HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

GEOMAR

From the Deep Sea to the Atmosphere

GEOMAR Helmholtz Centre for Ocean Research Kiel

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THE ROLE OF THE OCEAN IN CLIMATE CHANGE

How does the ocean influence our climate system?

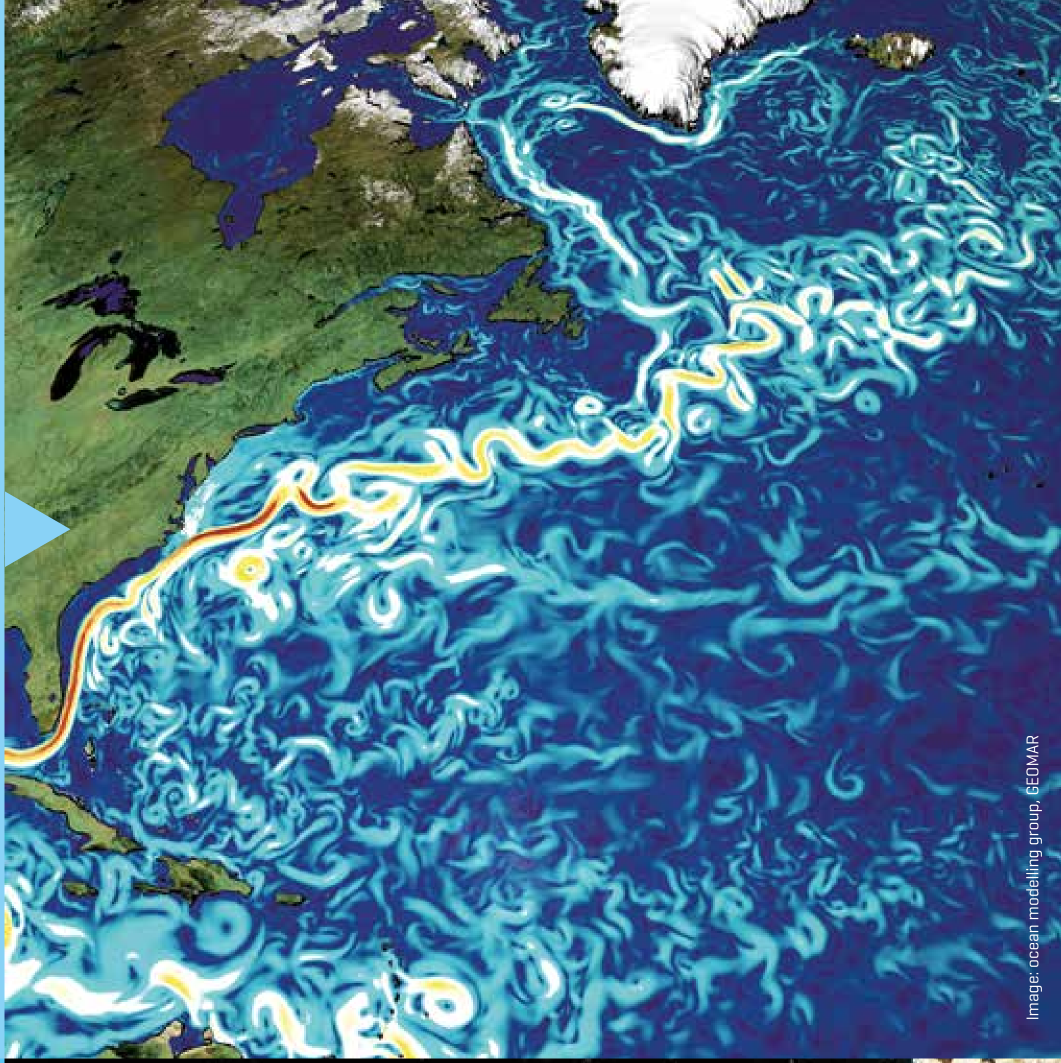

Image: ocean modelling group, GEOMAR

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HUMAN IMPACT ON MARINE ECOSYSTEMS

How do marine communities respond to man-made changes?

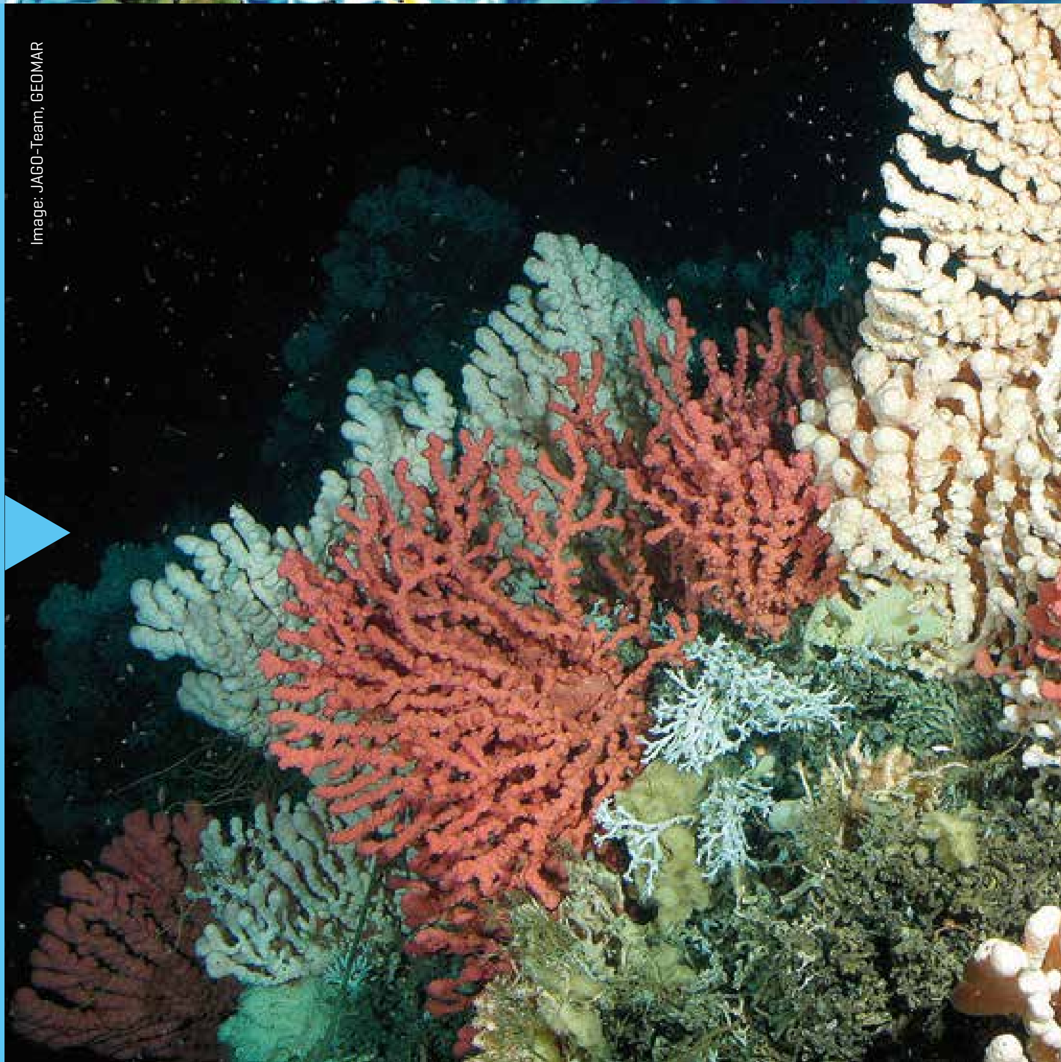

Image: JAGO-Team, GEOMAR

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BIOLOGICAL, MINERAL AND ENERGY RESOURCES

How can we utilize marine resources in an environmentally sustainable way?


Image: Science Party SO174

4

PLATE TECTONICS AND MARINE HAZARDS

How can we identify the natural hazards of the sea at an early stage?


Image: Image Science & Analysis Laboratory, NASA Johnson Space Center

The Main Areas of Research at GEOMAR

RV POSEIDON in the volcanic area off Sicily. Alongside the ROV PHOCA, teams of divers investigate sources of CO_2 at the ocean floor during an expedition off the coast of the Italian island of Panarea. Image: Christian Howe

Content


POSEIDON

An Overview of GEOMAR

The mission of the GEOMAR Helmholtz Centre for Ocean Research Kiel is to study the physical, chemical, biological and geological processes of the oceans and their interactions with the sea floor and the atmosphere. With this focus, GEOMAR covers a unique spectrum of research in Germany.

The main research topics at GEOMAR are

- **The Role of the Ocean in Climate Change**
- **Human Impact on Marine Ecosystems**
- **Biological, Mineral and Energy Resources**
- **Plate Tectonics and Marine Natural Hazards**

GEOMAR's four research divisions are:

- **Ocean Circulation and Climate Dynamics**
- **Marine Biogeochemistry**
- **Marine Ecology**
- **Dynamics of the Ocean Floor**

GEOMAR works closely with the University of Kiel in the education of young scientists and is also internationally networked through cooperation programs. Special programs for students and teachers aim at awakening interest in marine sciences at an early stage.

GEOMAR has a modern and efficient research infrastructure. This includes three own research vessels, the only manned German research submersible JAGO, and the unmanned deep-sea robots KIEL 6000, PHOCA, ABYSS and VIATOR. Furthermore, GEOMAR has excellent equipment in the field of isotope and trace element analysis, access to supercomputers and one of the largest marine science libraries in Germany.

Many of GEOMAR's fundamental research results are applied in industry. These include discoveries of marine drugs, marine aquaculture, marine mineral resource exploration and assessment, technologies for sustainable development and extraction of natural gas from submarine gas hydrate deposits, storage of carbon dioxide in solid form below the seafloor, and the development of deep-sea equipment and vehicles.

GEOMAR is a member of the Helmholtz Association of German Research Centres, and a leading participant in national and international strategic partnerships, such as the German Alliance for Marine Research (DAM), the German Marine Research Consortium (KDM), the German Climate Consortium (DKK), the Partnership for Observation of the Global Oceans (POGO) and the European Marine Board (EMB).

