



**IFM-GEOMAR**

Leibniz-Institut für Meereswissenschaften  
an der Universität Kiel

70°N

# From the Seafloor to the Atmosphere

Leibniz Institute  
of Marine Sciences

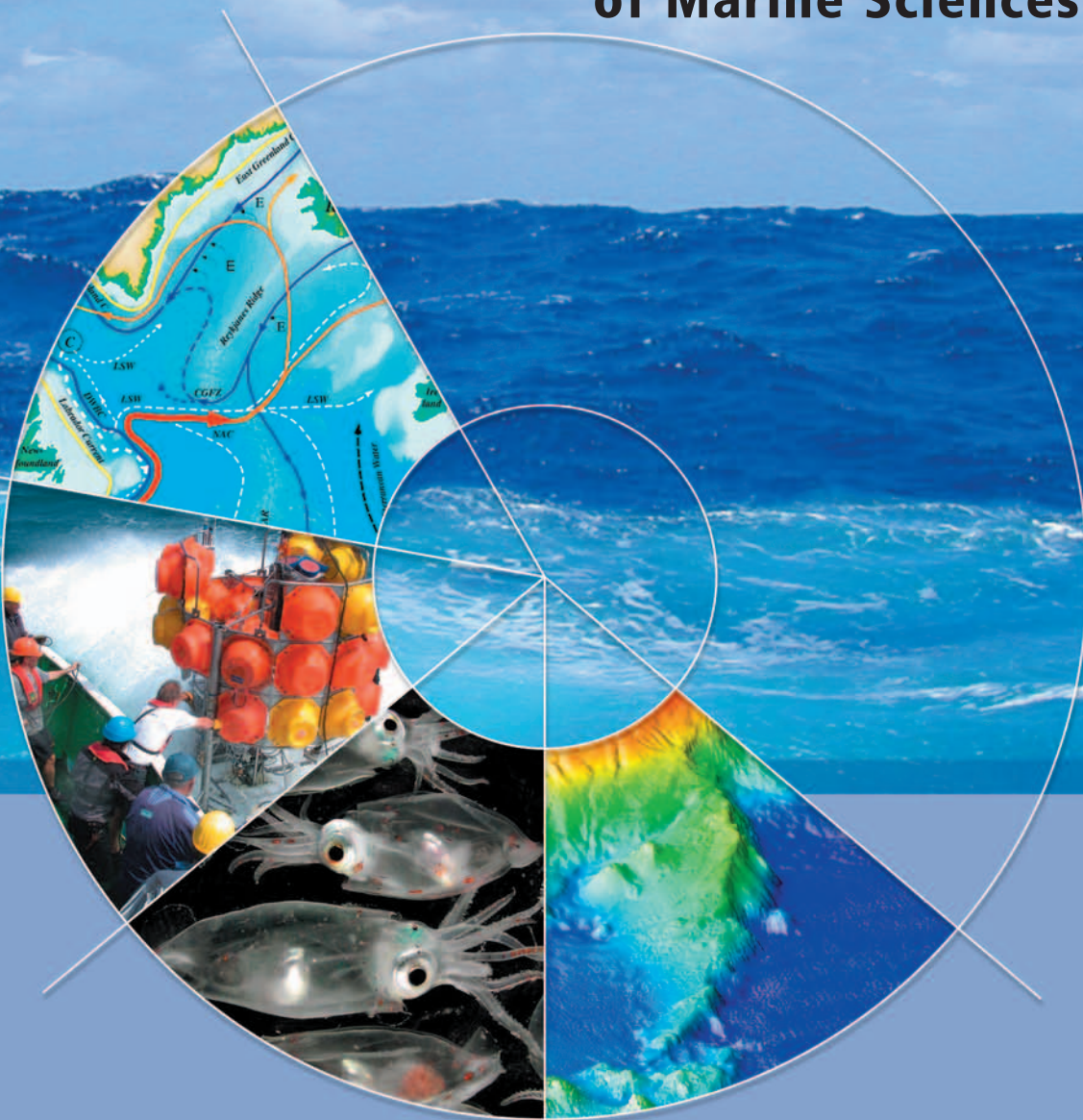
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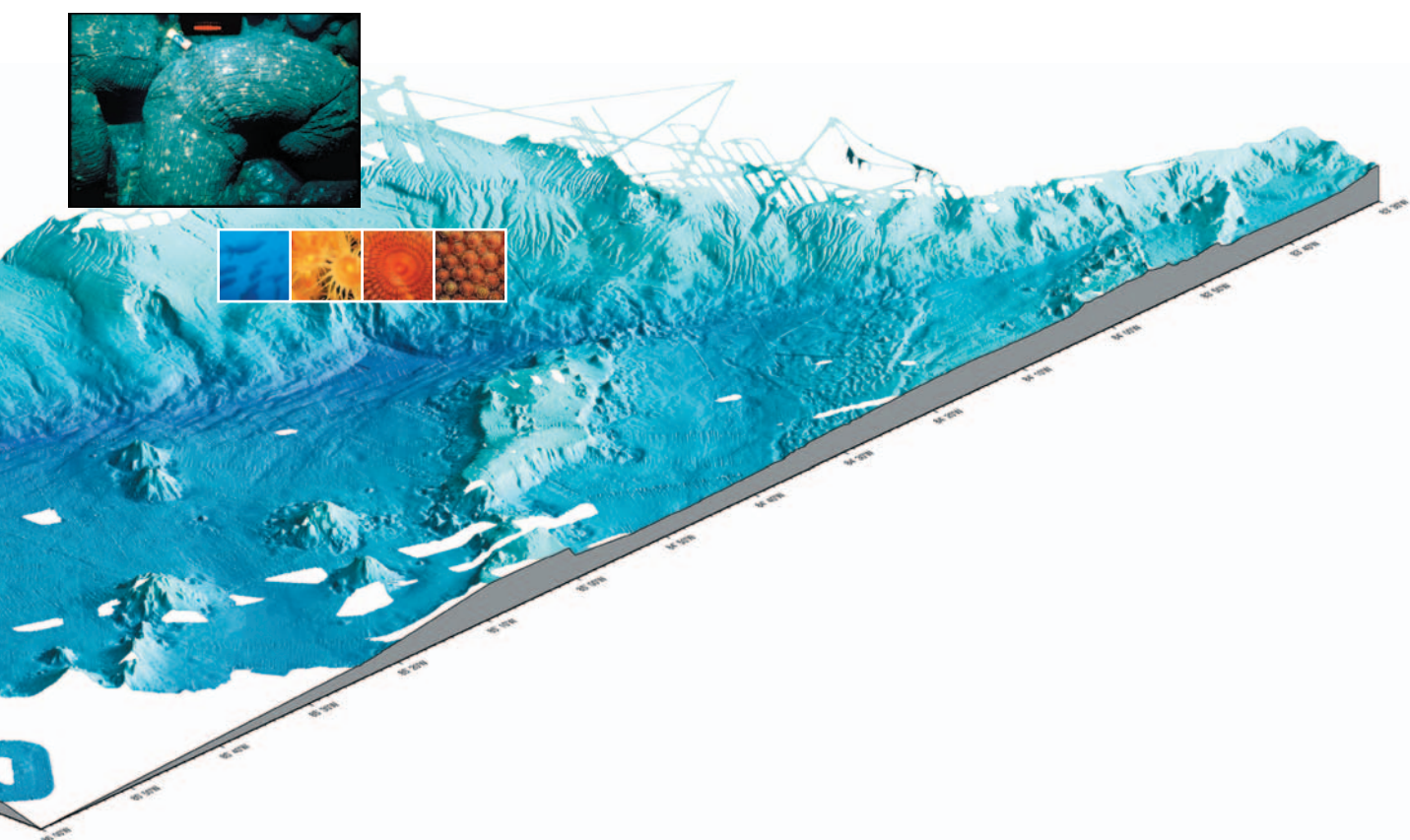


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## *From the Seafloor to the Atmosphere*

### **Dear ladies and gentlemen:**

The Leibniz Institute of Marine Sciences IFM-GEOMAR at the University of Kiel was founded in January 2004 through a merger of the former Institute for Marine Research (IfM) and the Research Center for Marine Geosciences (GEOMAR). The institute is a member of the Leibniz Association and has around 400 employees. With a yearly budget of over 40 million Euros, several research vessels, a multitude of facilities and laboratories, as well as a public aquarium that also serves as a research facility, IFM-GEOMAR sets international standards for marine research. The goal of the institute is to address key questions in marine science through interdisciplinary efforts in all relevant areas of oceanographic research. The topics of investigation range from seafloor geology to maritime meteorology and encompass all ocean basins of the world. This broad scientific spectrum and extensive infrastructure have established IFM-GEOMAR as an important member of both European and international networks of marine research institutes.

IFM-GEOMAR is structured in four main research divisions: [Ocean Circulation and Climate Dynamics](#), [Marine Biogeochemistry](#), [Marine Ecology](#), and [Dynamics of the Ocean Floor](#). In addition, there are two collaborative research centres of the German Science Foundation (DFG). The institute boasts an international team of scientists that places an emphasis on cross fertilization between different areas of research. This is the hallmark of the new Leibniz Institute, whose research programs include both applied and basic science. The second important pillar of IFM-GEOMAR is education. The institute places a strong emphasis on promoting undergraduate and graduate students in all disciplines of marine science. This well-founded education enables the new generation of scientists to meet future challenges not only in marine science, but in topics that will become increasingly important to society as a whole.

This brochure will introduce you to the diverse aspects of our work and will hopefully kindle your interest in the fascinating world of marine science.



**Prof. Peter M. Herzig**



**Prof. Peter M. Herzig**  
Director of IFM-GEOMAR

### **The Leibniz Association**

The Leibniz Association presently encompasses 84 research institutes and service centres. The tasks and responsibilities of these institutes are of supra-regional interest. Research results from these institutes are applied in national and state policy development, hence the Leibniz institutes are supported by both federal and state funds. The areas of research range from space and economic sciences to natural, engineering, and environmental sciences. The common goal of the organizations is to work on an interdisciplinary basis and on demand. The Leibniz institutes consider themselves to be working partners of scientific institutions, the industry, as well as federal and state authorities. Their cooperation with universities is particularly close and intensive.



