes or explosive volcano eruptions. In the second step they have to determine on the basis of evaluation programs and simulation calculations whether an event may escalate into a disaster. In this case they have to trigger an alarm. An additional challenge in connection with sudden events like tsunamis is being able to warn the population in time.

The Helmholtz Association operates state-of-the-art satellites, aircraft and measuring observatories on land and in the ocean that can supply data for early warning systems. Analytical and simulation tools are also available. To ensure that the Helmholtz Association can expand its leading role in the field of scientific, technical development of methods for early warning, this infrastructure should be integrated and networked better in future.

The focus here is on developing early warning systems on the basis of case examples, similar to the German-Indonesia Tsunami Early Warning System (GITEWS). The German Research Centre for Geosciences initially tested this system extensively and subsequently handed it over to the Indonesian authorities, ready for operation.



A creep meter in northern Chile measures tectonic shifts with unparalleled precision.

HAZARD

A natural event that causes damage. Possible hazards are earthquakes, volcano eruptions, cyclones and droughts.

VULNERABILITY

Vulnerability describes the proneness of a system to harmful external effects. Vulnerability depends on damage probability and the capacity of the system to cope and adapt.

RISK

The probability of suffering damage due to a hazard. Risk is determined by analysing the hazard and the corresponding vulnerability.

Disaster management

Disaster management constantly requires that decisions be made. In the preliminary phase, for example, the planners involved have to specify where flood dikes should be set up. Civil defence workers have to determine at short notice what indications of imminent volcano eruptions exist. In the event of a disaster, they have to direct the rescue services to the site of the operation as rapidly as possible. To respond correctly, all those involved have to be precisely aware of the respective risk.

Helmholtz researchers contribute to providing a better basis for these decisions. They develop new methods for analysing hazards, vulnerability and risks while taking into account socioeconomic aspects. They simulate the degree to which extreme events may damage the infrastructure of a region. In addition, they develop flexible precautionary and follow-up strategies that also function in a rapidly changing environment.

Understanding extreme events better

Extreme events like earthquakes with a magnitude of 9, tsunamis, severe storm tides or force 5 hurricanes occur very rarely. For that reason they are far less understood than everyday phenomena, such as normal low-pressure systems or light and medium earthquakes. When scientists simulated such extreme events in the past, they often had to use models that were designed for frequent small events. Often it was previously not possible to check models on the basis of large-scale rare events. However, it frequently turns out that simply upscaling the models is not sufficient to understand exceptional events.

Therefore, researchers of the Helmholtz Association attempt to reconstruct past extreme events in order to comprehend their specific mechanism and then develop better models. They utilise instrumental measurement series and data from geological archives for this purpose, such as sediments of water bodies or ice cores.

In this way they want to assess how frequently extreme events occur and what risks they pose. They examine how the individual parts of the Earth system are interlinked and whether extreme events may bring about further disasters. For instance, they try to clarify the question of the circumstances under which severe earthquakes may trigger volcano eruptions. Another research topic encompasses the economic and ecological consequences of flooding and massive emissions of pollutants. A further aim is to reliably forecast and simulate the hazards to air traffic posed by volcano eruptions.





Tsunami early warning centre in Indonesia.

Information for the public

Great uncertainty frequently prevails among the public immediately after a disaster because contradictory information circulates. Thus there is great need for rapidly available, scientifically reliable information. Various Helmholtz centres already have many years of experience in this area. Helmholtz researchers explain and interpret the events for the public, media and politics. The centres provide information, such as in the form of maps or damage assessments.

The Helmholtz Association wants to establish itself in future as a central scientific point of contact for natural disasters in Germany. For this purpose the competencies of the Helmholtz centres are pooled in a “Large-Scale Damage” task force. The function of the KATInfo coordination centre will be to collect, compile and make scientific information from the Helmholtz centres involved available quickly.

UNDERESTIMATED HAZARDS?

Aside from the known natural hazards, there are phenomena that have been given little attention to date, but may have a high damage potential.

They include solar storms and weakening of the Earth’s magnetic field. Researchers of the Helmholtz Association also want to investigate these phenomena and find out what threat they actually pose.

Destruction after a severe earthquake along the North Anatolian fault in Turkey (left).

Taking samples at Merapi volcano on Java (right).





Regional climate change

WHAT IS IN STORE FOR US?

Global warming has very different consequences for individual regions Zones of the Earth. Helmholtz researchers investigate such regional climate changes and thus provide the basis for adaptation and mitigation strategies.

Humankind is dramatically changing the climate of the earth. In the past hundred years the planet has become warmer by only one degree Celsius, as stated by the IPCC in its fourth report. However, the impacts are already very obvious. Glaciers are retreating rapidly worldwide. The areas in the Arctic covered with sea ice have diminished by around a third during the past thirty years. Sea level has risen by about twenty centimetres on average in the 20th century. The IPCC projects a further warming of up to four to six degrees Celsius by the end of the century, if the emission of greenhouse gases continues unabated. Such an extreme and sudden global warming would be unique in the history of humankind.

Earth's zones are not impacted equally by climate change. Polar latitudes, for example, are heating up faster than the tropics. Some zones are increasingly affected by droughts whereas in others there is greater precipitation. Even the rise in the sea level will vary considerably from region to region. Such differences in regional climate change are still not as well understood as global development.

The Helmholtz REKLIM initiative has been looking at various aspects of regional climate change since 2009 (see box on p. 11). In addition, scientists of the Helmholtz Association have now identified three other major research topics which have not as yet received adequate attention.

Rapid climate change from proxy data

Many factors drive the climate and sometimes cause sudden and abrupt changes and we still know little about the possible range of sudden climate fluctuations. Many of their drivers are still a "black box" to scientists. Researchers of the Helmholtz Association are applying new and innovative methods to uncover the causes and regional development of abrupt climate changes.

In doing so, they compare the current interglacial period with the previous interglacial around 125,000 years ago. One of the focal points is the rapid climate change at the end of the last two ice ages approximately 10,000 and 135,000 years ago. To understand the regional peculiarities of these changes, Helmholtz researchers make use of new, extremely precise climate archives. They include ice cores from Greenland and Antarctica, marine sediments from the North Pacific and the tropical Atlantic as well as deposits from the Mediterranean region and East China. Representative data, that is so-called proxies, are stored in such environmental archives (see box on p. 13). Data gleaned from these proxies supply indirect information on how precipitation, temperatures, wind speeds and other climate factors changed in the specific regions in the course of time.