GEOMAR in Numbers

80	million euro annual budget, including 25 million euros of project funding
1000	employees from more than 40 different countries
500	days at sea per year, of which 50 percent is on large research vessels
400	peer-reviewed scientific articles in international journals per year
3	research vessels (ALKOR, LITTORINA, POLARFUCHS)
4	deep-sea underwater vehicles (ROV KIEL 6000, ROV PHOCA, AUV ABYSS, VIATOR)
1	manned research submersible (JAGO)
11	underwater gliders
4	sea surface wave gliders
10	deep-sea landers
10	offshore mesocosms (KOSMOS)
100	ocean bottom seismometers (OBS)
35	geodetic seafloor transponder
6	onshore benthocosms
1	3D seismic system (P-CABLE)

Image: Mechita Schmidt-Aursch

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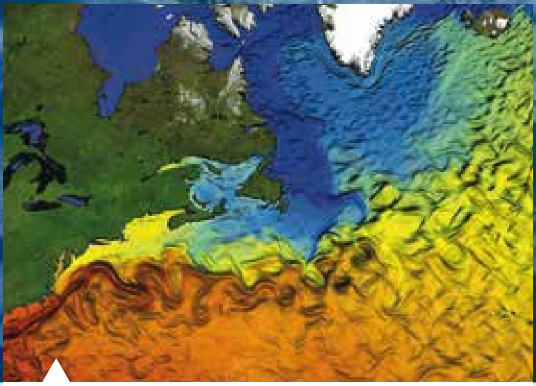
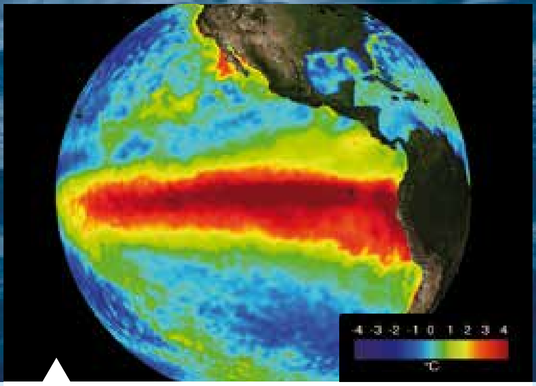
How does the ocean influence our climate system?



Gulf Stream

The Gulf Stream, one of the strongest ocean currents on Earth, transfers enormous heat into the North Atlantic. It thereby grants Europe a pleasant climate, where otherwise freezing cold would prevail. Is this engine of our climate stable, or will it start sputtering again, as it has in Europe's distant past? Figure: The Gulf Stream in the North Atlantic illustrated by simulated surface temperatures, ocean modelling group GEOMAR



Tropical Oceans

The tropical oceans play a crucial role in many natural climate variability phenomena. For example, El Niño, a positive anomaly of the sea surface temperature, originates in the tropical Pacific, and its effects can be felt worldwide. The lack of oxygen at low latitudes is also hazardous to marine ecosystems. Image: El Niño in December 1997, GEOMAR

Continuous measurements by autonomous probes, so-called floats, have allowed the collection of vast amounts of new data for long-term predictions and a greater understanding of our climate system in a time span of only ten years – more than was ever attained by all ship-based expeditions before. Image: Mario Müller, GEOMAR

Climate Change

Human activities cause a warming of our planet's surface. The oceans, especially the deep sea regions, absorb a great amount of heat and thereby can moderate the pace of this process. But how does the "information exchange" between the oceans and atmosphere work? The interaction is nonlinear, and many of the details and their impacts on our climate are not yet fully understood. At GEOMAR, we study the current state of the oceans, as well as their links to climate history and the climate of the future. Image: Flood in Venice, Wolfgang Moroder (CC-BY-SA 3.0)

The seabed's climate archive: Sediment cores are vertical sections into the seabed that provide a record of the past. Precise analyses of their chemical composition yield critical data on the climate of the past. Image: Katja Machill, GEOMAR

Sailplanes of the sea: Oceanographic gliders obtain valuable real-time information on the temporal and spatial structure of the oceans. GEOMAR operates one of the largest glider fleets in Europe. Image: Michael Schneider, METEOR

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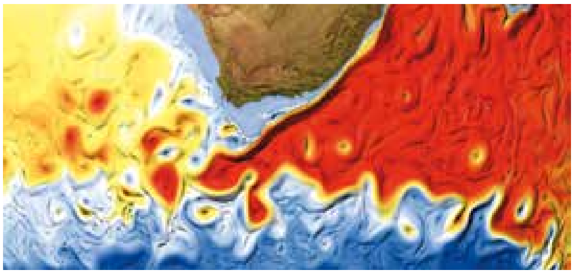
The Ocean – the Long-term Memory of our Climate System

Wind, sun and rain affect the ocean's surface and set it in motion. At speeds of a few centimetres to about one meter per second, the ensuing ocean currents are much slower than the air flow in the atmosphere. Nevertheless, the ocean circulation transports large amounts of heat and thereby influences the global and regional climate. Changing temperatures and salinities cause variations in the density of sea water and thus regionally allow oxygen-rich surface water to be transported into great depths causing the deep ocean to be supplied with oxygen. The global ocean circulation connects all the ocean basins and thus distributes inputs of nutrients, dissolved carbon and other chemical and biological substances.

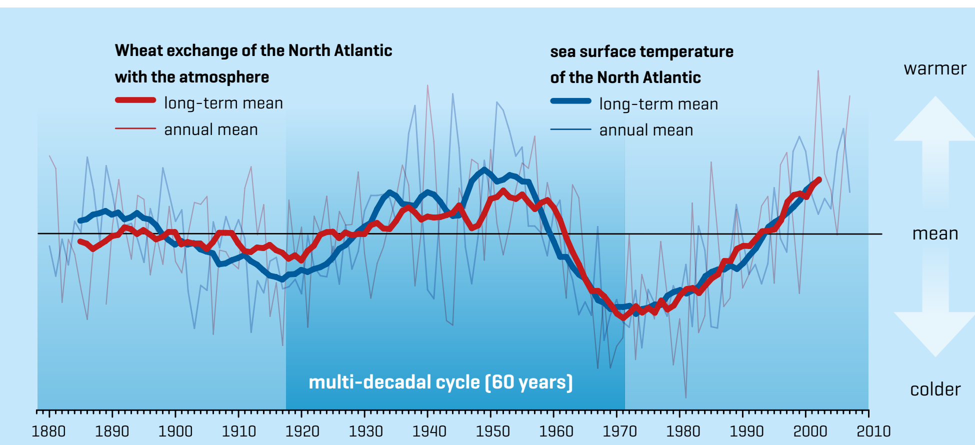
A glimpse into the history of our planet is indispensable for understanding long-term climate variability. Due to the lack of instrumental measurements, This information can only be attained through the use of so-called climate archives, which include such diverse records as ocean sediments, corals, ice cores and tree rings. Information about temperatures and rainfall in past climate epochs can be derived from these archives using sophisticated measurements of chemical and isotopic signals. This allows the reconstruction of natural climate variability and a better understanding of its causes.

The present state of the oceans and its variations can be determined by repeated, broadly-based measurements.



High resolution numerical models of the oceans aim to understand their natural variability and causes as well as predictions of future developments. Simulation and graphics: ocean modelling group, GEOMAR.

Deep-sea moorings: Measuring instruments are deployed at different depths to record various physical and chemical parameters for extended periods. Vertically installed measurement chains (moorings) allow long-term measurements at critical points in the oceans. Image: Michael Schneider, METEOR



Climate variability in the Atlantic

Long-term development of surface temperatures in the North Atlantic and of the heat exchange with the atmosphere. The decadal fluctuations are clearly visible over multiple decades. What may be the cause? Image: GEOMAR

While, additionally to the instrumental measurements, also Satellite measurements are used to monitor the current atmosphere and the ocean surface from space, but the deeper oceanic layers can only be monitored using direct measurements in the oceans. We use ship-based and autonomous platforms to make critical, long-term time series measurements in the most sensitive regions of the world oceans. The basis for a comprehensive understanding of the ocean and climate system is the combination of theory, modelling and observation. GEOMAR is a leader in the application of numerical models of the oceans' physical and chemical conditions, providing insight into climate variability, found naturally and induced by humans, and into the ocean and climate of the future.

Our scientists from the disciplines of meteorology, oceanography, physics and earth science work in close collaboration with colleagues around the world to improve our understanding of the global ocean and its role in the climate system. in GEOMAR's research division 1: "Ocean Circulation and Climate Dynamics"

MORE INFORMATION

- **The role of the ocean in climate change:** www.geomar.de/57
- **Ocean and climate:** www.geomar.de/223

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▲ **Experimental systems for the open ocean:** Mesocosms are giant test tubes. They are small, isolated worlds in the sea, in which the reactions of marine ecosystems to global change can be studied. Image: Maike Nicolai, GEOMAR

Ocean Acidification

Since the beginning of industrialisation, the ocean has taken up about half of the carbon dioxide emitted by humans. Carbon dioxide dissolves in water and forms carbonic acid, causing the pH of the sea water to drop. How do marine organisms, particularly calcifiers, react to this change? Will they still be able to build their calcium carbonate skeletons and shells in the future? Scientists from GEOMAR investigate these questions in laboratory studies and in experiments in the open ocean. Image: Solvin Zankl

HUMAN IMPACT ON MARINE ECOSYSTEMS

How do marine communities respond to man-made changes?

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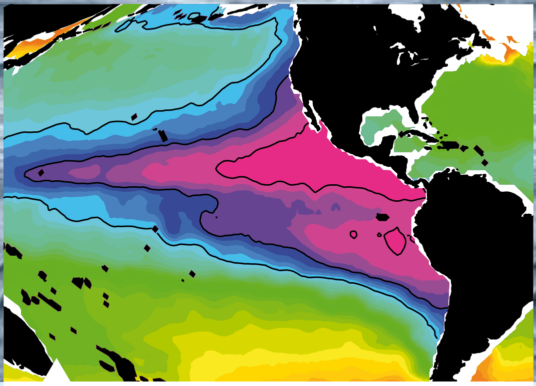
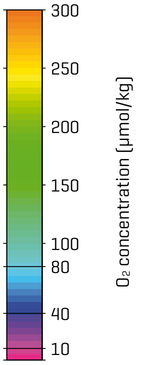


Marine Biodiversity

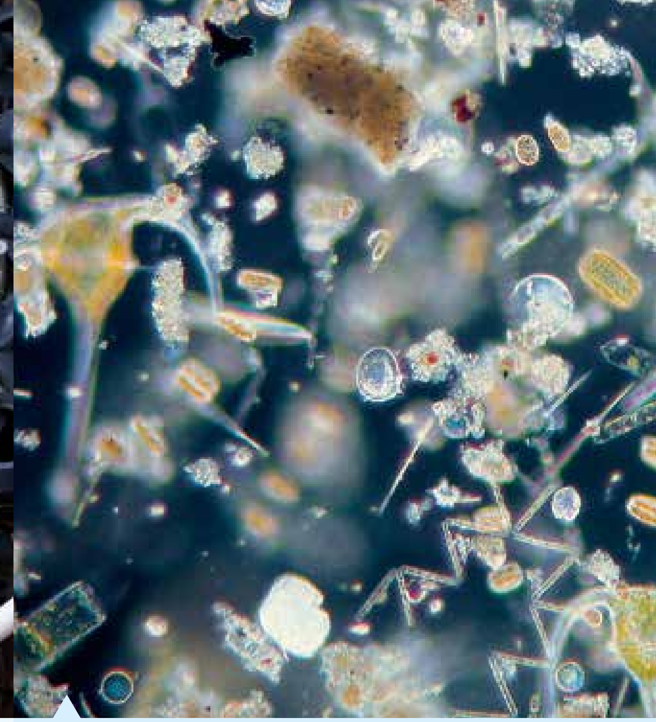
The oceans are currently losing more species than at any other time in the history of the earth. Scientists at GEOMAR are exploring the role of biodiversity in maintaining important ecosystem services, such as the production of biomass and oxygen in the oceans. The interaction of a wide range of environmental factors are being investigated using innovative experimental systems (displayed are the institute's benthocosms). Image: Maike Nicolai, GEOMAR