## RESEARCH DIVISION 1

# *Ocean Circulation and Climate Dynamics*

Understanding the ocean's role in our climate is the central goal of Research Division 1 (RD1). Interdisciplinary work spanning the four fields of [Paleo-Oceanography](#), [Physical Oceanography](#), [Maritime Meteorology](#), and [Theory and Modeling](#) is a particular strength of this department. The expertise includes large-scale and process-oriented modeling, sea-going capabilities for studying the dynamics of the present-day system, and paleo-oceanographic studies of past climate conditions. Oceanographic, geological and meteorological data are combined with satellite observations to develop models of complex ocean-atmosphere interactions.



A sediment core from the Arctic Ocean gives insight to 150,000 years of climate history. The dark layers document colder climate phases, the light layers were formed during warm periods.



### The Earth's Seafloor Diary

"The past is the key to understanding both the present and the future" is an axiom that also applies to our climate. However, from what source can we draw information about intervals in Earth's history during which no instruments for measurement existed, nor people to apply them? Fortunately, the climate on our planet has kept a diary on the bottom of the ocean. Organisms and other particles have rained down from the surface to the seafloor and built up layer upon layer of sediment over millions of years. Every

layer, akin to a chapter in history, has captured information about environmental conditions during the time of formation. Together, the chapters form a book that can reveal the history of our climate. On board ships, the scientists of the [Paleo-Oceanography](#) research unit use specialized drilling instruments to recover cores of seafloor sediments. Conditions that prevailed during times long past such as oxygen level, temperature, or biological productivity can be discerned in the sedimentary cross-sections of the seafloor.

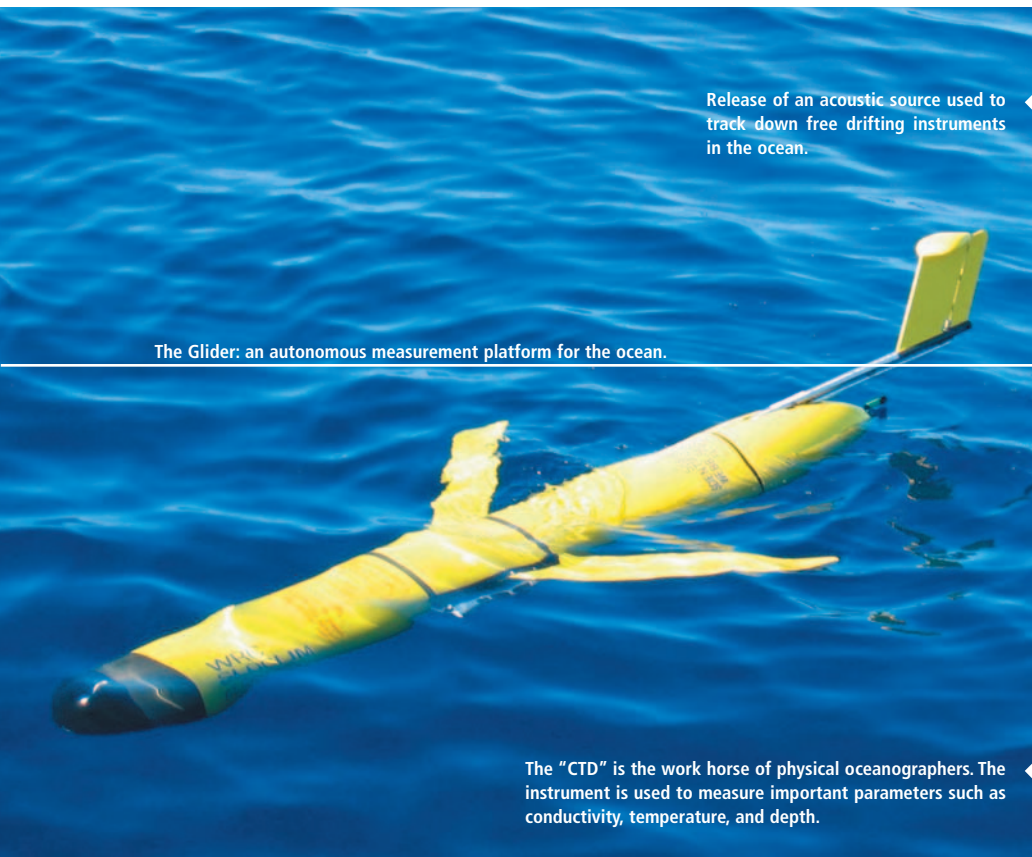
The ocean harbours a further climatic archive in addition to seafloor sediments. Coral reefs, both deep-sea and shallow-water, also represent a valuable source of information about the past. Similar to tree rings, coral organisms grow in annual increments and their skeletal deposits record different environmental parameters. Paleo-oceanographers use time-related data from corals and sediment cores to reconstruct the history not only of the Earth's climate, but also of the ocean itself.

### The Research Vessels

The fleet of research ships at IFM-GEOMAR is essential for fulfilling the primary mission of the institute, namely the investigation of oceanic processes. The institute operates four ships of different sizes. The largest are the two mid-sized research vessels POSEIDON and ALKOR. The POSEIDON is used for longer expeditions to the North Atlantic, the Norwegian Sea, and occasionally the Mediterranean Sea. The ALKOR is primarily used for research in the North and Baltic Seas, as well as in the Kattegatt and Skagerrak areas. Sometimes the ALKOR is implemented for student training courses. While the state of Schleswig-Holstein is the legal owner of the larger ships of the fleet POSEIDON and ALKOR, the small research cutter LITTORINA belongs to the University of Kiel. The ship works mainly in the western Baltic and is used for coastal research and student courses. The smallest of the ships is the POLARFUCHS, which is used for studies in the Kiel Fjord and Bight.







### The Engine for Oceanic Currents

The water masses of the ocean are in constant motion, driven by wind, mechanical mixing, and surface buoyancy forces. The path of the currents around the globe and their depth is mainly determined by temperature, salinity and the topography of the seafloor. Thus, while global climate influences the movement of water masses in the world's oceans, the currents in turn affect climatic processes on both global and regional scales. The [Physical Oceanography](#) research unit investigates the multifaceted processes that drive oceanic currents. The near-surface currents of the North Atlantic transport thermal energy from the Tropics and have a strong influence on the climate in Europe. These

water masses sink in the sub-polar North Atlantic and flow as a deep current southwards, thereby acting as a thermal conveyor. Because these sinking processes are potentially unstable, they represent the Achilles heel for the transport of warm water masses to northern Europe. If the thermal conveyor weakens, it could strongly impact the climate in northern Europe. In view of this critical and potentially unstable process, the physical oceanographers have placed a focus on understanding this key area of the Atlantic. A second focus is placed on the Tropics, where rapid ocean-atmosphere interactions occur. Here and in other areas around the globe, their prime goal is to discern the extent to which climatic

or oceanic processes influence the large-scale circulation of water masses. Sensors attached to drifting buoys or moorings measure multiple parameters such as velocity, salinity, and temperature at various depths in the water column. To improve data gathering, scientists at IFM-GEOMAR work together with industry to develop new technologies. Only recently, a new instrument was constructed that can glide autonomously through the water. The software for analyzing the real-time telemetry data was also developed at IFM-GEOMAR. This first Glider in Europe is currently being tested in the Mediterranean. Afterwards it will be deployed in the Atlantic to deliver data profiles on a daily basis.

Research vessels are swimming high-tech laboratories. They offer the facilities necessary to conduct modern oceanographic research. These include special biological, geological, geophysical, chemical, physical, and meteorological research equipment and data instruments, as well as cold rooms, cranes, winches, and laboratories. In addition, the ships must offer sufficient space for the crew and scientists to feel comfortable on board since some expeditions span several weeks or even months. The oceanographers of IFM-GEOMAR participate not only on cruises on their own fleet, but also on expeditions aboard other German or foreign research vessels. In this way, the ships can remain in a more restricted area of operation and costly transit cruises can be avoided. Internationally, the largest and most well-known ships also used by IFM-GEOMAR scientists are the SONNE, the METEOR, and the POLARSTERN.

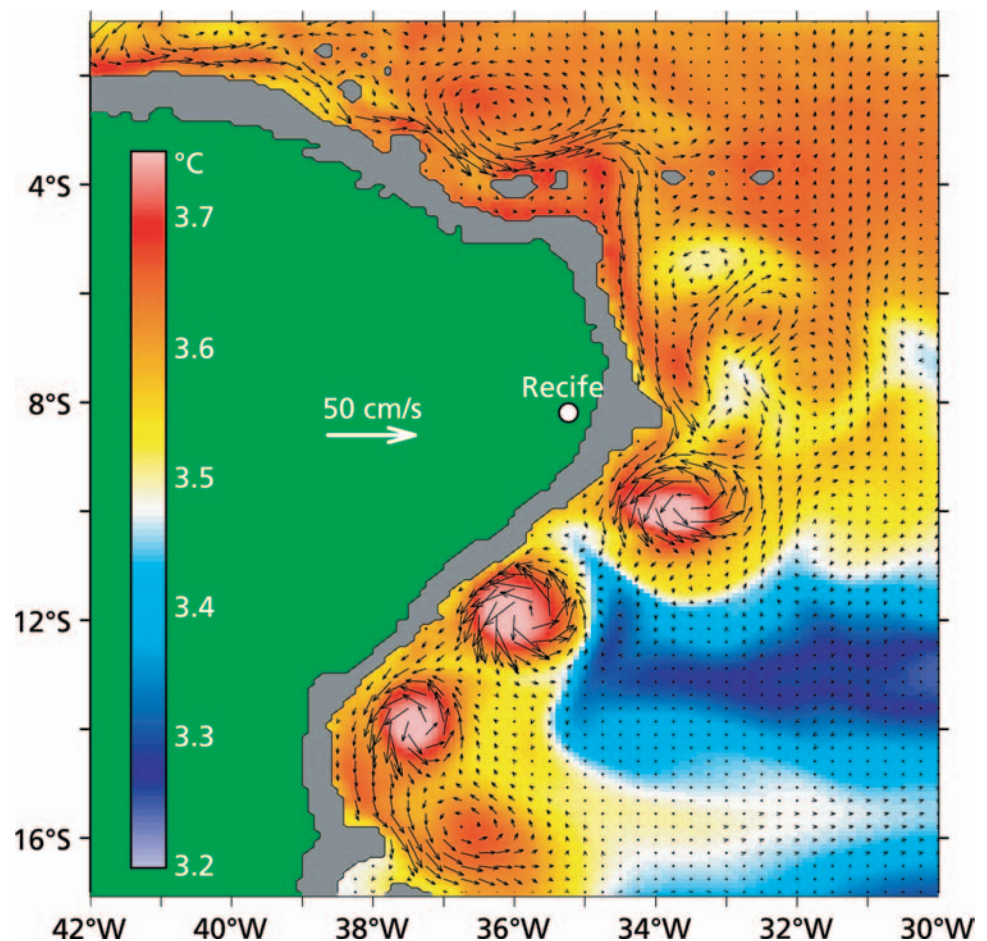




### The Computer as a Laboratory

Field data allows conclusions about the behaviour of oceanic currents, which are limited to the time and location of the measurement. When fed into a computer model, however, the data points deliver a foundation for interpreting past and future current variations.

