future ocean
KIEL MARINE SCIENCES

08 | ANNUAL REPORT

UNDERSTANDING THE OCEAN SUSTAINING OUR FUTURE

EDITORIAL

With great pleasure we present the third annual report of the Cluster of Excellence „The Future Ocean".

The Future Ocean was among the first eighteen of thirty-seven Clusters of Excellence funded by the German Research Foundation (DFG), receiving its first funding in fall 2006. The cluster is primarily organized around its thirteen junior research groups (JRGs) enhancing existing Kiel-based research efforts and supported by several research platforms. Throughout 2007 and 2008 these groups were established, group leaders and scientific personnel were hired. 2008 was hence the first year where all groups were fully operating throughout most of the year, and we are proud to present the very first scientific results in this report.

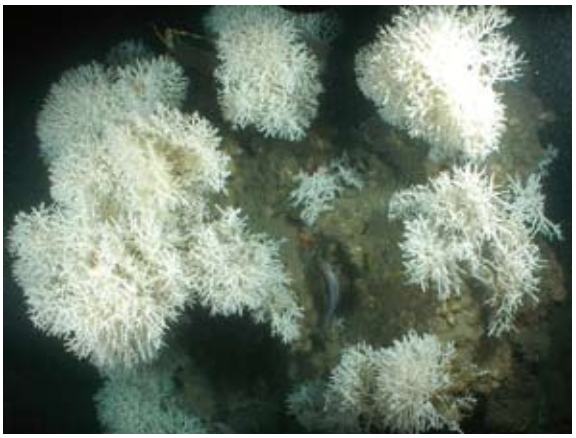
Besides the JRGs, the Future Ocean supports a large number of targeted scientific projects. 57 projects are currently funded, working on diverse topics, from 3-D visualization of seafloor structures to the sequencing of DNA molecules, from real-time ocean observations to sustainability studies of fish stock, from global climate modeling to aspects of the law of the sea and valuing the ocean. Many of these projects aim to be the nucleus for further studies, which might in the future spawn bigger projects, existing in parallel to the Future Ocean. This has been the case for a collaborative research center (SFB 754), addressing future ocean related topics. The project greatly benefitted from the marine science expertise in Kiel, but also from start-up funding received to compile the project proposal. In this report we present brief reports from selected Future Ocean projects to provide a glimpse into the full scientific spectrum the cluster comprises.

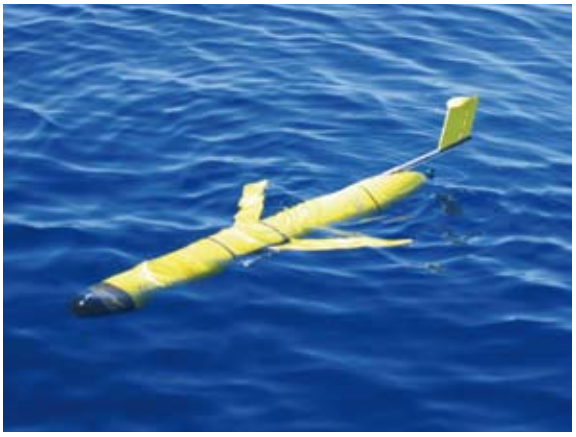
Last but not least, the Future Ocean also facilitates services to the university, in order to strengthen important aspects of science and education, as well as to communicate and promote the topics of the cluster of excellence to the general public. These are in particular the Integrated School of Ocean Science (ISOS), providing a model how enhanced graduate education can be implemented within a modern university. This is also the public outreach project, providing services to teachers and schools, organizing the public Childrens University around marine science themes, as well as exhibitions and display of Future Ocean themes at public events and fairs.

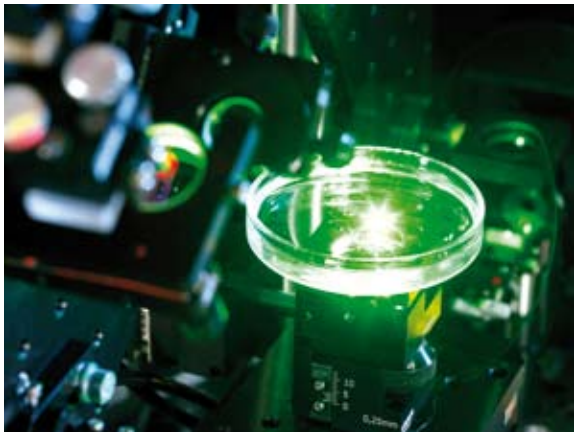
All this contributes to the overall goal of the Future Ocean, to consolidate Kiel's position as a leading place for marine science in Germany, and a world class address for consultation by policy and decision makers for future and forward orientated perspectives about the ocean and related topics.