Oxygen Minimum Zones

Low oxygen concentrations are particularly evident in the eastern areas of tropical and subtropical ocean basins. Are these areas increasing? And if so, what are the consequences for ecosystems and biogeochemical cycles? Visualisation: GEOMAR



A rosette water sampler (CTD-Rosette) collects water samples from different depths. Valuable physical, chemical and biological data for a variety of questions concerning marine research are obtained from these deployments. Image: Bernd Grundmann



The decrease of microalgal species at the base of the food chains leads to significantly less algal biomass. This results in less food being available at higher levels in the food web. Biodiversity, therefore, ensures the persistence of marine ecosystems. Image: Annegret Stuhr, GEOMAR

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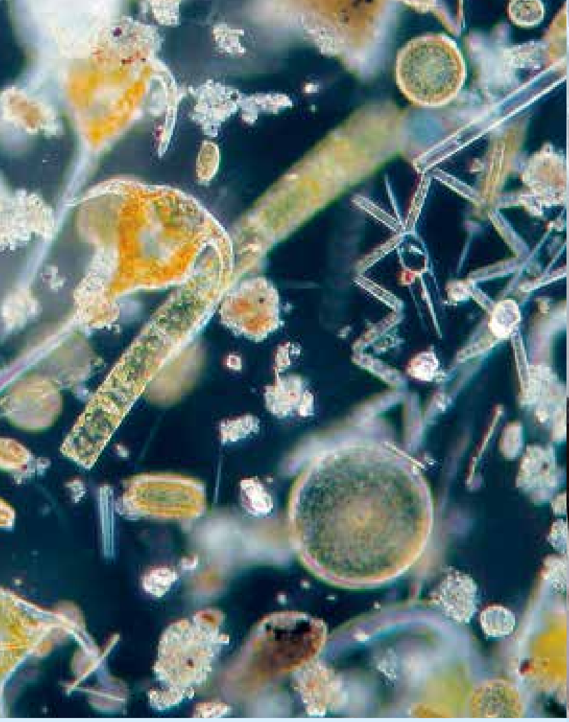
The Chemistry of the Sea is Out of Balance; the Ocean is Running Out of Air and Organisms

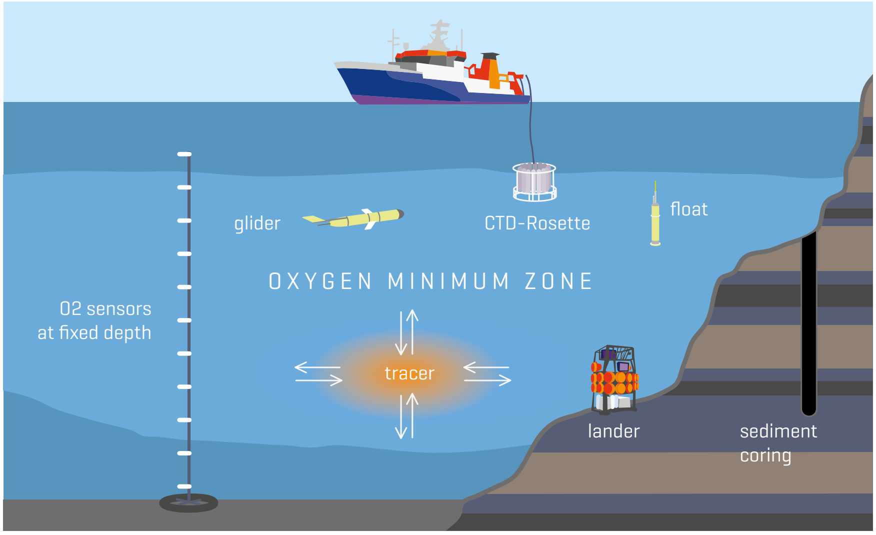
Humans are changing marine ecosystems, even before we are fully familiar with them and have understood their functionality. Marine biota are affected in many ways: the oceans are warming and becoming increasingly acidic, we are over-fertilizing and contaminating the sea with plastic and chemicals, and we are over-exploiting its biological resources. At GEOMAR, interdisciplinary research is being carried out to answer the question – how are the complex interactions between physical, chemical and biological changes in the oceans manifested by marine ecosystems? At the same time, we are partnering with the Cluster of Excellence "The Future Ocean" to conduct research beyond the natural sciences, in law, economics and the social sciences, to better understand the impacts of those changes.

Carbon dioxide, CO_2 in short, is a trace gas. Its proportion in the atmosphere has risen steadily since the beginning of industrialization. Burning of fossil fuels, such as oil, coal and natural gas, along with the destruction of biomass on land, has caused CO_2 concentrations to rise to levels higher than experienced by Earth for the past millions of years. The consequences are profound. Although CO_2 is being absorbed by the oceans, that remaining in the atmosphere absorbs long-wave thermal radiation, causing our planet to warm. One of the research priorities at GEOMAR is the investigation of carbon dioxide exchange between the atmosphere, ocean and sea floor and its impact on marine life. The amount of trace gas affects not only the climate but also the biological and chemical processes in the sea — in particular ocean acidification caused by the absorption of CO_2.

The input of trace elements (e.g., by dust) also plays a vital role in increasing productivity in many areas of the oceans. And, at the same time, long-term changes in the extent of oxygen depleted zones, especially in the tropical and subtropical oceans, have uncertain causes and consequences for ecosystem services, marine biodiversity and biogeochemical cycles. Compounding these uncertainties are the rapid



Global research on global change: Students of the GAME (Global Approach by Modular Experiments) project investigate the influence of microplastics on marine life at various study sites worldwide. Image: GAME, GEOMAR



Monitoring system for oxygen minimum zones: The combined use of different research equipment and techniques provides data to help better understand the important interplay between physical and biological processes that influence the oxygen content of the oceans. Figures: Rita Erven, GEOMAR

changes in the marine environment due to pollution and exploitation. In oceans where the chemistry is out of balance, many species may become extinct or be replaced by foreign organisms, causing the composition of the communities to change drastically at all levels. These are areas of intensive research at GEOMAR.

"Garbage in the sea" and pollution in general affect entire marine ecosystems. The problems include not only the direct consumption of residues by marine organisms but also the effects of toxins associated with microscopic plastic particles that are entering the marine food chain. GEOMAR is investigating these critical problems as well as more fundamental questions, such as if and how evolution will cause marine ecosystems to adapt to the changing conditions. Who wins, who loses? What will the marine ecosystems of the future look like? Besides GEOMAR's research divisions Marine Biogeochemistry (RD 2) and Marine Ecology (RD 3), experts in economics and law of Kiel University are involved in this field of research.

MORE INFORMATION

- **Human impact on marine ecosystems:** www.geomar.de/58
- **Habitat Ocean:** www.geomar.de/239

▲ **Recovery of a carbonate block in the Pacific:** Such massive carbonates allow to reconstruct the former presence of methane and methane hydrates in the seafloor and provide important conclusions on natural formation and degradation processes. Image: Bernd Grundmann

Mineral Resources

The exploitation of the mineral resources from the deep sea is expected by the middle of this century, if not sooner, as demand for raw materials increases. Can massive sulphides, cobalt crusts and manganese nodules help to meet that demand? How large is the actual global resource? Is environmentally sustainable exploitation of these resources possible? Image: Manganese nodules on the ocean floor of the Pacific, GEOMAR

BIOLOGICAL, MINERAL AND ENERGY RESOURCES

How can we utilize marine resources in an environmentally sustainable way?

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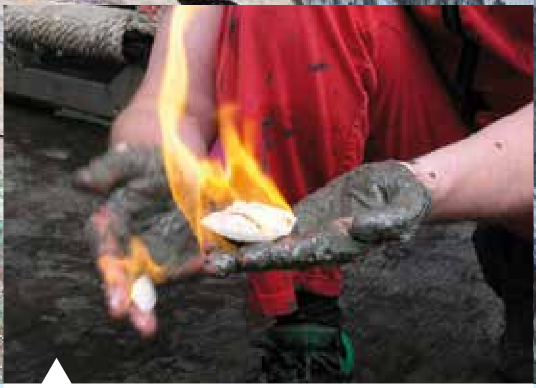
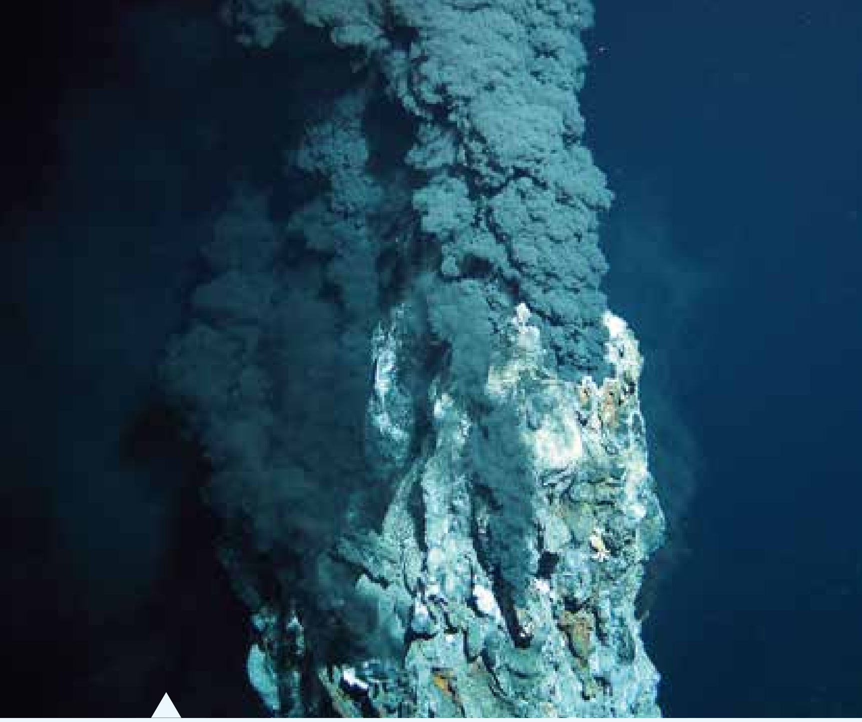


Gas Hydrates

“Burning ice” at the sea floor is a potential source of energy for the future. The methane concentration in solid gas hydrates is about 160 times higher than in it’s the natural state of methane as a gas. Gas hydrates are common in marine sediments at the continental margins. Can these fossil fuels be utilized in a safe and environmentally friendly way? At GEOMAR, the possibilities of tapping natural gas while simultaneously depositing carbon dioxide are also being investigated. Image: Science Party SO174

Marine Drugs

Can substances from the sea help us effectively fight serious diseases, such as cancer? Do the oceans contain concealed active agents that can assist in developing new antibiotics for resistant germs? Scientists at GEOMAR are looking for these agents in every part of the marine environment, examining their effectiveness and cultivating them for use in the pharmaceutical, cosmetic and food industry. Image: Sieg/Nölting