Scientists in the research unit [Theory and Modeling](#) have developed numerical simulations of current motions on time scales from weeks to thousands of years, and on spatial scales ranging from regional to global. The highly complex computer "lab experiments" deliver a quantitative analysis of the complex interactions between atmosphere and ocean currents. Combined with field observations, scientists can use computer models to evaluate processes such as the conditions under which the Gulf Stream system could become unstable. The more parameters and processes are integrated into the model, the more precise the simulation. Newer models incorporate interactions such as those between currents and marine ecosystems, thus providing a more accurate picture of oceanic processes. A previously unknown phenomenon was discovered by oceanographers from IFM-GEOMAR along the coast of Brazil. Measurements at a depth of 2000 meters revealed large eddies rather than the expected calm and uniform deep current. Computer models showed that the eddies can only develop when the deep coastal current is sufficiently strong. This deep current is considered to be one of the engines for the Gulf Stream system. The water masses are formed in the sub-polar region of the North Atlantic and flow south to the Antarctic. The modelers view the eddies as indicators for the strength of the engine. Should the engine slacken, the deeper eddies would also wane.



Simulation of the North Brazil Undercurrent, the deep western boundary current off the coast of Brazil.



SONNE



METEOR



POLARSTERN




### The Ocean as a Kitchen for our Climate

The scientists in the [Maritime Meteorology](#) research unit also investigate the interactions between the ocean and the atmosphere. Their main focus lies in the atmospheric response to oceanic processes. Present studies are seeking answers to questions such as: when and where do clouds originate, how large is the thermal exchange between the ocean and the atmosphere, and to what depth does solar radiation penetrate? A further focus is the study of the role of the Atlantic Ocean in the alternation between the

Azores high pressure and the Iceland low pressure systems, a process that has a crucial effect on winter weather conditions in Europe. To address these questions both qualitatively and quantitatively, the meteorologists at IFM-GEOMAR collect data at sea and integrate this information with satellite observations.

The combined data is fed into computer models that are used to depict climate development on regional and global scales during different time intervals. The time scales range from a few weeks to

extrapolations of several hundred years. Of particular interest is the question of the anthropogenic influence on the Earth's climate. Can the recent increase in natural catastrophes such as floods, tornadoes, and heat waves be explained by "normal" climatic fluctuations or are we already observing the consequences of human activity? Scientists at IFM-GEOMAR are involved in many national and international research projects that focus on these and other questions.



Cameras document cloud patterns above the ocean – a helpful tool for the interpretation of meteorological measurements.





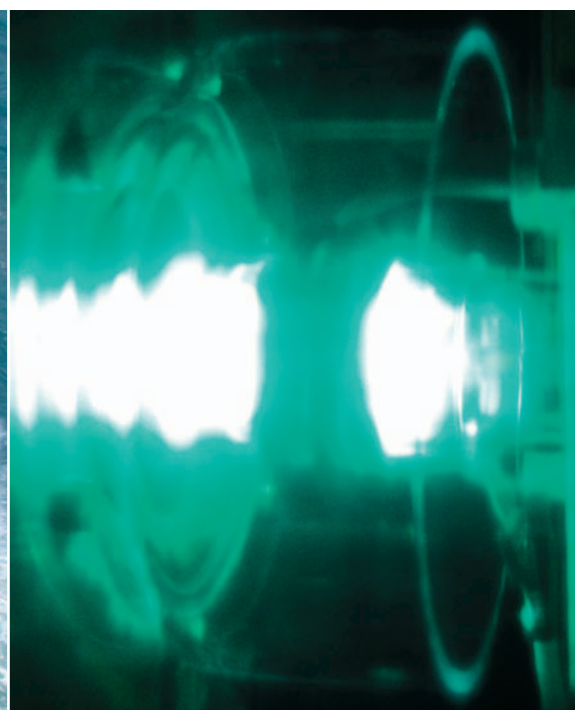
## RESEARCH DIVISION 2

### *Marine Biogeochemistry*

The **Marine Biogeochemistry** division investigates material transfers within

and between the ocean, the atmosphere, seafloor sediments, and marine organisms. The oceanographers in RD 2 focus in particular on processes within the boundary layers between the atmosphere, the ocean, and the sediments. At these interfaces, there is a highly dynamic exchange of elements and compounds. Advanced methods and simulations are developed through interdisciplinary cooperation between the research units **Marine Geosystems**, **Chemical Oceanography**, **Biological Oceanography** and **Biogeochemical Modeling**. These tools are applied to improve understanding of oceanic element cycles of the past and present, as well as to allow informed extrapolations into the future.

Lander systems developed at IFM-GEOMAR enable long-term observations and experiments in the deep ocean.



#### **The Lithothek**

The Lithothek at IFM-GEOMAR includes a storage facility for cores, a laboratory to study core samples, and an equipment hangar to service scientific expeditions. The facility holds a collection of more than 8,700 m of split sediment core samples, of which 4,900 m are from the Red Sea, the so-called PREUSSAG collection. Furthermore, the institute archives hard rock samples, corals, and pore water samples. A portion of the sediment cores is in cold storage to ensure preservation of sensitive sections of the record. Samples are generally available for research and, to a limited extent, for educational purposes and museum displays. A group of technicians is specifically delegated to process incoming and outgoing sediment cores and samples. They ensure proper archiving of the material and document available samples in a data bank.



### Gas Hydrates:

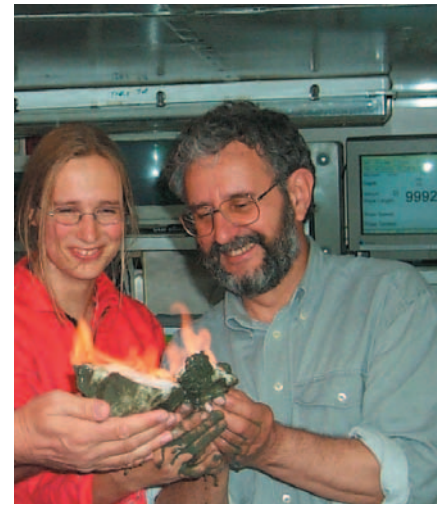
#### Energy Source or Climate Killer?

When scientists from IFM-GEOMAR discovered the largest underwater occurrence of gas hydrates in the Pacific Ocean off the Oregon coast in 1996, spectacular images of the flammable material were shown around the world. Gas hydrates are ice-like compounds in which gas molecules, such as methane, are trapped inside a cage of water molecules. They evolve naturally through complex processes in sediments at continental shelves and in Arctic permafrost.

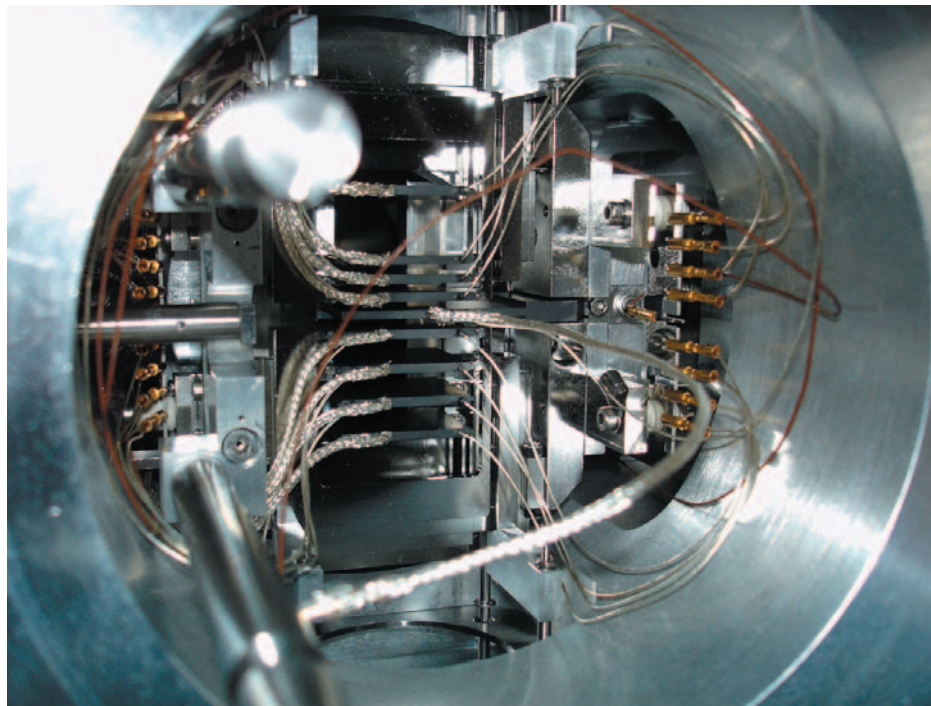
More than 160 cubic meters of gas can be stored in one cubic meter of hydrate. Estimates of marine methane hydrate reserves are comparable to the magnitude of known exploitable fossil energy reservoirs such as coal, oil, and gas. Methane gas hydrates therefore represent a potential energy source for the future. If released into the atmosphere, however, methane acts as a powerful greenhouse gas and would augment global warming. It is presently unclear to what extent these vast reserves of methane may be susceptible to climate-related change within the future ocean. IFM-GEOMAR has become one of the leading institutes world-wide in the study of the evolution and behaviour of marine gas hydrates. The knowledge gained is essential for a well-grounded assessment of the advantages and disadvantages in their use as an energy resource, as well as the potential risks associated with a changing ocean.