Environmental researcher in the Antarctic (left).

More frequent droughts are a consequence of climate change (right).



The work performed by the Helmholtz Association is intended to uncover and tap additional environmental archives containing information on regional extreme events. The architecture of dunes, for instance, may show how frequently storms occur in a region. Comparisons of the regional climate data with model calculations enable Helmholtz scientists to track down previously unknown remote impacts, feedbacks and threshold values in the climate system. In this way they can clarify the question as to whether global warming may also lead to abrupt climate shifts in the future. The retrospective view of the history of the Earth forms the basis for understanding the future dynamics of the global climate.

Climate change and air quality

In most cases climate and air quality are still examined separately. In fact, however, the two parameters have considerable influence upon one another. Consequently to understand the overall health effects of climate change, it is necessary to examine these together. Climate change may have impacts on air quality, in particular at the regional level. The manner in which air pollution and harmful substances spread, depends on the local weather, including the wind direction, wind force and precipitation. Climate change may also favour forest fires, for example when extended heat waves occur frequently in a region during the summer months. Such fires, as evinced in Russia in summer 2010, release gases and soot on a large scale. The wind can also transport these harmful substances over great distances. Air quality in itself also influences the climate. For example, the emissions of big cities change the radiation budget and thus have an impact.



Mugwort pollen under the electron microscope. This pollen may trigger allergies.

REKLIM

In the Helmholtz Climate Initiative REKLIM (regional climate change) eight Helmholtz centres acquire data on the regional impacts of worldwide climate change. This knowledge is intended to help municipalities, rural districts and federal states to develop mitigation and adaptation strategies.

REKLIM focuses on seven highly up-to-date research topics. They include coupled regional climate models, sea level changes and coastal protection, changes in the Arctic, the role of land surfaces in the climate system, interactions between air chemistry and climate, extreme events as well as strategies for regional adaptation to climate change.



Sensors near the Samoilov station in Siberia supply important long-term data.

Air pollution includes trace gases and aerosols with fine dust particles. Many of these pollutants are harmful to human health. Ground-level ozone, for instance, may irritate the mucous membranes. Nitrogen oxides, sulphur dioxide and fine dust particles are held responsible for asthma attacks and cardiovascular diseases. Today around 20 million Germans suffer from pollen-induced hay fever or more serious allergies.

The extent to which such harmful substances impair our health depends primarily on their concentration. Here again there is a possible connection with regional climate change: critical weather situations with formation of smog or high ozone concentrations may occur more frequently in certain regions.

Helmholtz researchers focusing on the research topic of climate change and air quality will examine the interrelationship between regional climate and air quality. The Research Field Earth and Environment closely works together with the Research Field Health. The investigations are aimed at helping to identify unfavourable living conditions, especially in urban environments and agglomerations. On this basis measures shall be developed making climate change bearable for people with chronic diseases. For the first time it will be possible to assess strategies for adaptation to climate change from a health perspective.

Within the Helmholtz Association there are mutually complementary competencies and infrastructures that are in some cases unique worldwide and excellently suited for examining such complex problems.



Risk assessment and risk management for climate adaptation strategies

Climate change is also reality in Germany: average temperatures are rising, vegetation periods are changing, extreme weather events are increasing. Even if we manage to lower greenhouse emissions in the future, many changes can no longer be avoided due to the inertia of the climate system. That means society has to learn how to handle the risks. We have to adapt to climate change.

To date, however, research on climate adaptation has been lagging far behind other areas of climate research. This is one of the reasons why relevant policy in Germany is predominantly based on ad hoc decisions. In most cases individual aspects of climate change are regarded isolated and an integrative, system-encompassing approach is lacking. In future national climate policy needs a better scientific basis in order to assess risks and evaluate various possible actions. If foresighted adaptation is not put into practice, society may suffer considerable damage.

Researchers of the Helmholtz Association are developing the scientific basis for suitable adaptation strategies. In doing so they take into account various climate scenarios and different models regarding development of society. Climate change and socioeconomic changes are examined together because the two processes are coupled to each other, for example in terms of land use, traffic and settlement.

One of the focal points of risk assessment is meteorological extreme events, e.g. storms, extreme precipitation and floods as well as long drought periods and storm tides.

At the Climate Service Centre (CSC) a team of natural scientists, economists, political scientists and communication experts is working on preparing the knowledge from climate research in a practice-oriented manner and conveying it to decision-makers in politics, administration and industry as well as the broad public.

PROXIES – WITNESSES OF CLIMATE CHANGE

Climate data have been recorded with instruments only for about a hundred years. However, natural environmental archives, such as tree rings, stalagmites, ice cores, corals and sediments from the bottom of lakes and oceans, reach back much further into the past.

Often diverse information is stored in these archives. Fossil pollen show what plants lived in a region. Air bubbles enclosed in ice cores reveal how much carbon dioxide the air contained thousands of years ago.

There is even a thermometer for the past. Researchers can reconstruct temperatures from the ratio of oxygen isotopes. Based on the word for representative, these climate witnesses are called proxies.



Industrial emissions influence climate change and air quality (left).

Valuable climate archive: this ice core is more than 150,000 years old (right).



Dynamics and services of ecosystems

ECOSYSTEMS OF THE FUTURE

The ecosystems of the Earth are currently undergoing massive changes. These changes affect distribution and diversity of ecosystems, as well as their functions and services for the people.. Helmholtz scientists study the consequences of these changes, ranging from supply bottlenecks to health problems. Their objective is to create a scientific basis for sustainable use and protection of ecosystems – for the well-being of humankind.

The ecosystems of the Earth have numerous functions. They supply us with food, clean water and raw materials. They influence the local climate and ensure that fertile soils develop and are preserved. Ecosystems have health, cultural and ideal values. They form the essential basis for all living creatures, including human beings. Also from an ethical point of view, humanity has an obligation to protect and preserve ecosystems for future generations.