Black smokers in the Atlantic: In areas of active volcanism, hydrothermal fluids leach metals from the oceanic crust. During their ascent to the ocean floor, the metals are dissolved in the hot fluids, which are colourless. When the fluids emerge from the seafloor and mix with cold seawater, the metals precipitate, producing the characteristic black colour of the "smoke". Image: ROV-Team GEOMAR

Eyes and arms in the deep sea: Remotely controlled deep sea robots, such as the ROV KIEL 6000, enable thorough exploration and testing of mineral deposits, for instance at volcanic-associated hydrothermal systems. Image: Bernd Grundmann

Opportunities and Risks of Marine Resource Extraction

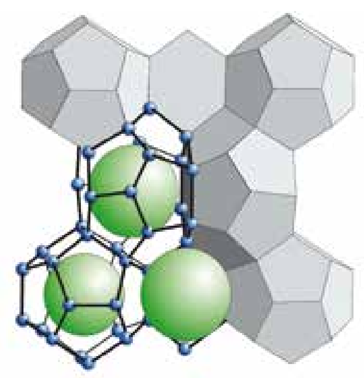
A wide range of mineral, energy and biological resources are contained in the oceans and buried beneath the sea floor. The locations and extent of those resources are still largely unknown. This is partly due to the size of the oceans (more than 70 percent of the planet is covered by the oceans) but also to the difficulties of accessing them (the average depth of the oceans is 3,800 meters). Some resources, such as fish stocks are facing extreme challenges; other promising discoveries of mineral and energy resources are now being made. Important questions remain about the quantity and quality of the mineral and energy resources, essential for understanding their commercial value and the sustainability of their future exploitation. Can these resources support new ocean industries? What are the strategies to preserve and protect the often unique and fragile ecosystems in areas of the deep sea where exploitation might take place?

The riches of the oceans are presenting challenges even in the most remote corners of the deep sea, from the water column to the resources buried in the sub-sea. Many fish species at the top of the marine food chain are being overfished. So far, the global catch has remained constant by increasing the fishing effort, but overexploitation and collapse is inevitable if the fish stocks are not managed. At GEOMAR, interdisciplinary approaches to fisheries science are being developed that will allow a higher long-term yield, while regenerating a sustainable stock of different species. At the same time, we are exploring other marine organisms that harbour substances for defence or other biological functions that could be of interest for the medical field. The search for active agents among marine organisms is not only a global search, but is taking place at our doorstep in the Kiel Fjord – these substances can be found anywhere. At GEOMAR-Biotech (GEOMAR Centre for Marine Biotechnology), molecules from marine algae, invertebrates and microorganisms are isolated, chemically characterized and their effectiveness tested using unique laboratory facilities that can culture drug-producing microorganisms at a large scale.

The natural resources of the oceans include not only the living resources but also energy and mineral deposits that occur in the deep sea. More than 50 years ago, manganese nodules were found in the deep sea in numbers sufficient to

90 percent of all large fish have already disappeared from the oceans: Overfishing endangers many fish stocks in the long term and thus the global food supply. New science-based management techniques are being sought to preserve this resource. Image: bluefin tuna in floating fattening cages, Solvin Zankl

Searching for defensive compounds in marine samples at GEOMAR-Biotech (GEOMAR Centre for Marine Biotechnology): The effectiveness of these substances is tested in a complex series of processes that can eventually be transferred to the pharmaceutical industry. Image: Michael Zapf



Molecular structure of gas hydrates: Under certain pressure and temperature conditions, water molecules (blue) form cages which enclose methane molecules (green). These solid phases can then be "mined" from seabed gas hydrate deposits, releasing the methane as an energy resource. Figure: Jens Greinert, GEOMAR

be of commercial interest. The fact that they were not exploited was due mainly to the enormous effort needed to reach the resources and return them to the surface. However, growing economic pressures for raw materials are rapidly changing that situation. At GEOMAR, we are working with the international community to assess the scale of this resource and to better understand the conditions under which sustainable exploitation might take place. At the same time, another form of mineral deposit has emerged as a centre of attention — polymetallic massive sulphide deposits. These are formed at so-called "black smokers", where hot, aqueous solutions up to 400 degrees Celsius emerge from the ocean crust to precipitate metallic sulphide minerals at the seafloor, rich in copper, zinc, gold and silver. At GEOMAR, we are using deep-sea robotic technology to assess the size and composition of the deposits at up to 6,000 meters water depth. We are also deploying custom-made autonomous deep-sea laboratories that provide long-term monitoring of the physical, chemical and biological processes of the active hydrothermal vents. A major challenge is the discovery of resources that may have formed in the distant past and are now buried under sediment far from the original vent sites. This requires sophisticated geophysical tools (seismic, electrical, and magnetic) for remote detection of the deposits under the cover of marine sediments.

Many of these same technologies are being used by GEOMAR scientists to discover the energy resources of the future, such as the enormous gas hydrate deposits on the global continental shelves. These deposits are both a future energy resource but also a potential threat to our climate because of their large content of greenhouse gases. In addition to exploring for and quantifying these deposits, researchers at GEOMAR are developing and testing the technologies that will be needed to exploit the gas sustainably. In particular, we are working on a way to extract gas from buried hydrates, while simultaneously depositing and sequestering carbon dioxide in solid form.

MORE INFORMATION

- **Marine natural resources:** www.geomar.de/59
- **Raw materials from the ocean:** www.geomar.de/240

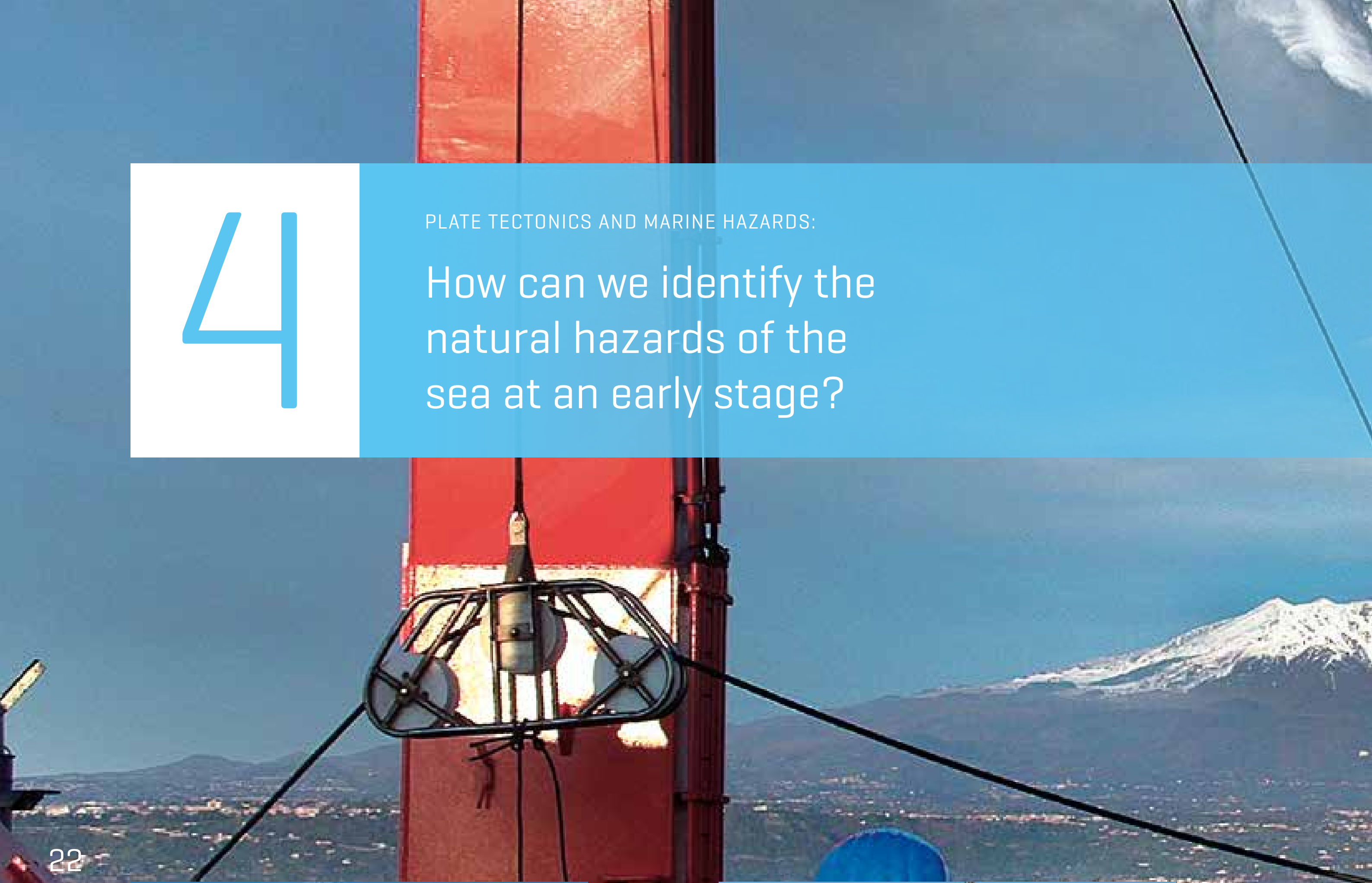


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PLATE TECTONICS AND MARINE HAZARDS:

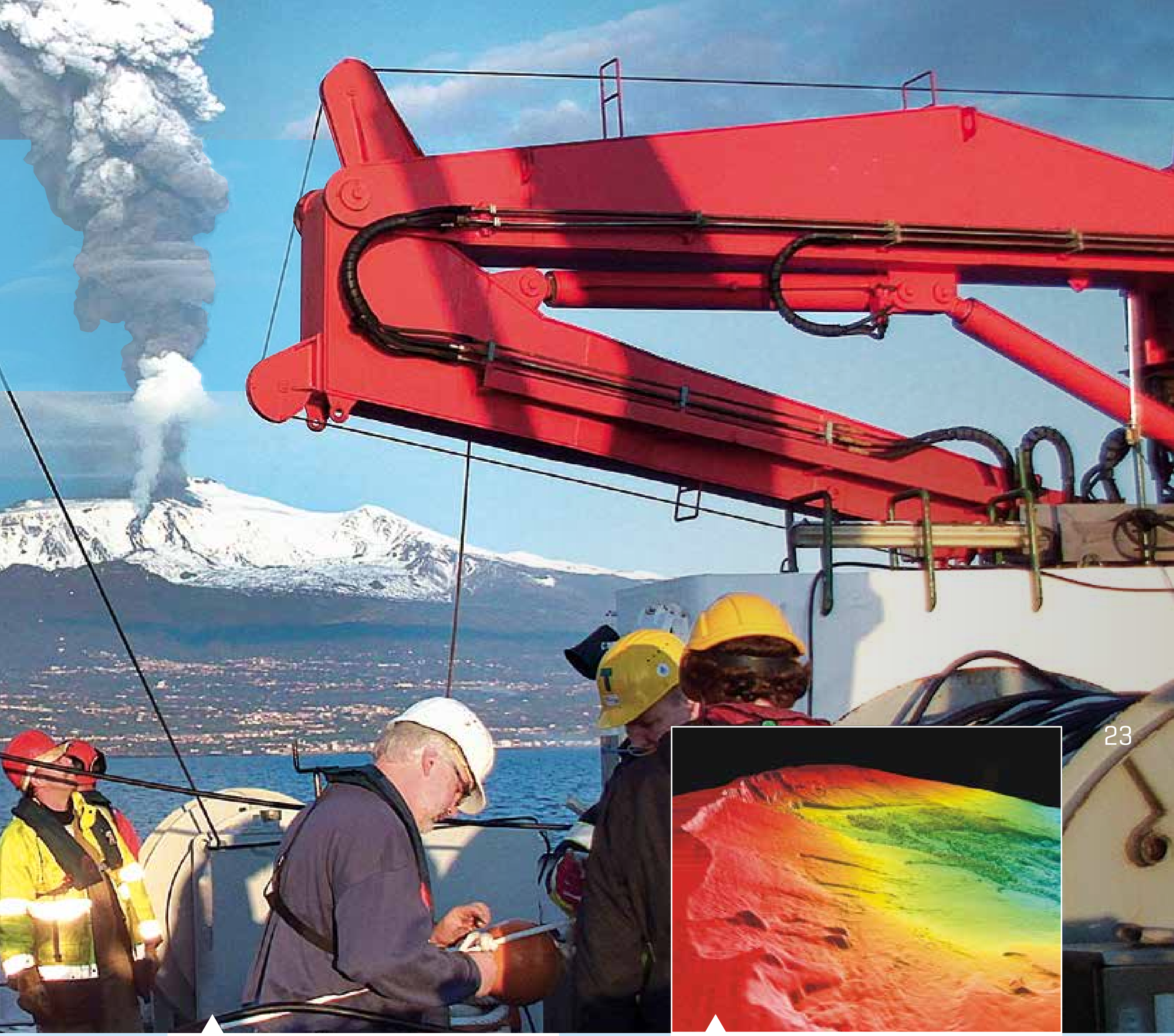
How can we identify the natural hazards of the sea at an early stage?

Earthquakes

This tower did not withstand the earthquake in the region of Maule, Chile, on February 27th 2010. With a magnitude of 8.8 on the Richter scale, it was the strongest earthquake in Chile since the devastating big quake of 1960 and the world's sixth strongest ever measured. Its cause lay about 35 kilometres below the sea floor in the South American subduction zone. Here, the Nazca Plate slides under the South American Plate and causes extreme friction. Image: Bernd Grundmann

Tsunamis

Submarine earthquakes with vertical offset can shake the water column severely, causing waves to propagate quickly over long distances and then pile up strongly in shallow coastal areas. These so-called tsunamis can have devastating consequences. The wave that reached the port of the city of Concepción after the earthquake in the region of Maule had a height of four to five meters and washed many boats ashore and hundreds of meters inland. Image: NOAA / NGDC, Walter D. Mooney, US Geological Survey



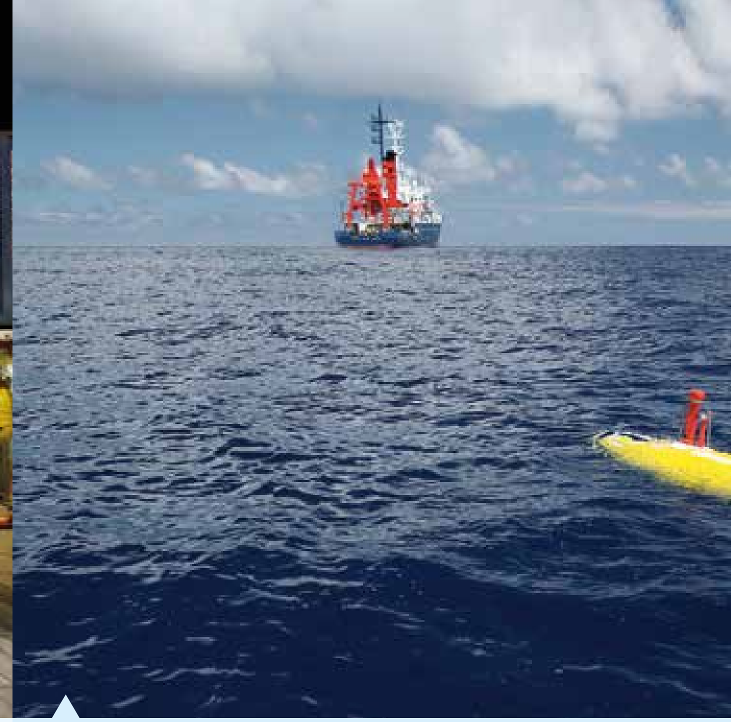
Volcanic Eruptions

Geophysical investigations with the research vessel METEOR in the Strait of Messina during an eruption of the volcano Etna. Volcanic activity can be observed both on land and under water. The latter often go undetected until they reach the water surface and new islands emerge. With their ejections of lava, gas and ash, volcanic eruptions can have a significant trans-regional impact. They can, for example, influence air traffic and even trigger climate change. Image: Sebastian Krastel-Gudegast, CAU Kiel

Submarine Landslides

The 320-km long escarpment off Norway caused by the Storegga landslide, which took place 8,100 years ago. The largest known events of this type are located at passive continental margins, and submarine landslides can have magnitudes larger than those on land. The underwater mass displacements triggered by such events can lead to the destruction of communication cables, pipelines and oil platforms or generate tsunamis that pose a particular risk due to their close proximity to the coast. Figure: Christian Berndt, GEOMAR

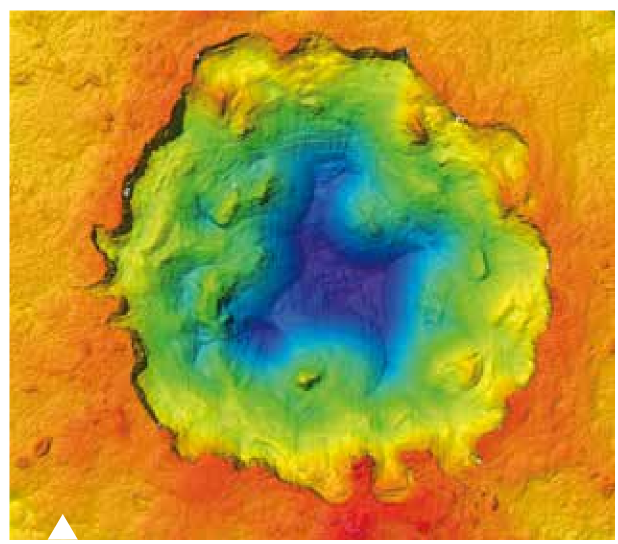
Ocean bottom seismometers are traditionally used to measure earthquakes on and below the sea floor. With data transmission in real time, however, they can also serve as part of a tsunami early warning system and thus help to warn inhabitants of coastal areas about possible devastating floods in due time. Image: Robert Kurzawski, GEOMAR



The autonomous underwater vehicle ABYSS can create high-resolution, three-dimensional maps of the seabed of up to 6,000 meters deep, so as to give a detailed insight into structures of the sea floor that may be related to natural hazards. Image: AUV-Team GEOMAR

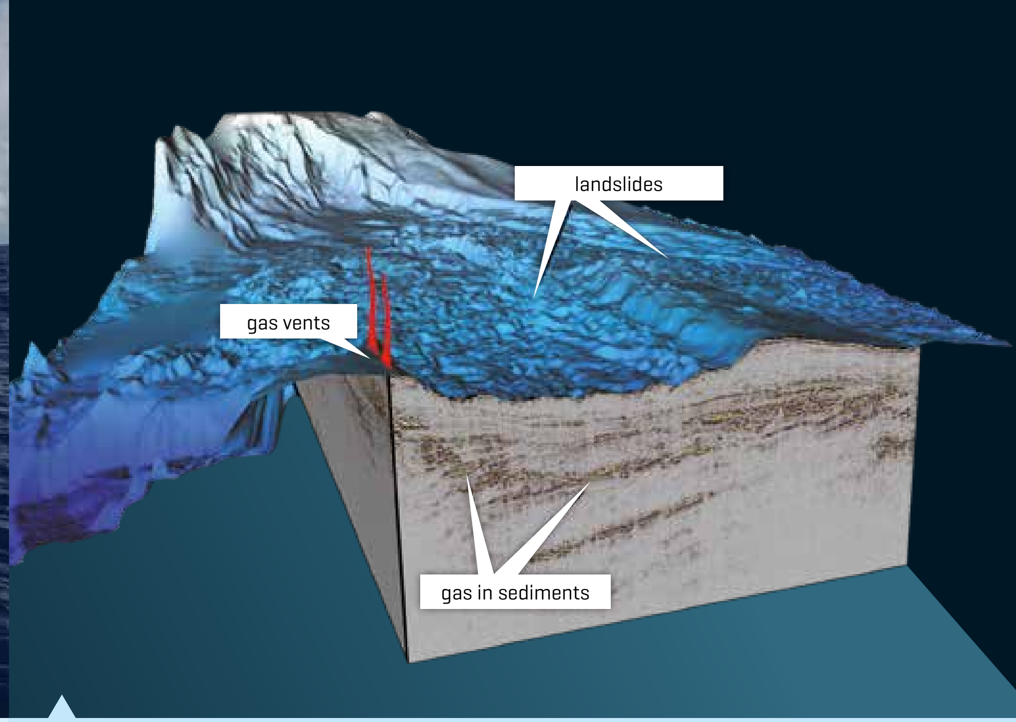
Taking the Earth's Pulse: Understanding Natural Disasters

The challenges of marine hazards are articulated in a book of this title published by GEOMAR scientists. The title captures the central topic of this field: the earth as a dynamic body under constant development: new ocean floor, which slides underneath the lighter continental plates at deep-sea trenches, is created at mid-ocean ridges. These processes are the fundamental sources of earthquakes, tsunamis and volcanic activity – the natural hazards which have disastrous consequences in many parts of the world. The scientists at GEOMAR are gaining a better understanding of these processes in order to create risk assessments for coastal areas and to warn against natural disasters at an early stage.