Understanding the formation of gas hydrates is only one of several topics being pursued by the research unit **Marine Geosystems**. Another main focus is

the study of sediments, rocks, and other natural archives of past climate and environmental change. Different working groups investigate processes of exchange between organisms, sediments and seawater. These involve major and trace elements and their isotopes, as well as gases such as methane and carbon dioxide. State-of-the-art benthic "Lander" technology has been developed at IFM-GEOMAR and is used to conduct long-term observations and experiments on the seafloor at depths of up to 6000 meters. Geochemical analyses conducted on board research vessels deliver immediate information about gas content and seawater composition. Subsequently, stable, radiogenic and radioactive isotopes can be determined by high precision mass spectrometry on shore.



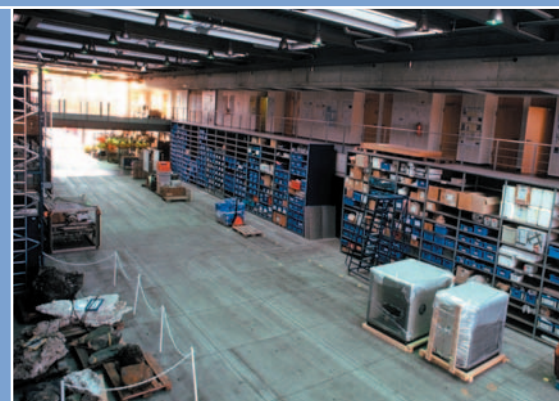
A picture that went around the world: gas hydrates or "burning ice" in the hands of IFM-GEOMAR scientists.



View inside a high-resolution mass spectrometer used to simultaneously detect different isotope signals in minute samples.

The Lithotek has a facility for high resolution logging of marine sediments, to obtain information about physical properties, the so-called multiple-sensor split core logger or MSCL. The core laboratory also permits digital core photography, measurements on sediments, the description of cores, and the processing of samples.

In addition to the sediment laboratory, scientists and technicians use the Lithotek to develop and test new sampling devices.







### A Shift in Ocean-Atmosphere Equilibrium

The global ocean and the atmosphere permanently exchange elements and compounds. The atmospheric concentration of many important gases that affect climate is, in turn, strongly influenced by the respective oceanic concentration. For carbon dioxide, the ocean plays the role of an enormous chemical buffer. It dampens changes in CO<sub>2</sub> concentration and hence changes in climate over geological time. However, the sudden rise in anthropogenic pollution of the atmosphere is causing a major shift in this natural balance and at the same time a significant reduction in the buffering ability of the ocean.

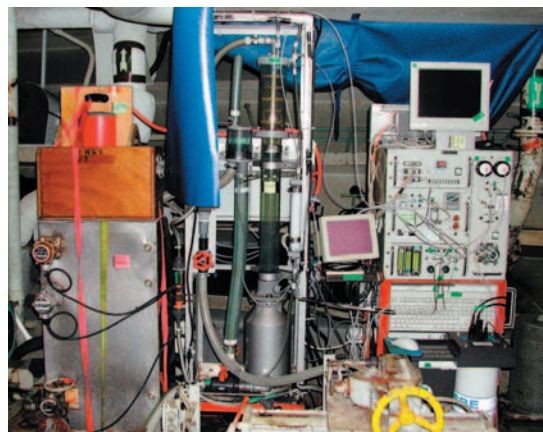


Samples can be collected at different depths with the rosette water sampler.

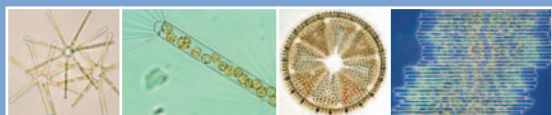
Scientists in the research unit [Chemical Oceanography](#) focus on understanding the chemical equilibrium between the ocean and the atmosphere in the past, as well as the role the ocean plays in determining present-day changes in the composition of the atmosphere. With this knowledge, they can help to predict future shifts in ocean-atmosphere equilibrium as a result of global change. More broadly, the chemical oceanographers study the distribution of substances within the present-day ocean, with an emphasis on the exchange of elements and compounds with the atmosphere and marine organisms.

Different working groups investigate the oceanic element cycles of carbon, nitrogen, halogens, and trace metals, all of which can influence the Earth's climate directly or indirectly. Atmospheric carbon dioxide from fossil fuels, for example, is dissolving in the upper layers of the ocean, thus leading to a reduction in the

greenhouse effect. Nitrous oxide (laughing gas or N<sub>2</sub>O), on the other hand, is released into the atmosphere. This compound not only reinforces the greenhouse effect, but also damages the ozone layer. The out-gassing of several halogen compounds such as bromoform and methyl iodide, which are sometimes produced by plankton, represents an additional natural attack on atmospheric ozone. Certain trace metals such as iron exert their influence on climate 'behind the scenes'. Iron, for example, is an essential nutrient for phytoplankton and its low concentration can limit productivity. Reduced plankton productivity due to nutrient limitation leads to a decline in the oceanic uptake of carbon dioxide, representing an indirect pathway by which trace metal concentrations can affect the climate system.



High-tech labs for CO<sub>2</sub> measurements in all ocean basins on the commercial vessel FALSTAFF (above) and the research vessel METEOR (below).







Barely visible to the naked eye: plankton.



Labs in the ocean: enclosures known as mesocosms are used to simulate different environmental conditions.

### Plankton – Small yet Significant

Phytoplankton and zooplankton, the microscopic plants and animals that float in the water column, build the base of the oceanic food chain. The organisms, their excretions, and their remains deliver nutrients for the majority of life forms in the sea. Most plankton species inhabit the upper layers of the ocean, which are permeated by light. Phytoplankton takes up carbon dioxide, nitrogen and other elements to produce organic matter by way of photosynthesis. The trace metal iron, which is carried into the ocean by desert dust, can be a limiting factor for phytoplankton growth. Of particular significance for the Earth's climate is the ability of phytoplankton to take up CO<sub>2</sub>, thus increasing the flux of this greenhouse gas from the atmosphere to the ocean. One of the most urgent issues being addressed by the research unit **Biological Oceanography** is the question of how phytoplankton productivity changes with respect to increasing levels of CO<sub>2</sub> in the modern ocean. The biological oceanographers at IFM-GEOMAR conduct both laboratory and field experiments to investigate the role of plankton in oceanic and

global element cycles. In addition to gathering data about the ocean of today, it is the question of the behaviour of plankton in the future that is of great importance. Anthropogenic changes in the environment, especially the increase in atmospheric greenhouse gases, are expected to have a significant impact on the ocean and its ecosystems. Molecular genetics is applied to gain information about cellular changes in planktonic organisms and their sensitivity to the altered availability of nutrients. Large-scale experiments using so-called mesocosms, large enclosures in which scientists simulate the ocean of the future, are used to observe the effects of changing environmental conditions on plankton productivity and biogeochemical cycling. A new direction of research for biologists at IFM-GEOMAR is also the study of the biological processes of trace gas production.

### The Future Ocean

Environmental changes caused by humans are having a significant impact on the ocean. Increasing CO<sub>2</sub> concentrations, for example, are leading to a decline in seawater pH to levels that have not existed for at least 20 million years. As a result, the world's oceans are becoming increasingly acidic with major consequences for their inhabitants. However, this is only one of a number of changes observed by oceanographers during the last few years. Field studies reveal alterations in oceanic currents, temperature, and oxygen content, to name but a few. At this time, it is impossible to foresee all consequences for marine ecosystems. Observational data concerning individual processes, chemical distributions and organisms are collected by the **Biogeochemical Modeling** unit and integrated into quantitative models. By this means, the scientists of the different research units of RD2 are able to combine their insights and peer forward into the ocean of the future.

### Submersibles

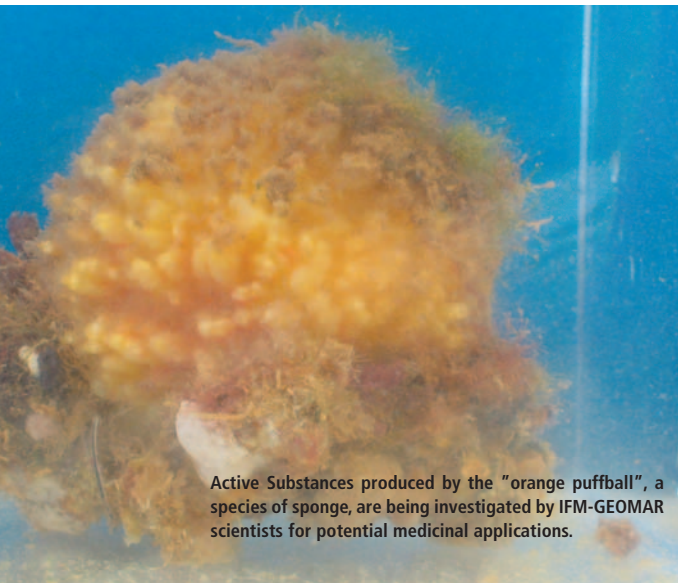
Research submersibles and remotely operated vehicles are the space crafts of the ocean. Their construction and operation is both costly and technically challenging. JAGO is one of the submersibles frequently used by IFM-GEOMAR scientists. It operates to a depth of 400 meters and provides space for two people. JAGO can be used to investigate a wide range of research topics being conducted at IFM-GEOMAR. For instance, JAGO facilitates research on gas hydrates, hydrothermal systems on the ocean floor, as well as cold-water corals and other marine ecosystems.