However, worldwide, ecosystems are affected by significant changes. Soils and seas are used more intensively than before, the climate is changing. Invasive plant and animal species that immigrate or are introduced by people pose another problem. As a result biodiversity changes at the regional and global level. The structure and function of ecosystems are altered or disrupted on a long-term basis.

There is a lot at stake whenever ecosystems can only perform their functions and services to a restricted degree. Material cycles and the climate may lose their equilibrium and natural disasters may worsen thus putting the economic bases of society at risk. It is therefore crucial to gain a profound understanding of ecological processes.

To determine how biodiversity can be utilised sustainably it is important, among other things, to improve our capability of assessing the dynamics and resistance of ecosystems. How great is the impact of offshore wind farms on biodiversity, for example? Only when such questions are clarified can the services of ecosystems be utilised responsibly.

In future the Helmholtz centres of the Research Field Earth and Environment will devote greater efforts to these central problems. The researchers will develop new concepts for ecosystem research

Near-natural landscapes ensure species diversity (left).

Bees and other pollinators are top performers in biological terms (right).



and ecosystem management. With its interdisciplinary orientation and unique scientific infrastructure the Helmholtz Association is ideally qualified for this task. The research stations, observation networks, experimentation fields and seagoing vessels enable the research centres to comprehensively observe ecosystems on land and in the sea. Furthermore, Helmholtz researchers organise large-scale experiments in which they study the influence of individual factors on an ecosystem in a targeted manner. On the basis of the data obtained, they develop ecosystem models from the molecular to the global scale. From these models they derive new management strategies that will make it possible to secure the adaptability and essential functions of ecosystems for the near future. Economic sectors that profit from these findings include agriculture, forestry, fishery, mining and alternative energies.

To make the research results available to the public, the Helmholtz Association has set up four regional climate offices in recent years. There various users from society and industry receive information and advice also regarding ecological research.

To be able to implement the planned research topics, it is necessary to supplement natural science research with socioeconomic research. For instance, the social sciences supply important information on the reasons why humankind alters ecosystems. Such reasons, including coastal protection, tourism, fishery and energy production, may be related to cultural traditions, the economic or legal system of a nation.

The Helmholtz Association also wants to examine the impact that altered ecosystem services have on human society. An example of such an interrelationship is the relationship between bees and other pollinator insects and agriculture. The decline in pollinators may lead to harvest losses among major crops and thus to losses in income among farmers.

PRECISELY BALANCED INTERPLAY

An ecosystem not only includes living creatures, but also the inanimate environment. This means an ecosystem encompasses a spatially definable habitat, such as a river, a forest or wetlands, and the biotic community consisting of animals, plants and microorganisms that lives in it.

The animate and inanimate parts of an ecosystem are linked to one another through their interrelationships, such as food chains, material cycles or exchange of energy. Ecosystems can compensate for disruptive influences to a certain extent, but constantly change in this process. Ecosystems are thus open, dynamic and complex systems.



Gorgonians dominate this biocoenosis on the floor of the Weddell Sea (left).

The submersible vehicle JAGO collects plankton and particles at some cold-water corals in the Mediterranean Sea (right).

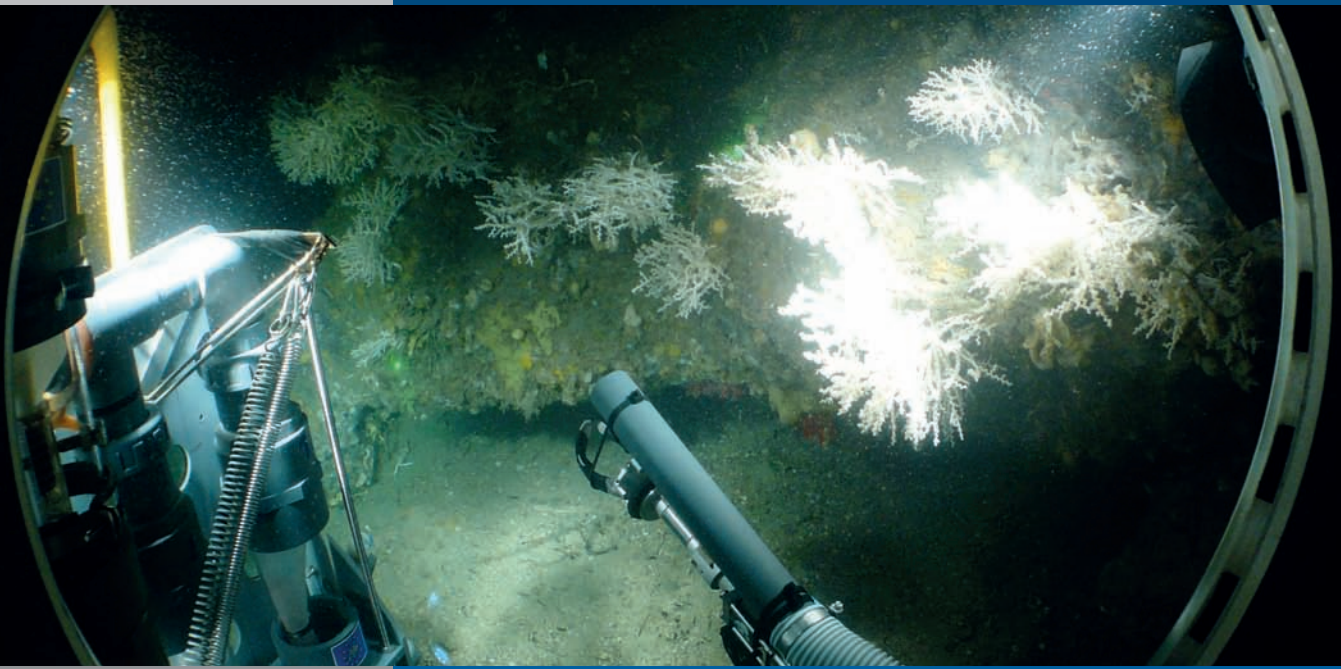
Analysis of ecological processes

Helmholtz researchers want to gain a fundamental understanding of how ecosystems change and what factors control the change. How fast do changes take place, how big is the area affected? What species and processes are good indicators of fluctuating environmental conditions? To find that out, selected ecosystems have to be observed on a long-term basis. Moreover, the Helmholtz centres conduct large-scale experiments in model ecosystems of which they develop new indicators and models.