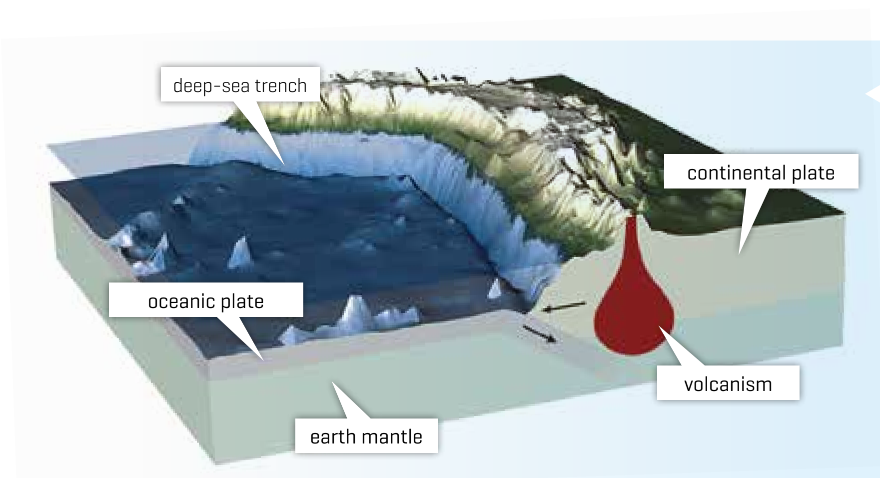


3-dimensional view on Franklin sea mount in the Pacific based on data from the multibeam system of AUV ABYSS. Graphics: AUV-Team, GEOMAR

A very long human life lasts for one hundred years — in geology, however, this time span can be compared to a mere blink of the eye. Geologists are accustomed to thinking about processes that last millennia to millions of years. During these periods, the dynamic Earth permanently reshapes itself because its surface is subject to constant change. Driven by convection currents in the hot interior of the Earth, thin tectonic plates float to the surface, drift apart, collide with each other or are pushed one beneath the other. Many



3D seismic survey of the sea floor off the east coast of New Zealand: Seismic methods allow GEOMAR researchers to identify the geological controls on the sources of natural hazards. New, innovative methods used at GEOMAR now also allow these measurements to be made in three dimensions. Figure: Sebastian Krastel-Gudegast, CAU Kiel



A continental subduction zone is an area in which an oceanic plate slides under a continental plate. The rocks of the subducting plate commonly "roll" back into the mantle, while mountains and island arcs are formed on the overriding plate. Here, deep-sea trenches form, which can reach over 10,000 meters deep. Sea water enters the subduction zone with the down-going ocean plate and then is released into the mantle to trigger melting and volcanic activity. Figure: Robert Simmon, NASA GSFC

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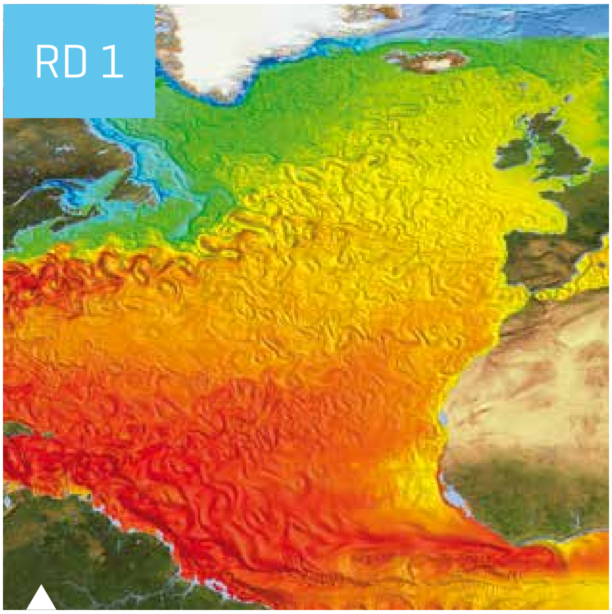
of these events take place hidden deep under the ocean surface, but the effects are felt by people around the world, especially in coastal areas. To uncover the causes and better assess the risks of such events, scientists at GEOMAR deploy active experiments to take the pulse of the Earth in the farthest corners of the oceans. Autonomous and remotely operated instruments, including ocean bottom seismometers and long-term geodetic observatories are just some of the innovative monitoring devices that are used for sensing and monitoring the sea floor. Information is generated by direct sampling and by indirect methods, such as seismic or hydroacoustic surveying. In addition, theoretical studies employing sophisticated computer models help to better understand the long-term processes that cannot be observed in the human lifespan. Already today, the analysis of observational data of some marine areas allows the potential risk of severe earthquakes or volcanic eruptions to be quantified. A precise temporal prediction of such events, remains a distant but potentially achievable goal.

MORE INFORMATION

- **Plate tectonics and marine natural hazards:** www.geomar.de/60



Temperature and surface currents in a high-resolution model of the North Atlantic. Source: GEOMAR

Biogeochemical observatory: BIGO-landers are used for the study of exchange processes between sediment and water column. Image: GEOMAR

RESEARCH DIVISION 1

OCEAN CIRCULATION AND CLIMATE DYNAMICS

RESEARCH UNITS

- Marine Meteorology
- Ocean Dynamics
- Palaeo-Oceanography
- Physical Oceanography

Climate variability can be externally induced or generated by Earth's atmospheric and oceanic processes. Research Division 1 develops the theoretical concepts required to understand and explore past and future climatic fluctuations and conducts the oceanographic, geological and meteorological experiments at sea to better constrain these models. Scientists in the division also undertake laboratory analyses, especially of the sediments of the ocean floor and their contained fossil organisms that are important marine climate archives. These studies are supported by sophisticated computer simulations of the complex Earth system.
www.geomar.de/en/research/fb1/overview/

RESEARCH DIVISION 2

MARINE BIOGEOCHEMISTRY

RESEARCH UNITS

- Biogeochemical Modelling
- Biological Oceanography
- Chemical Oceanography
- Marine Geosystems

The chemistry of the oceans as we know them is hugely influenced by biogeochemical processes. Research Division 2 explores the biological, chemical and physical interactions between important chemical substances and their isotopes in the oceans, as well as the complex exchange between the oceans, atmosphere and sea floor. Major focal points of this research are the investigation of carbon fluxes from the atmosphere to the deep ocean, ocean acidification, so-called oxygen minimum zones and the study of gas hydrates.
www.geomar.de/en/research/fb2/overview/

15 mm-sized blue button jellyfish (*Porpita porpita*), found during the METEOR expedition M97 in the tropical Atlantic. Image: Uwe Piatkowski, GEOMAR

RESEARCH DIVISION 3

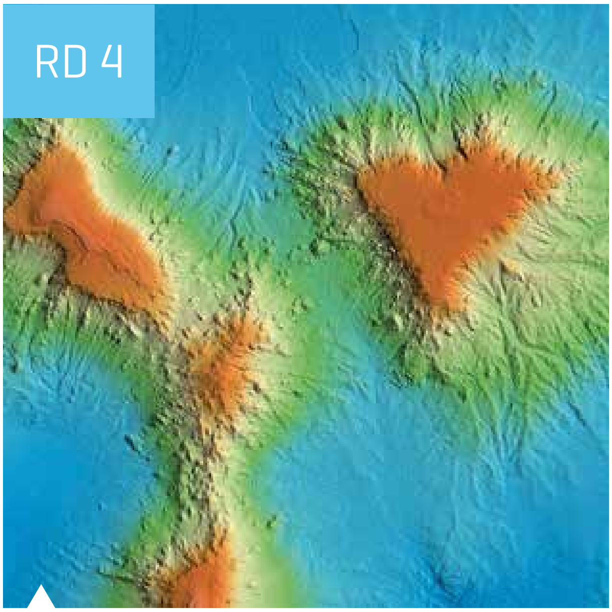
MARINE ECOLOGY

RESEARCH UNITS

- Experimental Ecology – Benthic Ecology
- Marine Evolutionary Ecology
- Marine Natural Products Chemistry
- Marine Symbioses
- Ocean Ecosystems Biology

The responses of marine ecosystems to global environmental change are among the fundamental questions for the future oceans. Research Division 3 is examining how various marine species interact in changing food webs, how the composition, diversity and function of different ecosystems are affected by external influences, how biodiversity influences the ecosystem services, and whether rapid evolutionary adaptation mitigates the negative effects of global change.

www.geomar.de/en/research/fb3/overview/



Seamounts in the central Eastern Atlantic, mapped in early 2018 during the expedition MSM70 of RV MARIA S. MERIAN. Visualisation: Nico Augustin / GEOMAR

RESEARCH DIVISION 4

DYNAMICS OF THE OCEAN FLOOR

RESEARCH UNITS

- Magmatic and Hydrothermal Systems
- Marine Geodynamics

The focus of the work in Research Division 4 is on the geological-geophysical investigation of the ocean floor and the continental shelfs. The core topics include processes of formation, development, transformation and subduction of the ocean floor and the associated effects on the environment, for example on climate and the formation of natural hazards. Another focus is on the investigation of deep-sea resources such as gas hydrates and polymetallic massive sulfides.

www.geomar.de/en/research/fb4/overview/

The Ocean Tracer Injection System (OTIS) “tags” water masses to gain a better understanding of the re-distribution processes of sea water. A trace substance is injected at certain depths, which then mixes with the surrounding water and can be detected even years later. Image: GEOMAR

SFB 754

Research projects at GEOMAR

In addition to its core funding as a Helmholtz Insitute, GEOMAR receives third-party funding for a variety of research projects, mainly from public sources such as the Ministry of Education and Research (BMBF), the German Research Foundation (DFG) and the European Union. GEOMAR is also a leading participant in two long-term research programs that are planned for the next ten years: the Collaborative Research Centre 754 and the Cluster of Excellence “The Future Ocean”

Collaborative Research Centre 754

The Collaborative Research Centre (SFB) 754 “Climate - Biogeochemistry Interactions in the Tropical Ocean” investigates ongoing changes in the tropic oceans, their possible effect on the oxygen minimum zones and the consequences for the global interplay of climate and biogeochemistry. The Collaborative Research Centre is addressing a number of key questons. How do the tropical oxygen minimum zones react to changes in climate, ocean circulation and biological production? How do the sources and sinks of nutrients respond to changes in oxygen content? What are the orders of magnitude, time scales, and most important control mechanisms of past, present and future changes in oceanic oxygen and nutrient balance?

SFB 754 combines the study of climate, biogeochemical interactions, and oxygen thresholds in today’s ocean with those of the past and attempts to evaluate the consequences for the future. The results of research in the collaborative centre are expected to aid in a better understanding of the coupling between the climate variability, oxygen content and biogeochemistry in the tropical ocean. This will permit more accurate predictions of future changes in the ocean.

SFB 754 has been funded by the German Research Foundation since 2008. Scientists from Kiel University, GEOMAR and the Max Planck Institute for Marine Microbiology in Bremen collaborate in the project.

Mehr: www.sfb754.de

Experiments with deep sea scallops of the species *Bathymodiolus azoricus:* The Kiel Marine Organism Culture Centre, which was established as part of „The Future Ocean" Cluster, supports the science at GEOMAR and Kiel University by performing complex experiments in the field of marine ecology. The main focus of the projects is the acclimatisation and adaptation of marine organisms to climate change and the interactions between micro- and multicellular organisms. Image: Jan Steffen, GEOMAR

future ocean
KIEL MARINE SCIENCES

"The Future Ocean" Cluster of Excellence

"The Future Ocean's" Mission is to use the results of multidisciplinary scientific research on the past and present ocean to predict the future of the Earth's marine environment. This includes understanding changes to the past, on-going and future ocean as well as the interaction between society and the ocean in regard to marine resources, services and risks. This Mission carries with it an obligation to develop and assess scientifically-based global and regional ocean sustainable development options, including their legal, economic and ethical aspects. This integrated marine science is conducted be teams from marine sciences, economics, medicine, mathematics, computer science, law, philosophy and social sciences.