We hope you will enjoy reading Future Ocean's annual report 2008, and continue to be interested in marine science.

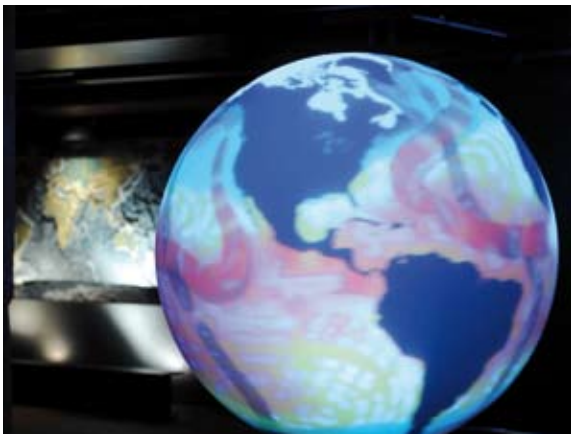
Speaker of the Cluster of Excellence „The Future Ocean"





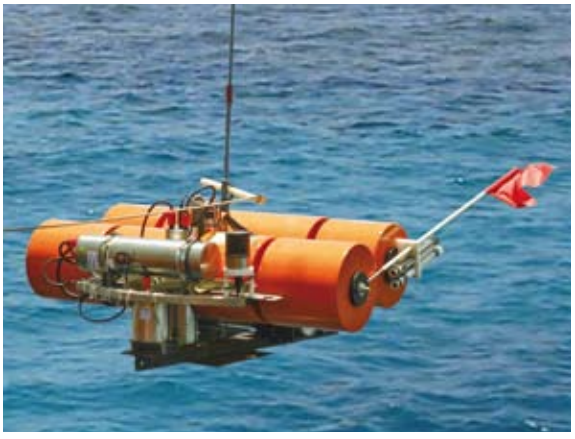


INDEX



54 | Public Outreach

60 | Integrated School of Ocean Sciences



64 | Transfer to Application

THE PROJECT

„We don‘t have to save the world. The world is big enough to look after itself. What we have to be concerned about is whether or not the world we live in will be capable of sustaining us in it.“

Douglas Adams

WE KNOW WHAT WE'RE DOING

Climate protection policy must implement new research findings more quickly

The oceans play a key role in the development of the climate. They are, however, often forgotten in the public debate. One reason for this might be that there has been less research in the deep sea than the „seas" of the moon. New research methods such as robots that travel independently through the sea should change that. In the opinion of oceanographer Professor Martin Visbeck it is, however, necessary to also support the work of the Intergovernmental Panel on Climate Change (IPCC) by establishing regional climate offices.

You are the spokesman for the Cluster of Excellence „The Future Ocean". Overacidified, overheated, exhausted of fish stocks due to trawling - is that what the future oceans will look like?

Visbeck: Too hot, too high, too acidic – that's too sensational and does not take into account the available opportunities. „Understanding the ocean – sustaining our future" is our motto at the network of Kiel Marine Sciences. We are currently investigating how the oceans react to climate change and ever greater exploitation by man. Sea levels are rising due to melting ice caps. At the same time, the circulation patterns of sea currents are changing. This has an additional effect on the sea level on a regional basis. This field needs more detailed research. At the moment around half of the CO_2 greenhouse gas produced through human action is stored in the oceans. However, there are indications that the potential of the oceans to act as a CO_2 sink decreases if the water temperature rises. The heating of the water leads to increased stratification which in turn reduces the formation of CO_2 binding deeper waters. Warm water dissolves less CO_2. It could be that the biological pump partially counterbalances this development: More plants produce more food for more animals - both sink to the bottom when they die. Until now, the biological pump has contributed less than 10% to the CO_2 sink in the ocean. If the seas consume more CO_2 this is not just positive: The slightly alkaline ocean will become ever more acidic. We are researching the consequences. It is to be feared that calcareous organisms such as lime algae, starfish, snails, mussels and coral will be adversely affected.

Does the development also offer opportunities?