To be able to develop specific management and protection proposals, the researchers have to analyse the specific features of the various ecosystems in detail. Polar regions, temperate latitudes and the tropics contain diverse biotic communities. The sea also comprises numerous different habitats, such as coastal areas, the high seas, the deep sea and near-surface layers. Entirely separate ecosystems form in areas greatly influenced by humankind, e.g. in cities and large agricultural regions. In spite of this diversity, it is possible to identify general principles and mechanisms that apply to all ecosystems. The Helmholtz these scientists can derive further options for the management and protection of ecosystems that are subsequently incorporated into international standards. This, in turn, has consequences for government policy in the agriculture, forestry and fishery sector as well as in connection with biodiversity protection.



Typical of Central Europe: beech forests.



Influence of global change

Helmholtz researchers examine what direct and indirect consequences global change has for certain ecosystems and their inhabitants. In doing so, they concentrate on regions that react extremely sensitively to climate change and on those that are important for human society. The researchers include oceans, coasts, rivers, forests, polar and arid zones as well as intensively used cultivated landscapes.

The Helmholtz research centres also focus on adaptation and mitigation measures. These refer to strategies for living with the altered conditions, reducing the impacts of global change or combating the causes of change. However, the consequences of these measures have to be analysed and evaluated as well. The researchers want to identify meaningful indicators enabling them to compare the status quo and the targeted state.

Sustainable use of ecosystems

In close coordination with the Helmholtz Research Fields Energy, Health and Key Technologies, the Research Field Earth and Environment examines how human use changes biodiversity and the functions of ecosystems. Researchers look at the impacts of current use and those of expected future uses. They focus on the question of the key services of ecosystems. These include the production of biomass, soil formation, carbon storage, climate regulation, water purification, water storage and the diversity of genetic resources.

WAYS OUT OF THE WATER CRISIS

Water is an essential, but often scarce resource. In many regions of the globe water shortage prevails and harmful substances threaten water quality. Research centres of the Helmholtz Association work in the Research Field Earth and Environment on developing solutions for these problems. They bundle their extensive activities in a new competence platform: the Helmholtz Water Network.

Water merely appears to exist in abundance on the Earth. After all, only a very small portion of water, about 0.3 percent, is directly usable as drinking water. However, water is also required as process water for industry, energy production or agriculture. The demand is rising as the world population grows and more and more food, energy and consumer goods are produced. Already more than 1.2 billion people live in regions with water shortage. Due to global climate change, supply problems will mount in the future. Particularly hard hit are regions in which several critical developments come together, such as in the countries around the Mediterranean Sea, in Central Asia and parts of India. There, water is already scarce. In addition, population and industry are growing rapidly and climate change causes the amount of precipitation there to decline further.

The Helmholtz Association can make an important contribution to tackling the global challenge of a reliable and sustainable water supply since it possesses broad specialised competence, infrastructure and a network organisation that is indispensable for modern water research. Germany is by far the biggest player in the field of water research and numbers among the leading water research organisations in Europe.

In the Helmholtz Water Network the Helmholtz Association forges alliances with recognised university partners. The specific focal points of the universities and the Helmholtz centres complement one another ideally enabling the creation of efficient structures. The Helmholtz Water Network aims at strengthening methodological key competencies in order to tackle global water problems and develop concrete problem-solving solutions in a model region. The focus in this context is on the following topics:

What impact does global change have on water resources?

In future a third of the world's population will suffer from considerable water shortage. There are several reasons for this. The world population continues to grow and is overexploiting water and soil resources. In addition, more and more urban conglomerations, so-called megacities will occur and extreme events like drought and flood will arise more frequently. All of this creates additional problems in terms of use of water resources. As a result, food also becomes tremendously scarce. Helmholtz researchers want to develop realistic future scenarios at an early stage and derive possible options on that basis.



Sustainable water resource management

Can a prospering industrial society protect resources without the economy suffering from that? Taking water as an example, Europe can show that this is possible. Modern water management is based on the concept of integrated water resource management. This involves regarding and managing water resources holistically. The objective of Helmholtz water research is to implement the holistic approach for regions outside Central Europe as well. This means various factors have to be examined. They comprise natural areas and ecological questions, on the one hand, as well as different political systems and institutional structures, on the other hand. These social boundary conditions also have to be incorporated into the new concepts of water management.

How do water and material cycles function on a regional scale?

The Helmholtz Water Network aims to develop methods for determining the pathways of nutrients and pollutants, such as pesticides or drug residues, in the catchment area of water bodies. It will additionally examine the interaction of these substances with the water ecosystems. Previously the customary procedure was to look at each substance individually and examine it only on very small spatial scales. Helmholtz researchers intend to go beyond that and analyse the turnover of different substances together and on a larger spatial scale. They will trace the pathway of the substances from the source to their input into the environment. The interaction of these substances with the water ecosystems will be studied as well. In addition, substances that number among the so-called new chemicals in accordance with the European Chemicals Agency (ECHA) are also to be included in the investigations. These are substances that industry puts into circulation for the first time and are thus subject to European reporting requirements. Research work is aimed at investigating the toxicological effects of the chemicals and determining long-term effects.

Another objective of the project is to develop so-called reactive transport models. These models not only calculate the distribution of substances, but also include possible chemical reactions of art measurement methods and analytical tools are necessary to develop such models.

Helmholtz researchers want to select test areas for national and international comparative studies and provide them with instruments for long-term observations.



In many megacities there is not enough drinking water (here: well in Santiago de Chile).

THE SCARCE ELIXIR OF LIFE

There are enormous amounts of water on the Earth, a total of about 1.4 billion cubic kilometres. However, 97.5 percent of that is in the oceans – as salt water. Fresh water is primarily bound up in ice, around two percent of the global water reserves (28 million cubic kilometres) covers Greenland and Antarctica in the form of an ice crust that is kilometres thick. The groundwater under the Earth's surface makes up approx. half a percent of the water reserves. Around 0.01 percent of the water on the Earth circulates in lakes, rivers and in the atmosphere, altogether about 240,000 cubic kilometres.

The water level of the Dead Sea is falling by one metre every year (left).

Scarce and valuable resource: clean water (right).