The Cluster also supports marine research in Kiel in the areas of knowledge transfer, public relations and international activities. It has established the post-graduate school ISOS and the postdoctoral network IMAP, and it further strengthens the research profile of marine sciences in the region by promoting the development of Kiel as a leading location for interdisciplinary and integrative exploration of the sea.

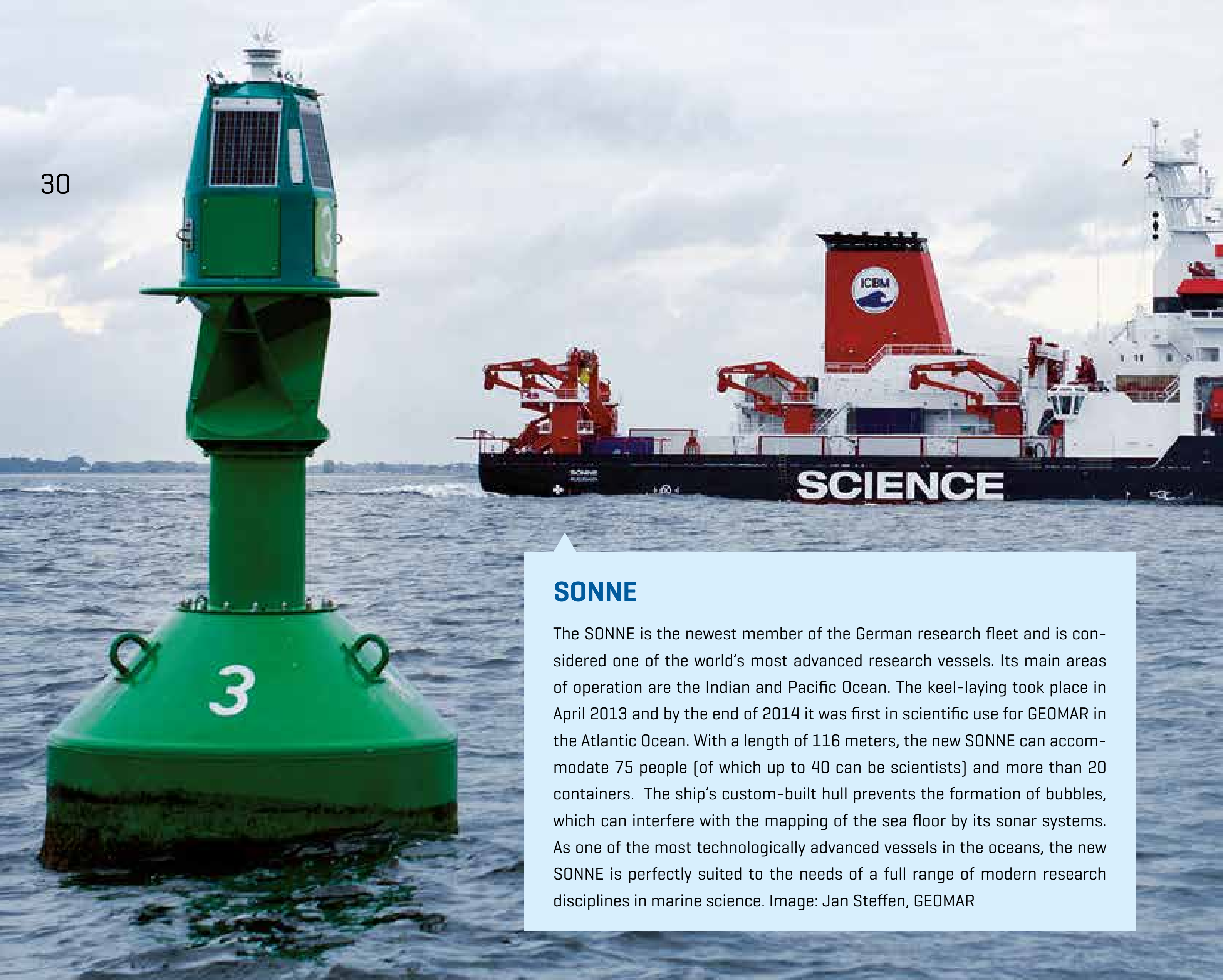
The research network is supported by Kiel University, GEOMAR, the Institute for the World Economy (IfW) and the Muthesius Academy (MKHS), and it is funded by the Excellence Initiative of the German Research Foundation on behalf of the federal and state governments.

Mehr: www.futureocean.org

„Future Ocean Dialogue": Conceptualized by the Cluster of Excellence "The Future Ocean" and GEOMAR, the "Future Ocean Dialogue" is a mobile exhibition that can fit into a single container and travel internationally. The exhibit showcases current issues in marine research, with its interdisciplinary approaches, while at the same time promoting Germany and Kiel as research centres. Image: Friederike Balzereit, The Future Ocean

Globally Operating German Research Vessels

Research vessels are indispensable for exploring the oceans. Expeditions into all kinds of marine environments contribute to a better understanding of the biological, geological, physical, and chemical processes in the ocean, to develop strategies for combatting the effects of climate change, to learn how to utilize the oceans in an economically efficient and environmentally friendly way, and to better predict dangers stemming from the sea. Innovative technologies help marine research stay "on track" with the processes in the oceans, including remotely operated underwater vehicles, autonomous deep sea drones, manned submersibles and systems anchored to the sea floor that are used for long-term monitoring of chemical and physical data. All of these sophisticated research tools are launched from a modern and efficient research fleet needed to meet the diverse challenges faced when exploring the oceans.



SONNE

The SONNE is the newest member of the German research fleet and is considered one of the world's most advanced research vessels. Its main areas of operation are the Indian and Pacific Ocean. The keel-laying took place in April 2013 and by the end of 2014 it was first in scientific use for GEOMAR in the Atlantic Ocean. With a length of 116 meters, the new SONNE can accommodate 75 people (of which up to 40 can be scientists) and more than 20 containers. The ship's custom-built hull prevents the formation of bubbles, which can interfere with the mapping of the sea floor by its sonar systems. As one of the most technologically advanced vessels in the oceans, the new SONNE is perfectly suited to the needs of a full range of modern research disciplines in marine science. Image: Jan Steffen, GEOMAR

MARIA S. MERIAN

The MARIA S. MERIAN is a universal platform for scientific work at sea. The ship's main areas of operation are the North Atlantic Ocean and adjacent seas. The MARIA S. MERIAN is especially equipped for research at the ice edge of the North Atlantic – it can navigate between ice flows and break ice up to 60 cm thick. To manoeuver precisely, the MERIAN also is equipped with a sophisticated propulsion system, greatly enhancing its sea-going scientific capabilities. Image: Nico Augustin, GEOMAR

METEOR

The METEOR operates worldwide, with international research groups playing an important role in all of its expeditions. Already, during the first 50 expeditions, scientists from 68 nations conducted their research on board the ship. So far, most of the research has taken place in the Atlantic, in the Mediterranean Sea and the Indian Ocean. The METEOR can operate at sea without having to call at a port for up to 50 days. Image: Sven-Helge Didwischus, GEOMAR

POLARSTERN

Since its maiden voyage in 1982, the POLARSTERN has been making expeditions to the Arctic and Antarctica and is at sea for about 320 days a year. Usually, the POLARSTERN travels to Antarctica during the austral summer and spends the northern summer in Arctic waters. As a double-hulled icebreaker, it can reach much of the polar regions and is functional at temperatures down to -50 °C. Its 20,000 HP engine can power the ship through ice a half-meter thick at a speed of 5 knots - thicker ice has to be broken by ramming. Image: GEOMAR


ALKOR

GEOMAR's Research Vessels

Currently, the vessel ALKOR as well as the research cutter LITTORINA and the research barge POLARFUCHS are located at GEOMAR.

LITTORINA

The LITTORINA ("periwinkle" in English) is a research cutter owned by Kiel University and operated by GEOMAR. The LITTORINA is mainly used for "small voyages" with its main areas of operation being the Baltic Sea, the North Sea and the Elbe-Weser estuary. And this, by no means, at a snail's pace: the ship can reach a speed of up to 10 knots (18 km/h). The vessel is operational for all disciplines of marine science. Image: Bernd Brockmann

ALKOR

The ALKOR is a regional research vessel for all disciplines. The areas of operation mainly comprise the Baltic and the North Sea as well as the coast off Norway. Built in the 1990s, the ship is equipped with four laboratories in which, among other things, air, water and sediment samples are examined. Oceanography, marine biology, fisheries research, geophysics and geology are the primary disciplines utilizing the ALKOR. Image: Maike Nicolai, GEOMAR

POLARFUCHS

The POLARFUCHS was built as a longboat for the research vessel POLARSTERN in 1982. After 14 years spent in the ice, it was taken ashore and upgraded for its new tasks in the coastal areas of the Baltic Sea. POLARFUCHS took up operations at GEOMAR in 1997. Today, it is mainly used for research and teaching of ecology in Kiel Fjord, Kiel and Eckernförde Bay, around Fehmarn, Kiel Canal and in the Schlei estuary. Image: GEOMAR

THE SUBMERSIBLE JAGO

JAGO – Germany's only manned research submersible – can reach a maximum depth of 400 meters and is used for exploration of and research on aquatic systems and habitats. The submersible dives freely, without being connected to the surface via a cable, and can carry two persons to the sea floor. JAGO allows spectacular view for its ocupants through two large acrylic windows and offers many opportunities for detailed photography and sampling using its hydraulic manipulator arm. With its relatively low weight of only three tons and its compact dimensions, JAGO can be launched from virtually any surface vessel worldwide that has sufficient crane capacity (five tons). Image: JAGO-Team, GEOMAR

ROV KIEL 6000

This remotely operated vehicle is one of the most modern diving robots for scientific work worldwide. With the capability of diving to depths of up to 6,000 meters, KIEL 6000 can reach 95 percent of the global sea floor. So far, it has been put to use during numerous expeditions to the hostile environment of deep-sea hot springs on the Mid-Atlantic Ridge and the submarine volcanoes around the Cape Verde Islands, in the Caribbean and in the Pacific. KIEL 6000 also has been used extensively to study CO2 and methane fields in the North Sea, active cold seeps in the Pacific and the Arctic Ocean and mineral deposits in the Indian Ocean. Image: ROV-Team, GEOMAR

Spaceships for the Deep Sea

More than half of the earth's surface lies below the oceans at depths of more than 3,000 meters, yet only a small part of the sea floor is currently known in detail. The exploration of the deep sea requires the use of advanced technology and can be compared to space research. High pressures, low temperatures and total darkness challenge researchers and research equipment in this extreme environment. In order to learn more about the deep sea, robotic systems such as remotely operated or autonomous underwater vehicles are increasingly being used.