Visbeck: There is a large number of opportunities ranging from the seabed as a potential storage site for isolated, liquid CO_2 to the opportunity of using methane deposits on the continental shelves as a source of energy. Companies are already mining undersea copper off Papua New Guinea from exhausted volcanoes. These are metal rich craters at hot deep sea springs. We cannot simply reject undersea mining but we have got to try to do it in an environmentally friendly manner. There will be a sharp rise in demand for copper for instance if all the Chinese and Indians also want to have electricity in their homes. Substances produced from marine organisms, also referred to as „blue medicine" are becoming a focus of attention. The disadvantage here is that only a fraction is known about the marine gene pool in comparison to the terrestrial one. In order to achieve sustainable economic use the cluster of excellence cooperates with resource economists on this topic, as understanding the ocean is the basis for sustainable management of the seas.

Your aim is „to intensify the transfer of research results into policy." Isn't it necessary to speed up this transfer first?

Visbeck: It has to change to meet new challenges. Up till now, the IPCC Assessment Report every couple of years has provided decision-makers with new knowledge. That is not ideal for dealing with short-term signals from the ocean and climate. The complex procedure of evaluating and publishing all the results is of a very high scientific value but the facts are often more than five years old. Advice to political decision makers, however, should be based on more recent findings and should be able to react to current events.

Is that why you are calling for regional support for the IPCC?

Visbeck: Exactly. Lower Saxony probably is not even mentioned in the IPCC report. But Lower Saxony is part of climate change - not only because the consequences can be felt here but also because Lower Saxony's politics and economy act on a global scale. Therefore, there is a need for information on regional options for action in order to be able to manage climate change - for example the export of energy-saving technology to the emerging countries. In order to achieve this, the regional climate expertise centres should analyse local phenomena, evaluate risks and point out conservation potential among other things. The IPCC cannot comment on every storm surge but there should be somebody who can do this in a professional manner.

Where should regional climate service providers act differently from the IPCC?

Visbeck: They should use scientifically accepted procedures in order to record local climate data and produce forecasts. Some effects of climate change are not obvious: For example, the increase in sea level can affect farmers on the Elbe marshes. If the sea pushes further up the river, low lying wells, used to provide water for the cattle, can become salty.

At the moment, we know less about the sea than about the moon. „Teenagers", as you call your submersible robots, are supposed to change all that. Have they already fulfilled the high expectations off the coasts of Majorca, Greenland and in the north-east Atlantic?

Visbeck: Yes, but they really are like teenagers, and still create a number of surprising problems as teenagers do. We were the first in Europe to use gliders as research platforms, that is unmanned submersible robots that move very slowly underwater almost like sailing. First, oil is pumped into the 2-m-long yellow glider. As it is heavier than water, it sinks to a depth of up to 1,000 m and then moves forwards with its small wings. Then the glider pumps the oil into an external inflatable bladder, this increases its volume and enables it to rise. It measures oxygen content, salt content, water pressure and temperature and transmits data to satellites once it reaches the surface every 46 hours - for approximately three months. There are also approximately 3,000 ARGO drifters travelling the seas. They measure the conditions of the upper 2,000 m of the oceans every ten days, but they can only move with the currents.

In Kiel, we have high hopes of using groups of gliders. About a dozen gliders, working in parallel, scan a limited area of sea. That is a modern, relatively cost-effective way of maritime research, which supplements exploring by ship.

By 2.100, melting Greenland ice could slow down the Gulf Stream by 30 percent. Does that mean that Europe will experience an ice age in the Earth greenhouse?

Visbeck: No, that's not the case. It is true that fresh water makes the surface layer lighter so that it is no longer thick and heavy enough to sink to deep depths even in winter. If this sinking capacity is reduced further, less (warmer) water will move north in the direction of Europe. If this density-driven part of the Gulf Stream circulation were to be reduced due to natural water inputs, this could indeed result in Europe becoming one or two degrees colder. In fact, we expect deep circulation to diminish only as the climate warms up. That means it would become warmer by only one to four instead of three to six degrees.

The slowing down of the Gulf Stream, however, also reduces its ability to absorb CO_2. Do certain phenomena of climate change intensify?

Visbeck: That is one the most exciting questions in climate research. It is possible that the „second" ton of carbon dioxide emitted is more dangerous than the „first" one, because it produces feedback effects. A weak Gulf Stream absorbs less greenhouse gas from the atmosphere and temperature increases faster. Warmed up, more stratified water can store less CO_2.

These effects are very worrying. You want to develop a global sustainable management of the oceans. Does sustainability have a chance against vested interests against the background of the countries competing for the treasures of the Arctic?