## RESEARCH DIVISION 3

### *Marine Ecology*



Active Substances produced by the "orange puffball", a species of sponge, are being investigated by IFM-GEOMAR scientists for potential medicinal applications.

Shipping, excessive fertilization, pollution, commercial fishing, and last but not least, global climate change, have far-reaching effects on marine ecosystems. Scientists are observing not only shifts in the geographic distribution of marine species and the disappearance of species, but also significant changes in seasonal activity and growth patterns. This can lead to temporal and spatial uncoupling between sensitive supply and demand relationships within oceanic food webs. In some cases however, physiological or genetic adaptation in species can reduce some of these detrimental effects. In the [Marine Ecology](#) division, the research units [Marine Microbiology](#), [Experimental Ecology](#) and [Fisheries Biology](#) investigate the impact of fisheries and changing environmental conditions on the structure and response of entire food webs, the interactions among species, and the dynamics and genetics of individual populations and communities.

#### **Medicine from the Sea**

Running away is not one of their survival strategies – in over 40 million years of evolution, sponges have developed other, highly effective, mechanisms of defence. In symbiosis with bacteria, they produce antibodies which can ward off both predators and disease. Today, the pharmaceutical industry is very interested in the arsenal of substances generated by sponges. Through a better understanding of the composition and capabilities of these unique products, scientists hope to gain valuable insights for the development of new and effective medicines against diseases such as cancer. For this purpose, the [Marine Microbiology](#) unit at IFM-GEOMAR is working in cooperation

with different pharmaceutical companies. The microbiologists isolate the natural elixirs from organisms such as sponges, hence making them available for manifold applications in modern medicine. Scientists at IFM-GEOMAR focus not only on the role of bacteria in the production of sponge antibodies, but also on the behaviour of many other micro-organisms. Highly specialised bacteria can be found in almost all oceanic ecosystems. They play an important role in oceanic food webs and element cycles. Through their influence on the transformation of greenhouse gases such as carbon dioxide and methane, marine micro-organisms can even affect global change processes. Various working groups in the [Marine](#)

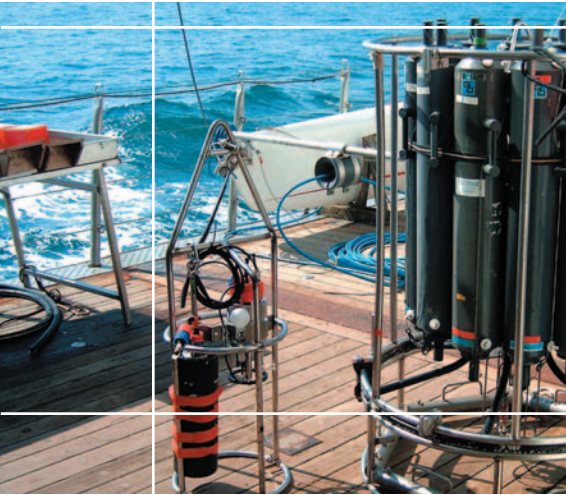
[Microbiology](#) research unit investigate the capabilities of bacteria in both laboratory and field studies using methods such as DNA-analyses. This enables a better understanding of the processes prevailing in different microbial communities.



#### **The Library**

The IFM-GEOMAR library is one of the largest marine science libraries in Germany. With an extensive collection of books and periodicals (110,000 media items, 794 open serial titles), as well as a special collection of historical works and rare monographs, the library of IFM-GEOMAR enjoys international recognition. Its homepage offers full text access to over 600 online journals, books, and databases. The library itself provides a number of services including comprehensive reference-section assistance and training in databank use, circulation services, and a digital processing centre for copying, scanning, and graphic design. The library is able to participate in the Linking Libraries Project, whose aim is to facilitate resource sharing among marine and aquatic science libraries worldwide. The libraries at the East and the West shore campus of IFM-GEOMAR serve pupils from schools all over the state of Schleswig-Holstein and are also open to the general public.



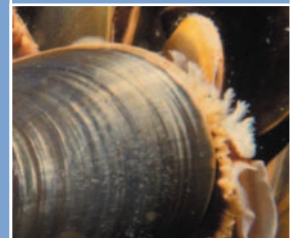


### To Eat and be Eaten

Nutrient enrichment of seawater during winter leads to blooms of phytoplankton in the spring. The microscopic algae build the base of the food chain and represent the source of sustenance for zooplankton. Supply and demand within food webs has developed to a well-synchronized balance over millions of years. However, is it possible that global change and associated warmer winters can disturb this sensitive equilibrium? This is only one of the many questions being addressed by the [Experimental Ecology](#) research unit. Both phytoplankton and phytobenthos, plants living at the bottom of the sea, form the base of complex food webs. Invertebrate animals are in intermediate positions, while large fish and marine mammals occupy top trophic levels. At the very top of the food web are human beings.



A special net is used to collect zooplankton and small fish.







The working groups of the **Experimental Ecology** unit attempt to discern the complex relationships within planktonic and benthic communities in order to identify the structure of oceanic food webs. The scientists pursue questions such as who is predator and who is prey, which organism protects others, who profits from changes through adaptation and who suffers drawbacks?



The role of chemical interactions between organisms is of growing interest since IFM-GEOMAR scientists discovered that many relationships are controlled by highly effective defence and alarm substances. Experimental ecologists are also focusing increasingly on the question of the anthropogenic influence on marine ecosystems. In both laboratory and field studies, they manipulate environmental parameters of planktonic and benthic communities to simulate observed changes in the ocean. The resulting effects on individual species and the community as a whole are documented and analysed. A further line of research is the study of the impact of imported species on ecosystems, as well as the identification of conditions leading to mass proliferations of certain algal species or jellyfish. The results of these studies enable an early identification of ecosystem changes and the prediction of future developments. The priority program AQUASHIFT of the German Research Foundation (DFG) is also part of the **Experimental Ecology** unit. The main focus of this program is the study of the impact of climate variability on aquatic ecosystems.



#### FishBase

The largest data bank for fish species worldwide is coordinated by scientists at IFM-GEOMAR. Currently, FishBase includes about 30,000 scientific species and 210,000 colloquial names. Fisheries biologists from numerous marine research institutes around the world have contributed to this project.

More information can be obtained under [www.fishbase.org](http://www.fishbase.org)



### Effects of Commercial Fishing on Fish Stocks

Almost 30,000 species of fish exist worldwide and about 18,000 of them are salt-water species. Of these, only about 100 are relevant to commercial fishing, yet their potential as a food supply is being threatened by extreme reductions in their stocks. Excessive commercial fishing is threatening not only fish such as herring, cod and sole, the entire marine food chain is strongly impaired in many areas of the ocean. To assess the consequences, the [Fisheries Biology](#) unit evaluates fish stocks and analyses the role of the respective species in the food web, as well as their behaviour and development under the influence of commercial fishing and climate change. The focus of fisheries biologists at IFM-GEOMAR is the North

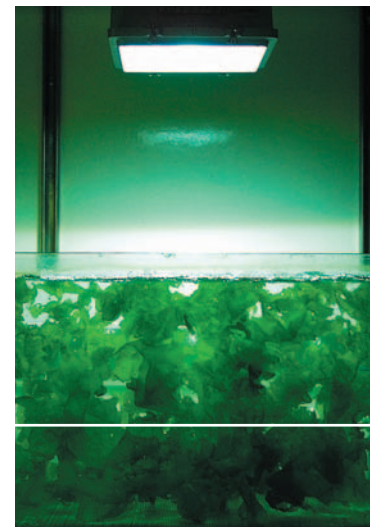
Atlantic and key areas of the North and Baltic Seas. Their scientific findings build a foundation for resource preservation and an ecologically viable use of commercial fish species.

Fish is a valuable component of the human diet. Yet how do we preserve this nutritional resource for future generations if many species of fish are threatened in their existence even today? Traditional fish farms, whose methods are in many ways detrimental to the environment, do not contribute to the preservation of natural resources. The common practice of releasing excess feed, chemicals and excrements into the surrounding water is among the problems associated with present fish farms. Modern aquaculture facilities, however, aim to produce

fish on a commercial scale without damaging the environment. The fisheries biologists at IFM-GEOMAR are working towards perfecting aquaculture systems with closed circulation cycles. With the help of micro-organisms, the waste water is cleansed of excrements and excess feed, while worms and algae take up remaining solids and dissolved nutrients and convert them to usable substances. Waste water that has been filtered and sterilized in this manner can be returned to the fish basins in a continuous cycle. These modern aquaculture systems, which also implement sources of food other than fish in the production process, help to preserve the ocean and its resources.



Fishermen with a catch of tuna on the Cape Verde islands. The impression of abundance is misleading: in many areas of the ocean tuna stocks have been greatly reduced due to excessive commercial fishing.



Algae in the basin of an integrated circulation system.

### The Data and Computer Centre

The data and computer centre of IFM-GEOMAR is responsible for administering and operating all central compute, application and file servers. The computer specialists have interconnected more than 400 workstations and ensure web security for all employees. Furthermore, they have established access to the high-speed net of the University of Kiel to carry out high performance computations. The computing staff is also responsible for managing the large data bases collected by the scientists of IFM-GEOMAR, as well as the web site of the institute. The hardware includes computers of all sizes, ranging from supercomputers to PCs.