Acid mining lakes are to undergo microbiological remediation in future (left: "Restloch 107" in Lausitz).

Agriculture in Jordan Valley: artificial irrigation aggravates water shortage (right).

Integrated observatories

Six Helmholtz centres have implemented a Germany-wide network of integrated long-term observatories within the research infrastructure TERENO (Terrestrial Environmental Observatories). This concept is now to be applied to water research in other countries, primarily in the Mediterranean region. The focus is on hydrological questions. For instance, precipitation, discharge and soil moisture in the catchment area of water bodies will be measured. The data collected will form a solid foundation for hydrological models. In regions with a low data density to date this approach will make it possible to forecast the development of water resources more reliably. The Helmholtz Association will consequently hold a leading position worldwide in the field of complex terrestrial observatories.

Hydrological models

Water research has been utilising analytical and numerical models that represent individual processes or certain segments of the environment for a long time now. It has been common practice to develop a specifically tailored model for each problem. However, since social questions are becoming more and more complex, this approach is no longer adequate. Today hydrology faces the challenge of transferring its extensive knowledge on the water cycle and its interactions with the environment to suitable modelling tools. Developing such models is a further objective of the Helmholtz Water Network. New software structures and modern data integration tools will form the basis for this. In this way the Helmholtz Association sets its sights on a leading position in the development of hydrological models and with respect to initial and further training in this field.



New analytical methods identify degradation pathways of harmful substances in groundwater.

Scarce water resources in the Mediterranean

Water shortage is already extremely pronounced in the Mediterranean region. There are various reasons for this. According to forecasts, however, during the next 100 years only half as much new groundwater as previously will be formed there. At the same time the population in coastal areas will grow from the present figure of 180 million to over 250 million people by the year 2025. Primarily due to migration, this region has great development potential, such as in the tourism sector. In view of the future challenges, the Mediterranean region needs appropriate water management.



As a contribution to viable development of this region, which also holds geopolitical significance for Germany, the Helmholtz Association plays an active role with research projects in the circum-Mediterranean region.

On the basis of selected areas in the Mediterranean region, the Helmholtz Association, together with local partners, wants to demonstrate how scarce water resources can be used sustainably. Helmholtz researchers perform functions ranging from data procurement and water management all the way to technology development. They work, for example, on innovative seawater desalination facilities that at the same time produce energy. They develop new technologies for treating process water and take part in infrastructure projects. In addition, they look at how the efficiency of irrigation system can be enhanced.

WATER RESEARCH THROUGH COMBINED EFFORTS

To further boost water research, in 2009 the Helmholtz Association started to develop a concept which is aiming at a better positioning of water research also on international level, the so-called "Water Science Alliance".

The objective of this alliance is to create a reliable long-term framework for working on major and complex topics of water research in an integrated manner. This will enable the water research community to act as an internationally competitive scientific player and tackle the challenges of the future with appropriate problem-solving concepts.

www.watersciencealliance.ufz.de

MAKING OPTIMAL USE OF BIOLOGICAL RESOURCES

The aim of a sustainable bioeconomy is to make efficient and sustainable use of biological resources. It targets mitigation of the present overexploitation of ecosystems and seeks long-term innovative solutions for this purpose. In-depth knowledge about plants, microorganisms, animals and their biotic communities forms the basis of a sustainable bioeconomy. Several research fields of the Helmholtz Association are working jointly on putting the concept of a sustainable bioeconomy into practice.

Nowadays many sectors of the economy already utilise biological resources. Plants, animals and also microorganisms constitute the basis of agriculture and forestry, fishery and the food sector. Parts of the chemical, pharmaceutical, cosmetics and textile industries also depend on them. Moreover, biomass in the form of wood, biogas and biofuels is gaining significance as an energy resource.

However, the limits of sustainable use will soon be reached. More and more land is cultivated to grow plants and feed animals. The demand for food and animal feed, energy and raw materials is rising because the world population has grown rapidly in the past century and continues to increase. Supply bottlenecks may arise and ecosystems may be impaired by overexploitation.

The tremendous advancements made in genetics and molecular biology provide great opportunities for solving these problems. Through these research disciplines scientists have been successful in recent years in protecting crops against diseases. As a result, harvest losses have declined so that more food and biomass are available. Currently experts are looking for crops that need less

water and plants that utilise nutrients more efficiently and at the same time produce larger yields.

To push sustainable use of biological resources further, biologists have to cooperate more closely with other research disciplines. At present bioeconomy research in Germany is very fragmented. There are few links between economic sectors that utilise biomass. Biotechnology has primarily made use of simple carbon compounds as raw materials for the chemical industry up to now and chemical process engineering has focused on processing fossil resources. Agriculture predominantly serves the purpose of food production.

This fragmented research landscape is one of the main obstacles on the road to a sustainable bioeconomy. The Helmholtz Association wants to make a substantial contribution to organising bioeconomy research in Germany. The Research Fields Earth and Environment and Key Technologies and Energy work jointly on achieving this objective. The Research Field Earth and Environment contributes the following topics:



Plants as the basis for food, renewable resources and bioenergy

Plants are used in a multitude of ways. They serve as food and animal feed, as renewable resources, and can be used to produce bioenergy and renewable materials. To meet the growing demand, biomass availability has to be increased – with constant or even better quality. There are limits to growth, however, because soil and water resources are finite and there is a lack of plant varieties having high resource use efficiency. Furthermore, climate change is altering cultivation conditions.

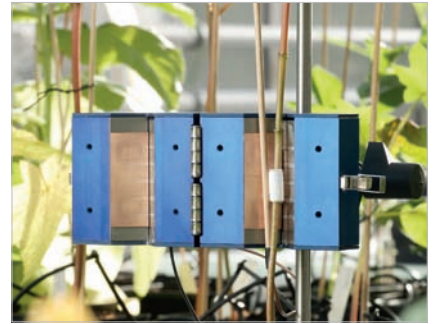
Helmholtz researchers work, for example, on improving the stress resistance of plants thereby making use of state-of-the-art genetic and biochemical tools. They also study how plants interact, for instance with pathogens or microorganisms in immediate proximity to their roots. Scientists at the Helmholtz centres also develop new methods for describing functions like photosynthesis and growth by means of computer models. These methods support research to develop new varieties of crops as well as resource-protecting and efficient production processes. However, the researchers also examine entirely new types of products, such as those produced from plant cell wall materials. These plant components are very rich in energy and supply raw materials for high-quality products.