ROV PHOCA

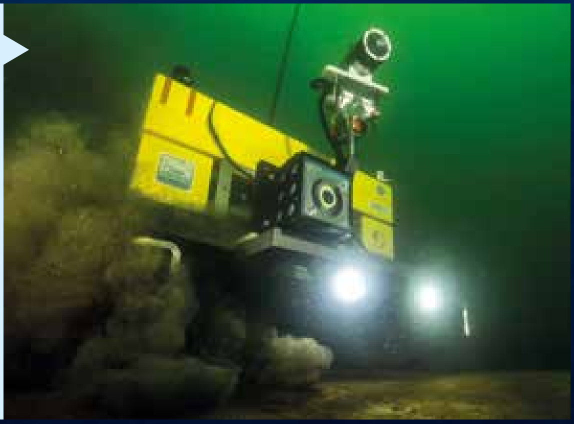
Like KIEL 6000, the ROV PHOCA is a remotely operated vehicle, controlled by a steel-armoured fibre optic/copper cable. It can be equipped with a number of scientific instruments and sensors that complement its two manipulator arms and various cameras. It is operated by two pilots from a control center on board the host research vessel. PHOCA is smaller and lighter than its "big brother", KIEL 6000, and can therefore be used on smaller ships and at depths of up to 3,000 meters. PHOCA allows exploring the geology, geophysics, geochemistry, volcanology, chemistry and biology of the marginal seas up to depths of 3,000 meters. Image: Peter Linke, GEOMAR

AUV ABYSS

The streamlined AUV (autonomous underwater vehicle) ABYSS is used to map the sea floor in high-resolution. Its sensitive onboard equipment can also collect physical data from the water column, take photographs, and measure subsea geophysical signals – all without the intervention of humans. Its name refers to the abyssal zone, the sea floor at 2,000-6,000 meters depth where ABYSS commonly works. It flies through the deep sea just above the ocean floor at speeds of up to four miles per hour, dodging obstacles in its path. Before each mission, which can last for up to 20 hours, AUV ABYSS is programmed with destination, course and task, and at the end of its work, it flies itself to the surface where it can be recovered. Image: Nico Augustin, GEOMAR

MANSIO-VIATOR

The MANSIO-VIATOR system is being developed at GEOMAR as part of the Helmholtz Alliance ROBEX in order to expand the range of applications for autonomous deep-sea crawler vehicles. In contrast to existing solutions, it does not require a fixed cable connection for power supply and data transmission. Once the system is set down on the seafloor, the VIATOR crawler (lat.: the traveller) is able to operate independently in a given terrain and then dock at its MANSIO station (lat.: the hostel) to exchange data and energy. Photo: Christian Howe, Submaris



Further Research Equipment

With eleven underwater gliders, the GEOMAR has one of the largest glider fleets in Europe. There are also four surface gliders, ten KOSMOS mesocosms developed at GEOMAR, ten deep-sea observatories (lander), a pool of ocean-bottom seismometers (OBS) with 100 units and other innovative equipment for deep-sea exploration.

GLIDERS

Oceanographic gliders can be described as sailplanes for the ocean. Equipped with sensors, they are used, for example, to determine water temperature, salinity and oxygen over large distances, moving freely through the top 1,000 meters of the ocean. Instead of a propeller drive, they use a buoyancy engine consisting of a high-pressure pump to change their buoyancy, allowing them to rise or descend in the water. Their wings then convert this movement into forward motion. Since this type of propulsion is very energy efficient, a single battery charge allows a glider to travel for several months, covering distances of over 2,000 km. Image: Mario Müller, GEOMAR

WAVEGLIDERS

Wavegliders are surfboard-like surface gliders that can be remote-controlled by satellite. They are independently of research vessels over long periods of time to carry out measurements or communicate with observation platforms in the deep sea. A waveglider is propelled through a lamella system, which is attached eight metres below the surface board. The board moves up and down with the waves. This sets the lamellas in motion, which provides propulsion and pulls the board along the surface. In this way, a waveglider can travel through the oceans without external energy supply. Solar panels provide additional power for sensors, satellite communication and navigation. Image: Jan Steffen, GEOMAR

MESOCOSMS

The Kiel Offshore Mesocosms for Future Ocean Simulation (KOSMOS) are giant "test tubes" for the oceans that allow a glimpse into the ocean of the future. Conditions that will soon affect the oceans can be simulated in these enclosed "worlds" and the reactions of marine communities studied at a large scale as if they were located in a different ocean than today's. GEOMAR's ten self-constructed KOSMOS mesocosms are a ground-breaking innovation. The experimental systems can be transported and installed in the water using medium-sized research vessels, and they can either be anchored in bays and fjords or drift freely in the open ocean. Image: Yves Gladu

LANDERS

Landers are underwater laboratories, designed for operating at the deep sea floor at depths of up to 6,000 meters. They can be equipped with different measurement systems and experimental modules depending on the particular scientific question. The onboard experiments are controlled electronically and can, provided with their own power supply, operate autonomously for months. Ballast weights attached to the legs help fasten them to the sea floor. After dropping the weights with acoustically controlled release hooks, the devices resurface with the aid of high-buoyancy floats. Image: GEOMAR

OCEAN BOTTOM SEISMOMETER

An ocean bottom seismometer (OBS) records vibrations of the seabed which are generated by earthquakes. In order to do so, the OBS is lifted overboard and then sinks to the ocean floor in 8,000 meters depth, where it works independently. Information on location, depth and fracture behaviour of an earthquake can thus be obtained. In addition, sound waves can be generated by airguns in shallow water on board the research vessel, which run through the water column and penetrate into the seabed. This sound transmission provides information on the structure and thickness of the rock layers. A coherent picture of the subsea can thus be generated for a variety of individual measurements of the OBS. Image: Jan Steffen, GEOMAR

Cold trap at the thermal ionization mass spectrometer "TRITON" being filled with liquid nitrogen. Image: Pohl/Warnk/Gall

The high performance computer for marine and climate research was put into operation at the end of 2014 and is jointly financed and operated by Kiel University and GEOMAR. Image: Jürgen Haack, Kiel University

Laboratories and Analytics

Specialised laboratories and analytical devices are available to the scientists at GEOMAR for the detailed study of samples and for accurate experiments under controlled conditions. These include cleanroom laboratories, a wide range of mass spectrometers and specialized laboratories for culturing and studying molecular biological and genetic samples. Analyses of seawater samples can achieve the lowest concentrations of trace elements, and geochemical analyses of rocks, sediments and minerals can be made with sophisticated electron beam and laser instruments. We can also precisely date seabed samples in order to gain new insights into the earth system and in particular its marine areas.

More: www.geomar.de/en/centre/central-facilities/laboratories

Modelling

In addition to direct observations and sampling, computer-based modelling of is of particular importance in the field of marine sciences. Be it high-resolution ocean models, in climate predictions, in genetic analyses or the reconstruction of geological processes – all areas of modern marine research use complex numerical methods. This is the only way hypotheses can be tested efficiently and predictions about future developments can be made. For this purpose, GEOMAR has a powerful IT infrastructure with access to supercomputing centres and failsafe storage systems at its disposal.

More: www.geomar.de/en/research/fb1/fb1-tm/topics/

The heart of the **Technology and Logistics Centre (TLZ)** is a central assembly hall in which a gantry crane is available to move even heavy equipment. Image: Jan Steffen, GEOMAR

Technology

In order to answer current research questions, GEOMAR relies on high-precision marine technology, which has to be operated and maintained before, during and after an expedition. The Technology and Logistics Centre (TLZ) provides this service. New devices are also developed in the TLZ and existing ones modified in close cooperation with the scientists in order to answer emerging questions. For this purpose, modern workshops for handling a variety of materials are available. GEOMAR's large-scale equipment, the ROVs KIEL 6000 and PHOCA, the AUV ABYSS, HYBIS and the submersible JAGO, among other research equipment, are also based at the TLZ.

More: www.geomar.de/en/centre/central-facilities/tlz/

Have a lot of fans: GEOMAR's seals. Image: Jan Steffen, GEOMAR

Seal Enclosure and Aquarium

The journey begins in the Baltic, continues on into the North Sea and the Atlantic Ocean and ends in the Mediterranean and the tropical coral reefs — GEOMAR's public aquarium invites its visitors to join a short expedition into the multi-faceted seas of our planet. The interior areas with its sea trout, cod, dogfish, anemone fish, sea bass and many other species allow an escape into the colourful and fascinating underwater world. Meanwhile, seals can be observed under water and above in the outdoor enclosure next to Kiel Fjord, day and night. GEOMAR shows the animals in their authentic habitats, creating a unique atmosphere that fascinates tens of thousands of big and small visitors every year.

More: www.aquarium-geomar.de (german)

The marine science library at GEOMAR is one of the largest of its kind in Germany. Image: Christoph Kersten, GEOMAR

During a lecture. Image: Kröger/Dorfmüller, Kiel University

Library

The library is partially open to the public and houses a large collection of current and historical marine scientific journals. The extensive collection of books and magazines (132,000 media units, 750 current periodicals and continued works) includes, among other things, a special collection of expedition reports and valuable rarities. The library website allows users to search over 600 online journals, books and databases. By networking with various national and international libraries, literature that is difficult to access also can be obtained quickly.

More: www.geomar.de/en/centre/central-facilities/bibliothek

Teaching

GEOMAR supports the broad curriculum of Kiel University with two masters and one bachelor's degree courses in the field of marine sciences. Other courses, particularly in geology and geophysics, allow marine sciences to be chosen as a major subject. Interdisciplinary training is further enhanced by the Integrated School of Ocean Sciences (ISOS), a program of "The Future Ocean" Cluster of Excellence. International collaborations, such as the German-Russian study programme POMOR, the German-Canadian Helmholtz Research School for Ocean System Science and Technology (HOSST), and the international master's program Global Approach by Modular Experiments (GAME), complete the picture and provide an excellent basis for a successful career in the field of marine sciences.

More: ww.geomar.de/en/studying

Working at a milling machine in the TLZ: The training of soon-to-be technicians takes place in the workshops. Image: Maike Nicolai, GEOMAR

Marine Research "live": Scholars get to know the biology of the Baltic Sea on board the research vessel ALKOR. Image: Joachim Dengg, GEOMAR

Training

GEOMAR helps train not only the marine scientists of tomorrow but also young people with non-academic career goals in a variety of areas. GEOMAR offers attractive training opportunities in animal care, the aquarium, in administration, the library, the data centre, laboratories or in the more technically-oriented professions in the technology and logistics centre. Apprentices receive an exciting insight into current marine research from experts of more than 40 different nationalities. With their work, the trainees help to set the stage for deciphering the secrets of the oceans.

More: www.geomar.de/entdecken/schule/berufsorientierung/ausbildung (german)

School Program

GEOMAR allows schools to have access to their research facilities and encourages direct contact with scientists through collaborative projects with schools, projects of individual pupils, materials for education and teacher training. Questions of current research, such as the role of the ocean and atmosphere in the climate system, biological and chemical cycles in the ocean, marine ecology, and the dynamics of plate tectonics and the sea floor are presented in a pupil-friendly fashion within the school program of GEOMAR. The work is interdisciplinary and closely related to regular school subjects of physics, chemistry, biology, geography, mathematics and English.

More: www.geomar.de/entdecken/schule (german)

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