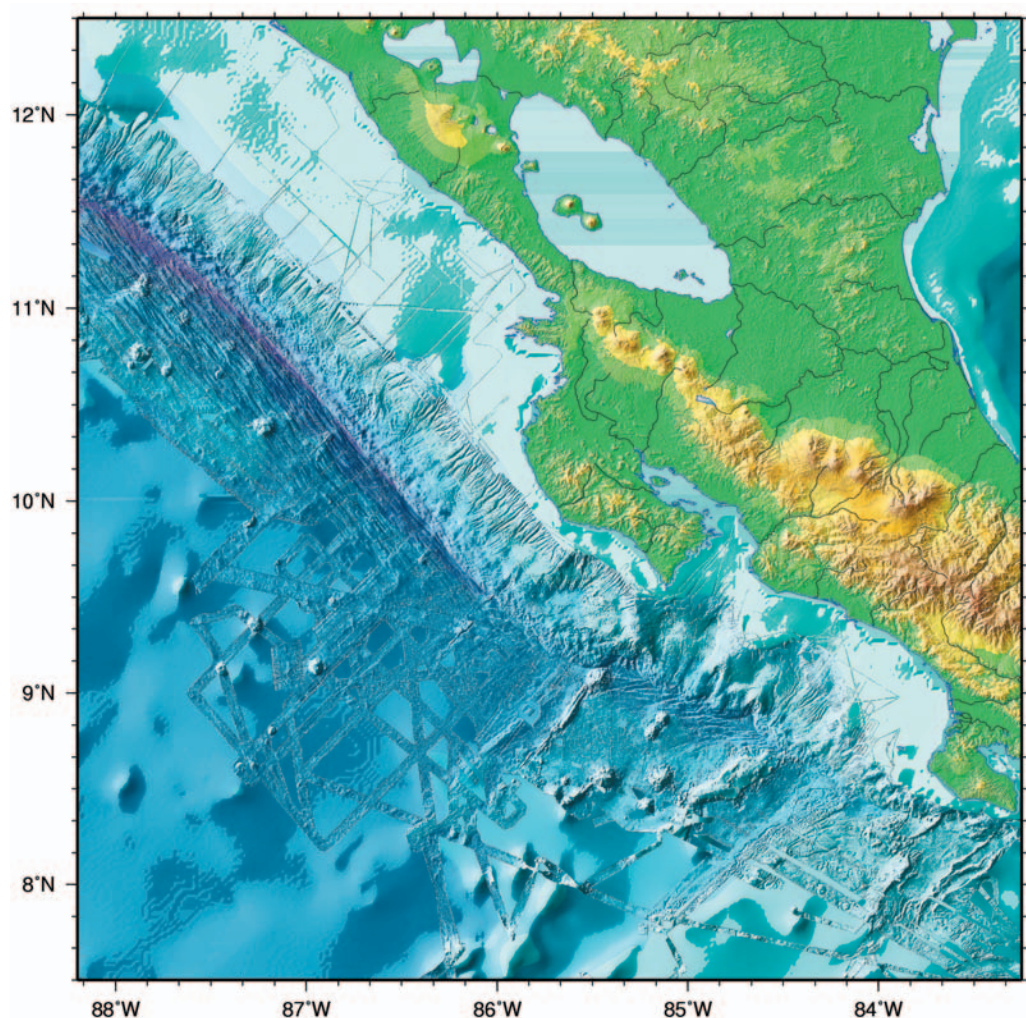


## RESEARCH DIVISION 4

### *Dynamics of the Ocean Floor*

Vast mountain chains, deep canyons, spouting volcanoes and hot vents – these are the topographic elements that characterize the seafloor and make up more than two thirds of the surface area of our planet. The outer layer of the Earth is a relatively thin crust that “swims” on a hot and plastic mantle. This crust is comprised of many individual plates that are in constant motion relative to one another. At their boundaries, plates can drift apart, collide, or move past each other, thereby forming new crust, destroying crust, or deforming it. The “side effects” of these plate movements are earthquakes, volcanoes, and tsunamis. These tectonic and volcanic processes at plate boundaries also influence our lives indirectly. For example, gases released from the sea can interact with the atmosphere and thereby influence the global climate. In the division Dynamics of the Ocean Floor, the research units [Geodynamics](#) and [Magmatic and Hydrothermal Systems](#) investigate the geophysical, geochemical, hydrothermal and volcanic processes that occur at the bottom of the ocean.

Relief map of the Pacific coast off Costa Rica and Nicaragua. The tracks indicate areas of the subduction zone mapped with multibeam echo sounder by IFM-GEOMAR scientists.



#### Co-operative Research Efforts

Institutes working individually can no longer meet the challenges in modern marine science. In all disciplines of oceanography, the concerted effort of specialists from all over the world is required in order to find answers to today's global problems. IFM-GEOMAR participates in many of these national and international projects ranging from the promotion of graduate students to the establishment of a worldwide network of ocean observatories and the shared use of research vessels. The most important partners of IFM-GEOMAR in Europe include the French institute IFREMER (Institut Français de Recherche pour l'Exploitation de la Mer) and the NOC (National Oceanography Centre) in Southampton, Great Britain.



### Plates in Motion

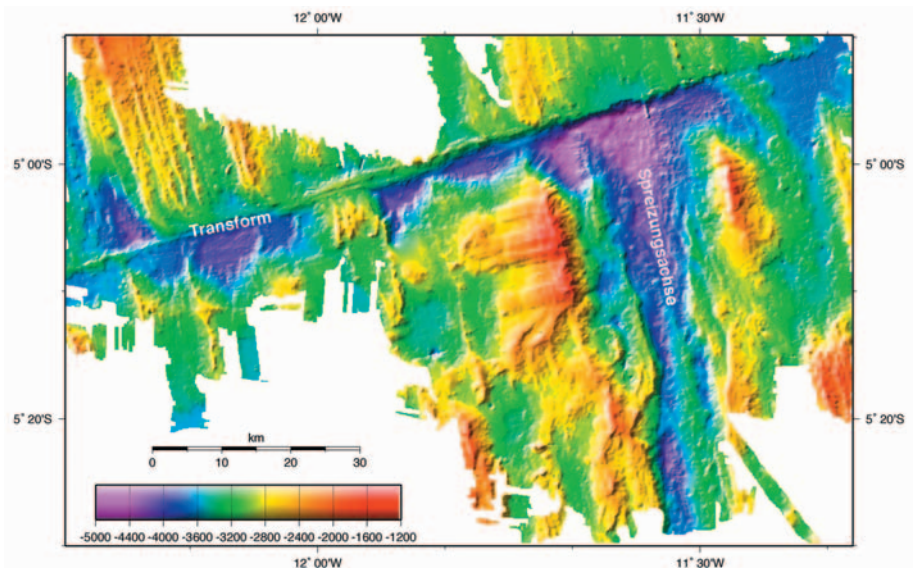
The dynamic processes on the seafloor usually take place unaware to us. Occasionally, spectacular or catastrophic events remind us of the seething earth beneath our feet. The results of the powerful forces unleashed during such events are visible everywhere: the Himalayas, for example, are comprised of oceanic crust that was folded and thrust upwards about 65 million years ago. A recent example with tragic consequences is the tsunami that flooded the coasts of Southeast Asia on December 26, 2004, leading to the loss of hundreds of thousands of lives. The giant wave was triggered by an earthquake deep in the Indian Ocean. The epicentre was localised at a subduction zone, a plate boundary at which one plate is thrust beneath the other. As the two plates collide, tension increases until one plate "slips" past the other in a sudden movement. The resulting release of energy can lead to earthquakes, underwater landslides, and tsunamis.

The scientists of the research unit **Geodynamics** investigate seafloor processes at active and passive continental margins. Subduction zones are tectonically active and can be found not only in Southeast Asia, but around the entire Pacific Ocean in a zone known as the "Ring of Fire". Passive continental margins, on the other hand, are located around the Atlantic Ocean. Different instruments can be

deployed in order to collect data on seafloor seismic activity. Some of these instruments, such as the ocean bottom seismometer and the ocean bottom hydrophone, were developed at IFM-GEOMAR. New pressure sensors which are anchored on the seafloor can be used not only to detect earthquakes, but can be incorporated into early warning systems for tsunamis. In addition to these research projects, the Geodynamics unit is involved in large-scale mapping of the seafloor using side-scan sonar. Specialized software is applied to process the data and produce bathymetric maps. These three-dimensional depictions of the seafloor deliver images of areas on our planet that are normally hidden from our eyes.



An ocean bottom seismometer (OBS) developed by IFM-GEOMAR to measure seismic waves.



A bathymetric map of a segment of the Mid-Atlantic Ridge. At this plate boundary, the African and South American Plates are pushed apart by the formation of new ocean floor.

### The "Konsortium Deutsche Meeresforschung, KDM"

The "Konsortium Deutsche Meeresforschung, KDM" or German Marine Research Consortium was founded in Kiel on December 8, 2003. The members of KDM are the ten large university and non-university marine research institutes in Germany. The chairman of the consortium is Prof. Peter Herzig from IFM-GEOMAR. The primary aim of KDM is to focus the interests of German marine research and to represent its members in national and European political forums, as well as in the general public. A further goal is the planning and coordination of research projects in all disciplines, as well as the coordination and long-term planning of investments in the fleet of research vessels and major oceanographic equipment.

The Consortium has an office in the Berlin Scientific Forum with Prof. Erwin Suess appointed as managing director. More information about the "Konsortium Deutsche Meeresforschung" can be found on the web site: [www.deutsche-meeresforschung.de](http://www.deutsche-meeresforschung.de).





### Recycling of Oceanic Crust

New oceanic crust is being constantly produced along huge cracks in the depths of the ocean which are formed when tectonic plates move apart. Magma formed deep in the mantle rises through these cracks and, when cooled, builds new oceanic crust. By this process, the seafloor is being constantly renewed at these divergent plate margins.

Massive sulfides from the PACMANUS hydrothermal fields off the coast of Papua New Guinea.