To implement their results quickly, the Helmholtz centres of the Research Field Earth and Environment work closely with breeders and the agricultural industry.

Integrated production systems

To cover biomass demand, it is necessary to go beyond optimising the plant system. Agricultural production has to be intensified. That can be achieved by improving production systems so they are more effective and at the same time allowing sustainable use of the available land. Climate change, however, gives rise to new challenges: extreme weather events will occur more frequently in future and will cause additional losses of yield.

Sustainable production systems should protect soil and groundwater. Helmholtz researchers therefore develop dedicated production systems, such as so-called multi-species grassland systems, for land that is not suitable for food production. These systems produce biomass for energy generation and at the same time protect biodiversity.



Magnetic resonance imaging for plants: a portable magnetic resonance device (NMR) measures the transport of substances.

A NETWORK FOR BIOECONOMY

In future Helmholtz researchers want to further promote the bioeconomy concept in special network projects. In this context they focus on five topics:

- renewable resources
- biogas
- sustainable production
- conversion of biomass
- strategies for implementation of a bioeconomy.

The network projects are aimed at strategically bundling bioeconomy research within the Helmholtz Association and developing synergies. In addition, the Helmholtz centres establish partnerships with universities, non-university-affiliated research institutions and industry.



Cereal plant at a phenotyping facility: new crops have to be more stress-resistant (left).

Microalgae produce fuels and remove carbon dioxide from the air in this process (right).





Lysimeters record transport of substances between atmosphere, plants, soil and groundwater (left).



Growth in a solar simulation chamber: When does barley thrive best? (right)

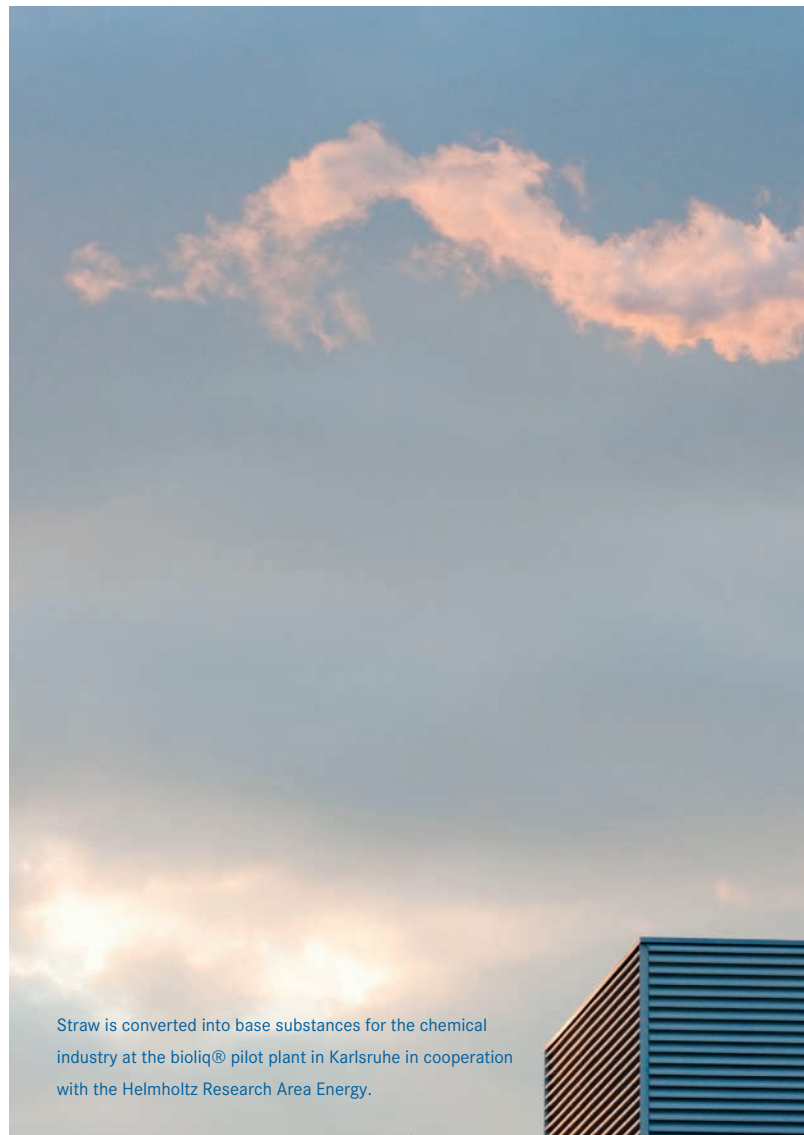
Another research topic concerns rapidly growing trees grown in plantations that achieve good yields even in arid regions.

Such integrated production systems can contribute to soil improvement and water protection. In addition, the researchers compare different production systems, both in Central Europe and in South America. For instance, they study energy crops and so-called agroforestry systems in which trees and annual crops grow on the same area.

Polygeneration: chemical plant and energy centre

Biomass serves as the basis for diverse products. Plant residues and animal waste can be converted into heat, electric power, fuel or raw materials for the chemical industry. The objective of sustainable bioeconomy is to utilise biomass as completely as possible. This can be achieved through so-called “polygeneration”: at a single facility different manufacturing processes are coupled so that several products are created. Helmholtz researchers devise methods for producing energy and raw materials from biomass. This includes developing process control strategies or novel concepts for using gaseous feedstocks.

Furthermore, they work on utilising residual substances created during the production of biofuels. For this purpose they develop methods of microbiological production and utilisation of methane, methanol, hydrogen and carbon monoxide. They also preoccupy themselves with the biological synthesis of base chemicals, such as carboxylic acids.



Straw is converted into base substances for the chemical industry at the bioliq@ pilot plant in Karlsruhe in cooperation with the Helmholtz Research Area Energy.



INFORMATION OFFICES

To coordinate bioeconomy research efficiently, the Helmholtz Association is setting up four information offices, the BioEconomy INFO Centres. They coordinate the activities between regional research clusters and prepare the results for politics and society.

The offices organise regional conferences and develop joint projects. Coordinated interaction with stakeholders guarantees that the research results of the Helmholtz Association are discussed with society and implemented.