Visbeck: That's a discussion that we foster in our project. Economic interests are opposed to the interests of ocean as a natural habitat often enough. The current competition is partly due to the fact that the rules of the game on questions such as which part of the seabed is allocated to which countries and which is common good have only recently been agreed. To date, there is no map of the seabed, agreed by all states bordering the oceans that would allow reliable borders to be drawn. That has unfortunate consequences for researchers: At the moment, you can no longer charter a research ship. All of them are being used on behalf of various countries to map the continental shelf. Europe only realised in 2007 that its surface area is larger underwater than above water.

Catches have dropped consistently since 1994. Every fourth species of sea fish is threatened with extinction. Are human beings destroying the sea before they've learned to understand it?

Visbeck: Pressure on fish stocks has indeed increased significantly. It is questionable how far a change to sustainable fishing can repair the damage. If, for example, you were to transfer ownership of the fish stocks to the fishermen they would have a vested interest in maintaining them. That's in contrast to the past where the only rationale was to take as much as possible from the general stock. On top of that, there is a need for real nature conservation in the form of large protected areas in the sea where fishing and other forms of exploiting the sea are taboo.

In spite of the fishing ban, cod stocks off Newfoundland are not recovering, possibly because of the warming of the sea. Is climate change the final blow for overfished stocks?

Visbeck: Climate change is beneficial for certain types of fish and detrimental to others. There are certain shifts in the ecosystems. Unfortunately, fish quotas were determined according to the success of the previous catches and not through considerations of maintaining existing stocks. But even before setting EU fish quotas scientific aspects are heard but are not the decisive factors. Knowledge-based methods do exist but often cannot be implemented because of political realities - and this leads to repeating the errors of the past. In the 1940s and 1950s, fishing was industrialised without the knowledge of where this would lead. We know all about it today, but continue to do it in spite of that. The fish we eat will increasingly come from fish farms. However, there are many harmful forms of fish farming. Of course, we promote sustainable ones.

Will the voice of science be better received in terms of climate protection than it is with quotas?

Visbeck: We hear the words but there is a lack of necessary action. Climate change is, without doubt, a very big challenge for humanity. But even if we are under pressure, we need to keep a cool head and not choose the next best solution. We are worried about instant solutions such as suggested fertilising of the seas to buffer additional CO_2. Such technical tricks are cheap in comparison to CO_2 emission reductions but in general one may only be replacing one evil with another.

INFO

The interview was conducted by
Joachim Zießler
for the Landeszeitung Lüneburg on 11 January, 2008.

THE FOUNDING INSTITUTIONS

CHRISTIAN-ALBRECHTS-UNIVERSITÄT ZU KIEL

The Christian-Albrechts-Universität zu Kiel (CAU) established the Cluster of Excellence „The Future Ocean" together with the Leibniz Institute for Marine Sciences IFM-GEOMAR and integrated it into the research focus of marine- and earth sciences in Kiel. Investments into this concept have paid off extremely well for both parties. Several innovative projects were realized and effective networks set up. Important questions in the area of marine and earth science were already specified and resolved. From the promotion of young researchers, via the Childrens University, to the transfer of application the cluster of excellence makes significant contributions to strengthen the Kiel University within the national and international competition. The recent rise of the Kiel University into the top class among Germanys universities in funding through the DFG can also be attributed to the establishment of dedicated research foci at the university. An extension of the Future Ocean is therefore a high priority goal, in order to be able to use the potential of the developed networks for the solution of future-oriented problems in marine- and geosciences.

MUTHESIUS ACADEMY OF FINE ARTS AND DESIGN

The Muthesius academy of art (MKH) is the only arts academy in Germany being a member of a cluster of excellence. This special position opens particular perspectives for the supra-regional perception of the MKH and the advancement of a profile within the field of „artistic research". The representation, visualization and communication of research processes and scientific results leading to a visual Corporate Identity of the Future Ocean are among the core competences of the MKH. Such tasks strengthen the external visibility of Kiel Marine Science. The successful co-operation will reach a peak during the Future Ocean exhibition and accompanying events in the Deutsches Museum in Munich 2010. Artistic practice is usually tied to subjective perception. Contemporarily culturally important processes are abstracted from direct perception through their global character and block the access to artistic reality. For the MKH it is therefore in its vital interest to give teachers and students access to this research to allow for independent artistic work. The oceans are a space of elementary importance for mankind. Therefore, as an academy of arts, we feel an utter obligation to actively take part at the research and communication of the related topics.