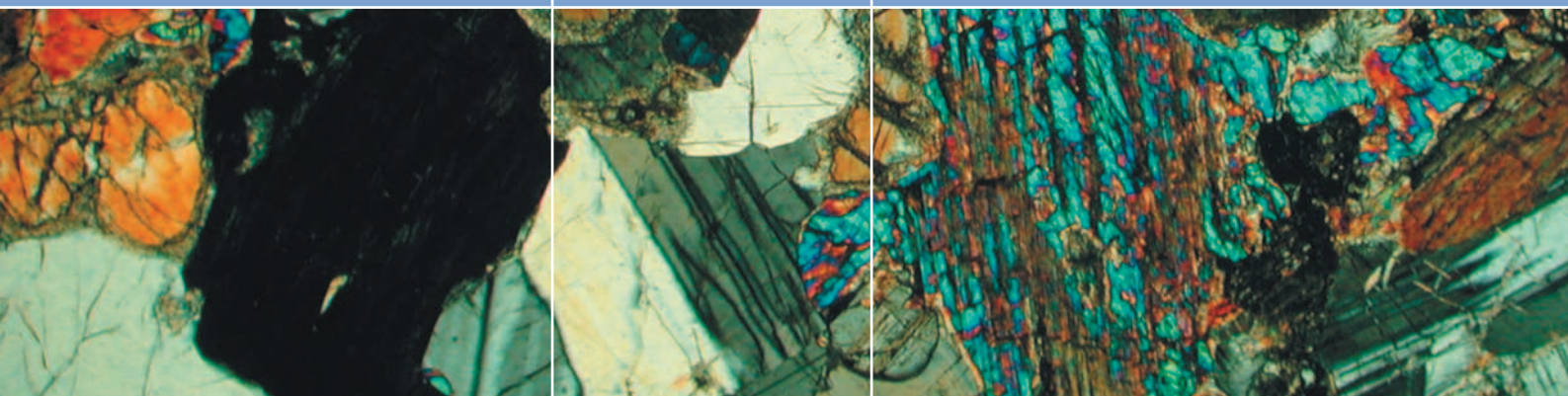
An IFM-GEOMAR scientist sampling gas from the Pacaya Volcano in Guatemala to analyze its composition.



The margins extend for about 60 thousand kilometers along the peaks of underwater mountain chains known as mid-ocean ridges. Since the Earth is not expanding, the production of new crust in some areas leads inevitably to the destruction of crust in other areas. These are the subduction zones, the plate boundaries at which one plate is thrust beneath the other and sinks deep into the mantle. Here the oceanic crust is recycled into the mantle. This seafloor conveyor belt that leads to the recycling of oceanic crust is the focus of the [Magmatic and Hydrothermal Systems](#) research unit.

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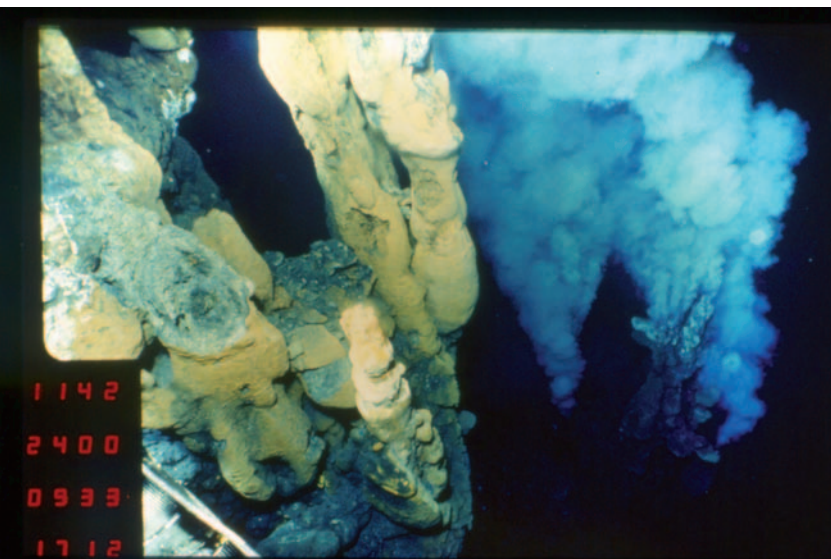
Colorful microscopic image of seafloor basalt.



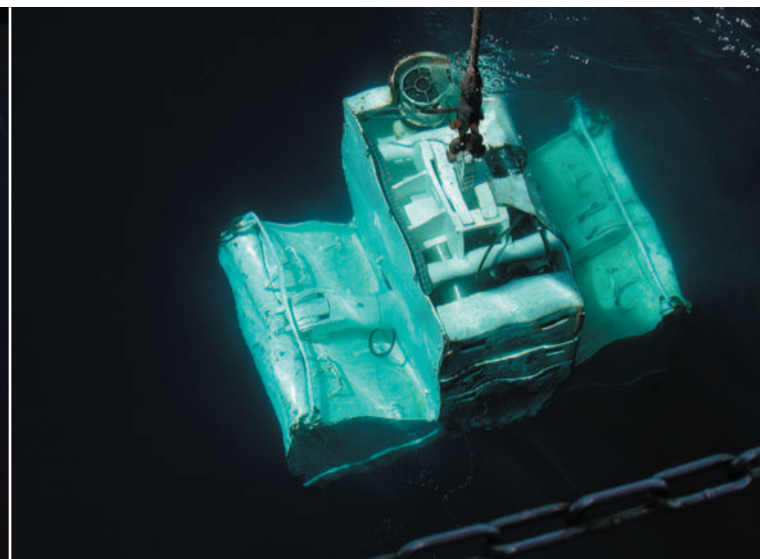


Marine geologists at IFM-GEOMAR collect rock samples in order to determine their volcanic history through volcanological, geochemical and dating analyses, as well as to interpret the transport and eruption mechanisms during their genesis. There are many different means of rock sampling, both shipboard and from research submersibles. In the laboratories back on shore, scientists analyse the chemical composition of the rocks using mass spectrometers, X-ray fluorescence, and other state-of-the-art methods. This information builds a foundation not only for understanding processes of crustal formation, but also for understanding the geological evolution of our planet. Two large

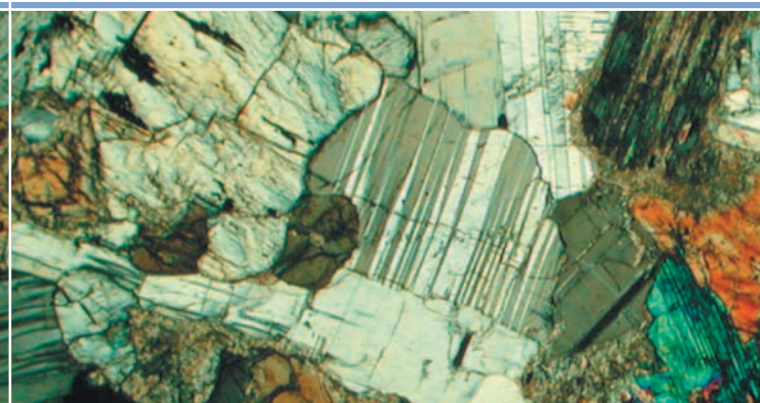
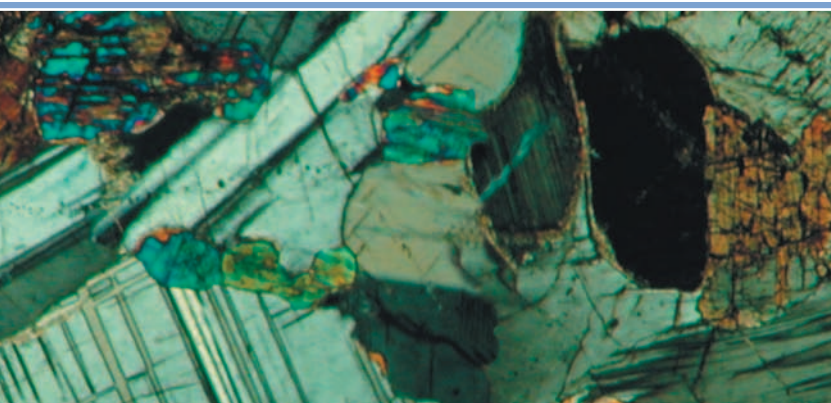
research projects that focus on processes of crustal formation are coordinated by marine geologists of the [Magmatic and Hydrothermal Systems](#) research unit. The German Research Foundation (DFG) priority program "From Mantle to Ocean: Energy-, Material-, and Life Cycles" involves multidisciplinary studies of spreading axes and represents a cooperative effort between IFM-GEOMAR and other German institutes. The second program called "InterRidge" is a large international project coordinated in Kiel that focuses on understanding processes at mid-ocean ridges.



Hydrothermal vents on the ocean floor:  
a white smoker in the Southwest Pacific at 1,700 meters depth.

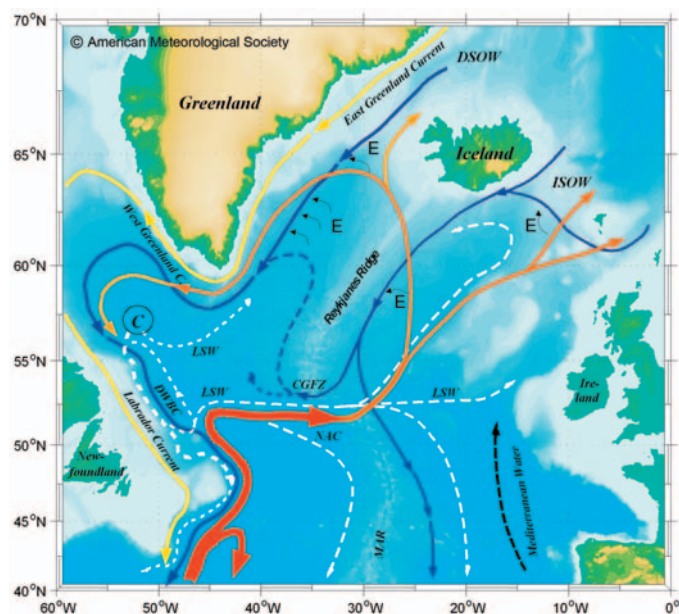


A grab sampler is launched to 5,000 meter depth in the Pacific. Equipped with a video camera and floodlights, the instrument is used to target rock samples on the seafloor.