MAKING OUR EARTH SYSTEM KNOWLEDGE USEFUL FOR EVERYONE

How quickly is the sea level rising? When do invasive species jeopardise local biodiversity? Where is there a threat of drought? How great is the risk of earthquakes? Answers to such questions are important for urban planners, farmers, politicians and companies, to name only a few examples. The Helmholtz Association now opens up access to concentrated knowledge on the Earth system in useful and comprehensible form. A new information and dialogue platform – the “Earth System Knowledge Platform” (ESKP) – has come about in this way.

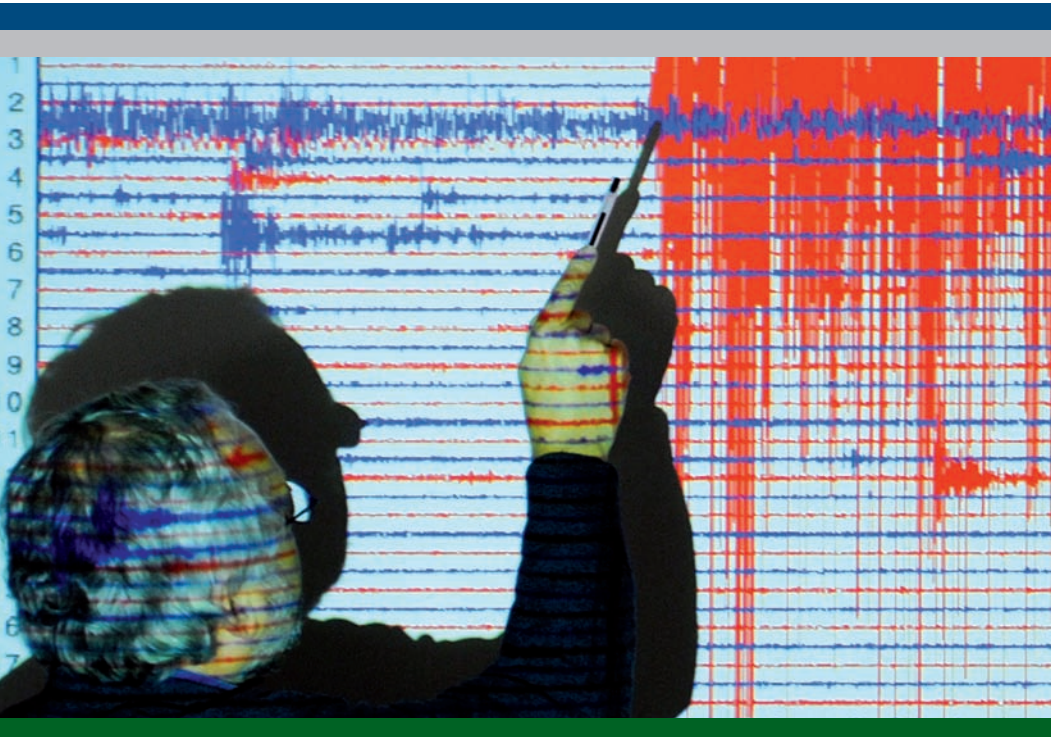
At present the Earth is changing rapidly: humankind is growing, consuming more and more energy and resources, intervening in natural cycles and altering the climate through greenhouse gas emissions and land use. The central objective of the Earth System Knowledge Platform (ESKP) is to provide information on the impacts, opportunities and risks of global change. In addition, the platform presents strategies for adapting cities and regions to the expected changes. The ESKP thus performs an important information and advisory function for the public – for politics, industry and society as a whole.

The ESKP bundles and networks the knowledge that the Helmholtz centres in the Research Field Earth and Environment compile. Furthermore, the platform integrates data and information from external partners. It provides, for instance, observation data, scenario

calculations and forecasts. In a dialogue with users the researchers of the Helmholtz Association develop their own statements for the platform. The ESKP also forges links between scientific disciplines. It brings interdisciplinary teams together so joint approaches and new methods can be developed.

The ESKP is to be set up quickly and will initially tackle the topics of extreme events and adaptation to climate change. In the medium term the platform will constantly incorporate other focal points, such as biodiversity, water, polar regions and the impacts of land use.

The topic of extreme events focuses on providing knowledge on natural hazards like earthquakes, volcano eruptions and storms. Moreover, the platform aims to communicate possible adaptation strategies and provide information at short notice in the event of



disasters. In doing so, the ESKP will receive support from existing structures at the various Helmholtz centres, such as the Centre for Disaster Management and Risk Reduction Technology (CEDIM), which is jointly operated by the Karlsruhe Institute of Technology and the German Research Centre for Geosciences in Potsdam.

As far as the topic of adaptation to climate change is concerned, the ESKP can fall back on existing information systems too, in particular the Climate Service Centre (CSC) in Hamburg and four regional climate offices at various Helmholtz centres. An interdisciplinary team at the CSC of the Helmholtz-Zentrum Geesthacht is working on preparing knowledge from climate research on a practice-oriented basis and communicating it to decision-makers in politics, administration and industry as well as to the broad public.

Communication with the Earth System Knowledge Platform will take place interactively. The aim is to create a knowledge and question transfer between science and society. New questions arise for the platform and thus for scientists in the research field from the needs of users. The ESKP will initiate special research projects for especially complex questions. In this way the platform ensures efficient knowledge transfer. The Helmholtz Association can make its knowledge available in bundled form and combine it with the knowledge of other research institutions. Users do not have to look for answers in often scattered sources of detailed information, but get the opportunity of clarifying their complex questions via a single contact point.

The ESKP will act at the international level and closely link all participating Helmholtz centres. This will be achieved through a combination of central coordination and decentralised cooperation: a small central unit shall handle general organisation and coordination and work out process bases. Other members of the staff assigned to the ESKP work at the research centres involved and are integrated into the research there. They form the link between the respective Helmholtz centre and the ESKP. Together with the central unit they further develop and implement the joint strategy.

As a result, the ESKP will be a key instrument for the Helmholtz Association in mastering the challenges of global change.



Vital information: signposted escape routes are part of the tsunami early warning system GITEWS in Indonesia.



On a journey through time to the year 2100: the climate globe visualises various climate scenarios.