## SFB 460: Dynamics of Thermohaline Circulation Variability



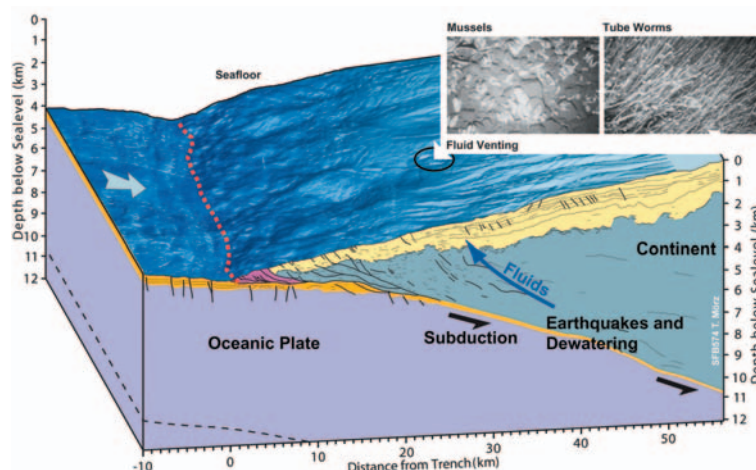
Schematic representation of the surface and deep-ocean circulation of the sub-polar North Atlantic.

The Gulf Stream and its heat transport, which extends far into the Nordic Seas, is the main cause of Europe's relatively mild climate. Yet what is the motor that drives this gigantic current? Scientists have identified an area in the sub-polar North Atlantic in which the northward flowing upper-layer water of the Gulf Stream sinks to a depth of 1000 to 4000m and is converted to cold water flowing southward. This large-scale oceanic overturning circulation is influenced by complex processes, in which temperature and salinity of the water play a key role. The oceanographers in SFB 460 use physical, chemical, and meteorological data to investigate the processes controlling this "thermohaline circulation". Since the start of the program in 1996, scientists at IFM-GEOMAR have contributed substantially to the development of instrumentation for data gathering. New technologies include multi-disciplinary time-series stations and real-time telemetry from moored instruments. The extensive information is then used to develop ocean models to analyse current structures and variations, as well as to evaluate large-scale ocean-atmosphere interactions in the past, present and future. The primary interest of SFB 460 is to identify long-term changes in the circulation pattern and heat transport of the North Atlantic, as well as the role of this key area in processes related to climate change and the associated uptake of anthropogenic carbon dioxide.

## SFB 574: Volatiles and Fluids in Subduction Zones:

Climate Feedback and Trigger Mechanisms for Natural Disasters

Powerful forces are involved when two crustal plates collide. Tectonic motions at subduction zones, where the lighter continental plate overrides the heavier oceanic plate, can sometimes have disastrous and far-reaching effects. These range from direct consequences such as earthquakes, volcanoes and tsunamis, to detectable effects on global climate. In this respect, volatiles such as methane, carbon dioxide, sulphur, and chloride play a key role. These compounds are bound together with water in the oceanic plate, but are released with increasing temperature and pressure as the plate sinks. While some of these volatiles and fluids travel to depth, a portion rises to the surface through conduits in the disrupted margin wedge created by tectonic activity. SFB 574 has been investigating the role of volatiles and fluids recycled at subduction zones along the Central American convergent margin since 2001. Different working groups focus on understanding the processes involved in fluid migration and on identifying the trigger mechanisms and probability of occurrence of natural disasters. The research program includes land-based observations and deep-sea measurements, as well as geochemical lab analyses and numerical models of fluid and volatile budgets.



The oceanic plate is subducted beneath the continental margin off Costa Rica, thereby releasing volatiles and fluids. The areas of emission provide a habitat for organisms such as mussels and tube worms.

### What are Collaborative Research Centres?

The German Science Foundation supports different kinds of research programs in all areas of science. One of the program types is the "Sonderforschungsbereich (SFB)" or Collaborative Research Centre. The SFB program is unique in that it unites scientists from different disciplines on a research topic that is assessed to be of high priority. Collaborative Research Centres are established as temporary programs with the aim, not only of promoting multidisciplinary cooperation, but also of supporting young scientists and students. The German Science Foundation places high expectations on these special projects, in particular the achievement of scientific results of international standard. The maximum support time for an SFB grant is 12 years, divided in project assessment intervals of three to four years. All science faculties at universities can apply for an SFB, while non-university research institutes such as IFM-GEOMAR participate in cooperation with the lead university. Therefore, although the research for SFB 460 and SFB 574 is conducted at IFM-GEOMAR, the projects are officially affiliated with the University of Kiel (CAU).



## CURRICULA AND TEACHING ACTIVITIES

The Leibniz Institute of Marine Sciences cooperates with the Christian Albrechts University in Kiel (CAU) to offer students a broad education in marine science and maritime meteorology.

### IFM-GEOMAR is responsible for the curricula in

- Physical Oceanography (full curriculum)
- Meteorology (full curriculum)

The first four semesters are nearly identical with a course of study in Physics.

Advanced courses of study include:

- Biological Oceanography
- Fisheries Biology
- Marine Chemistry

Students in other courses of study at the CAU can choose marine science classes as subsidiary subjects. IFM-GEOMAR also offers seminars and classes in Marine Geology and Geophysics.



### International Cooperation:

- **BIO-OCEAN:** international course of study in Biological Oceanography for students with a major in Biology. BIO-OCEAN is offered in cooperation with the University of Southern Denmark in Odense (SDU).  
[www.bio-ocean-study.com](http://www.bio-ocean-study.com)
- **POMOR:** German – Russian course of study for applied Polar and Marine Sciences. Up until now, it has only been available for Russian students, however, the course will become available for students from other European countries. The program is offered in cooperation with the Universities of Bremen and St. Petersburg, the Alfred Wegener Institute for Polar- and Marine Research (AWI) and the Association of North German Universities.  
[www.pomor.de](http://www.pomor.de)
- **GAME:** international academic and research program in Marine Ecology for "Diplom" or Master of Science candidates in Biology, supported by the Mercator Foundation. More than 20 institutes from 5 different continents participate in GAME.  
[www.ifm-geomar.de/index.php?id=game](http://www.ifm-geomar.de/index.php?id=game)

Further cooperative study programs are in planning. For example, a course of study in cooperation with the Ocean University of China.



### The Christian Albrechts University of Kiel (CAU)


The CAU in Kiel represents the centre of scientific learning in the state of Schleswig-Holstein. More than 2,000 scientists teach and conduct research at the Christian Albrechts University, which is attended by over 20,000 students. The university was founded in 1665 by Christian Albrecht, the Duke of Holstein-Gottorf. At the time, it was comprised of the four faculties Justice, Theology, Medicine, and Philosophy. The faculties Math and Sciences, Economy and Social Sciences, Agriculture and Nutrition, and Technology were added over the years, providing a broad spectrum of higher education. Kiel's location on the bight with a direct connection to the open ocean naturally led to the development of yet another scientific focus: the interdisciplinary field of marine science. Today IFM-GEOMAR, which is closely associated with the CAU, enjoys an international reputation and provides an optimal working environment for oceanographers from all disciplines – biology, chemistry, geology, and physics. For this reason, the German Science Foundation initiated two long-term collaborative research centres at the University of Kiel: the investigation of thermohaline circulation processes in the North Atlantic and the study of climate feedback and trigger mechanisms for natural disasters at tectonically active subduction zones.



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## THE AQUARIUM

The underwater voyage begins in the cold waters of lakes and rivers, continues from the Baltic to the North Sea and on to the Atlantic Ocean. From there the visitor travels to warmer waters of the Mediterranean Sea and finally, to the colourful and fascinating world of tropical coral reefs. The aquarium of IFM-GEOMAR offers the public a glimpse of different underwater worlds on our planet. The indoor part of the aquarium houses carp, sea bass, molly miller, thornback ray, anemones, seahorses, and many other fascinating inhabitants of the seas. Several seals play and frolic in the large outdoor basin, which has both surface and underwater viewing possibilities and offers public access 24 hours a day. The IFM-GEOMAR aquarium attempts to display the animals in a submarine habitat that is as authentic as possible. More than 85,000 visitors enjoy these exhibits every year.

On the one hand, the aquarium serves to introduce the public to the seemingly endless diversity of life in the sea, on the other hand it also provides a research facility for the Marine Ecology division. Here, scientists investigate the effect of nutrient quality, temperature and other environmental factors on the growth rate of different organisms. One of the main research objectives has been the development of environmentally sound aquaculture systems. These systems enable the recycling of matter and energy using organisms of different trophic levels as biological filters. Wastewater is transformed to usable water without polluting the environment. IFM-GEOMAR has set international standards in developing these techniques and defining methods of application in commercial aquaculture.

**NaT-Working Marine Research**

As part of the initiative NaT-Working, the Robert Bosch Foundation supports a variety of programs whose aim is to promote young people's contact to science and technology. NaT-Working marine science is one of these programs and involves IFM-GEOMAR, 8 high schools in Kiel, the environmental organization "Hohe Tied" e.V., and the Leibniz Institute for the Education of Science. Complementary to science classes at school, the high school students discuss current topics in marine science, such as climate research or marine ecology, with scientists at IFM-GEOMAR. Through laboratory sessions and practical courses, they get a better insight into scientific methods and thought processes. The intention of the program is to give the students a head start for their university education. The projects vary from short courses to long-term studies and are conducted both in the schools and at IFM-GEOMAR.







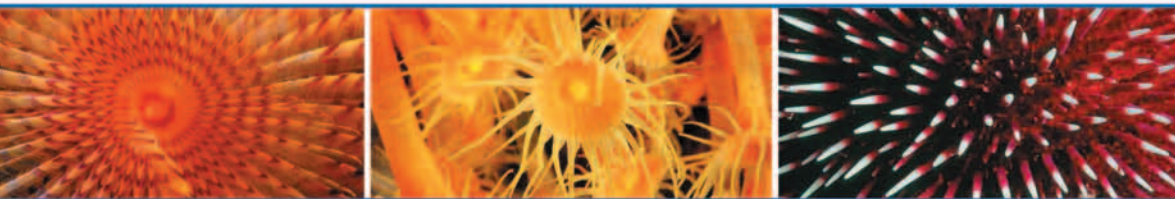
IFM-GEOMAR



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