Seismograph of the earthquake in Sumatra on 26 December 2004 (left).

Politicians need reliable information for their decisions (right: 2010 UN Climate Change Summit in Cancun).





Infrastructure: Observatories

AT THE PULSE OF THE PLANET

Long-term observations are the key to understanding global change. The Helmholtz Association is supported through two pillars in monitoring the Earth: remote sensing and observatories. These observatories are on land, in the air and at sea. In future the existing facilities will be more tightly networked in order to enhance their benefits.

Long-term field experiments will complement the observations.

The Earth is a constantly changing planet. Some processes that characterise the face of the planet take place on a scale of micrometers or even nanometers. Others only become perceptible on a global scale. Through measurement programs and observatories the Helmholtz Association keeps an eye on all scales, from the microscopic range to the entire planet.

The satellites, ships, buoys, moored systems, radar stations, aircraft and balloons of the Helmholtz Association record critical parameters from a great distance enabling us to take a look at the big picture. However, remote sensing data have to be compared with data measured on site. Observatories on the ground, in the air and on the water are important for this purpose. If their sensors are networked, observatories can also record large-scale interrelationships. At the same time they permit a look at the fine details since their sensors are also able to observe small-scale processes down to the microscopic level. Additionally, observatories make it possible to gain insights into areas on our planet that are extensively inaccessible to remote sensing methods, e.g. the Earth's interior or the oceans.

For the researchers of the Helmholtz Association the observatories are a key tool for understanding the Earth system, monitoring natural hazards (see p. 6) and obtaining data on global change. The data from the observatories are incorporated into models that, in turn, allow scientists to make predictive statements on the future development of the Earth system, both on a global and regional scale. To make even better use of its diverse observatories, the Helmholtz Association would like to place greater emphasis on an integrated, interdisciplinary approach in future.

Up to now many observatories have concentrated on a certain part of the Earth system. For instance, they record individual physical variables like seismic waves or monitor a certain ecosystem. However, in recent years scientists have determined that seemingly independent parts of the Earth system are linked to each other via complicated interactions. Desert dust swept away by the wind, for example, may trigger algal bloom in seas thousands of kilometres away. Another example of far-reaching interactions concerns is oceanic currents: they are not only influenced by processes in the



atmosphere – especially wind – but also by events on land, such as the water volume that rivers or glaciers discharge into the ocean.

To identify interrelationships that have remained hidden to date, it is necessary to use a more holistic approach that includes the interfaces and interactions between the various parts of the Earth system. A major future challenge will be to link the existing Helmholtz observatories even better to one another. The collected data could be made available to the research community within an integrated data platform. In addition, the observation systems that already monitor the interfaces of the Earth system today should be strengthened. They include, for example, the tsunami early warning system GITEWS, the four land observatories of the TERENO initiative, the coastal observatory COSYNA, the IAGOS aircraft-based observation system, the long-term deep-sea observatory HAUSGARTEN and parts of the international GOOS ocean observing system. The Helmholtz Association also targets establishment of new technologies. They include integrated multiparameter observatories as well as new, high-performance satellite platforms. Networking of these facilities will further increase their scientific benefits.

Moreover, the Helmholtz Association wants to set up so-called ‘Exploratories’. The purpose of these facilities is not only to enable observation of the environment, but also implementation of long-term field experiments, which is decisive for identifying causal interrelationships. In an exploratory fashion researchers can in a targeted manner manipulate environmental conditions and find out at what threshold values an ecosystem changes.

Another objective of the Helmholtz centres in the Research Field Earth and Environment is to enhance the scientific quality of long-term measurement programs. Long-term campaigns are important because creeping changes like global change can only be recorded and understood through measurement series over many years.

Germany's highest research location: the summit observatory on Zugspitze (far left).

On the way to the stratosphere: measuring devices for investigating the ozone layer (centre left).

Back from the deep sea: in the Gulf of Mexico an autonomous observation platform (Lander) is recovered.

A radiometer measures the soil moisture on a test field (far right).

Helmholtz researchers now want to work out a conceptual framework by means of which long-term programs develop step by step and can be adapted to altered circumstances and new questions. This means, for example, uniform standards have to be specified for data storage and the IT infrastructure.

The objective of the Helmholtz Association is to expand its observation platforms into intelligent observatories. This necessitates even more pronounced incorporation of models that interpret and extrapolate measurements. Networking measurement platforms offers the opportunity of consistently bundling knowledge from different areas of the planet.

THE HELMHOLTZ RESEARCH FIELD EARTH AND ENVIRONMENT

Facts and figures

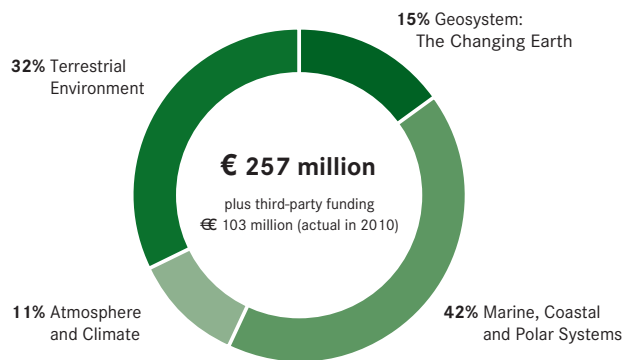
In the funding period from 2009 to 2013 there are four strategically oriented research programmes:

- Geosystem: The Changing Earth
- Marine, Coastal and Polar Systems
- Atmosphere and Climate
- Terrestrial Environment

The structure of the Research Field Earth and Environment

Target costs of core funding in 2010: € 257 million

(incl. proportionate non-programme-related research)



Core-funded costs	257
Geosystem: The Changing Earth	38
Marine, Coastal and Polar Systems	108
Atmosphere and Climate	29
Terrestrial Environment	81

Total staff, including infrastructure personnel, corresponding to 3,467 FTE (full-time equivalents)

Scientific staff, corresponding to 1,296 FTEs, of those 874 core-funded, 421 through third-party funding

842 supervised PhD candidates

1,861 publications in ISI-indexed journals (Institute for Scientific Information)

76 patents awarded

2,125 research collaborations

232 industrial collaborations

(status as at 2010)

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page 5 top.

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