LEIBNIZ INSTITUTE OF MARINE SCIENCES

Who owns the ocean? What are the consequences of the increasing acidification of the world ocean? Can marine organisms help us to defend severe diseases? These research topics of the Cluster of Excellence „The Future Ocean" are also of high relevance to IFM-GEOMAR.

In terms of natural sciences, IFM-GEOMAR provides the backbone of the cluster research. Although only four groups are directly located at the institute, namely Ocean Acidification, Seafloor Warming, Seafloor Resources and Submarine Hazards at Continental Margins, IFM-GEOMAR is also very active in most of the other areas of the cluster. The multidisciplinary approach of the cluster is highly valuable to the four major research foci of IFM-GEOMAR that include the Role of the Ocean in Climate Change, Human Impact on Marine Ecosystems, Living and Non-Living Marine Resources and Plate Tectonic Processes and Geological Hazards.

In 2008, major scientific interactions between the cluster and IFM-GEOMAR appeared in the fields of ocean acidification (mesocoms experiments, cold water corals), oxygen minimum zones (expeditions of RV *Maria S. Merian* and RV *Meteor*), seafloor warming (impact on gas hydrates in subpolar regions) and living resources (sustained fisheries and aquaculture). PhD students of IFM-GEOMAR got involved in the Integrated School on Ocean Sciences (ISOS) for cross-disciplinary networking within the cluster.

In addition to the science, IFM-GEOMAR supported very actively public outreach projects of the cluster, in particular the exhibition „The Future Ocean" and the Children University. Through the cooperation within the Cluster of Excellence „The Future Ocean" the cutting-edge basis in marine sciences is broadened by scientific, legal und economic aspects.

KIEL INSTITUTE FOR THE WORLD ECONOMY

As an international center for research in global economic affairs the Kiel Institute for the World Economy engages in creating solutions to urgent problems in global economic affairs. With its research activities the Kiel Institute has a profound scientific basis to advise decision makers in policy, business, and society and to inform the broader public about important developments in international economic policy.

The oceans play an important role for humans as an economic resource base by providing fish or minerals and

below the seafloor oil and natural gas. They are also the backbone of economic globalization as they provide the medium to transport the vast majority of internationally traded goods. Besides these economic aspects the oceans also provide services that influence human welfare by absorbing CO_2 emissions as well by providing opportunities for recreation, values that are not reflected in markets but are equally important.

The Cluster of Excellence „The Future Ocean" gives us the unique opportunity to integrate economic analyses with the research insights from natural sciences, humanities, and law. This interdisciplinary approach has brought our research on global economic affairs closer to the societal needs for science based advice to decision makers and information of society.

The research collaboration in the cluster of excellence has not only provided a fruitful cooperation of the Kiel Institute with the partners on ocean research, it has also gone beyond the oceans. The Leibniz Institute for Marine Sciences and the Kiel Institute have founded the Kiel Earth Institute as a virtual research institute that will carry forward the spirit of the Future Ocean to other integrative research topics.

CHRISTIAN-ALBRECHTS-UNIVERSITÄT ZU KIEL

The Christian-Albrechts-Universität zu Kiel is the only full university in Schleswig-Holstein. It is home to more than 22,000 students as well as 2,000 university teachers and researchers. From A for Agricultural Sciences to Z for Zoology, the university currently offers around 80 different subjects of study.

Creating links among the different scientific cultures is the top priority at Kiel University. After all, reality that is reflected in scientific research is multi-layered and complex and so are the research focuses of the university: marine and geological sciences, life sciences, cultural spaces as well as nanosciences and surfaces. During its nearly 350-year history, the Christian-Albrechts-Universität zu Kiel is closely linked with the city of Kiel. Together with the university hospital it is now the largest employer in the region.

LEIBNIZ INSTITUTE OF MARINE SCIENCES

The Leibniz Institute of Marine Sciences (IFM-GEOMAR) is one of the world's leading institutes in the field of marine sciences. The institute investigates the chemical, physical, biological and geological processes of the seafloor, oceans and ocean margins and their interactions with the atmosphere. This broad spectrum makes IFM-GEOMAR unique in Germany. Additionally, the institute has successfully bridged the gap between basic and applied science in a number of research areas. IFM-GEOMAR has four major research foci: Ocean Circulation and Climate Dynamics, Marine Biogeochemistry, Marine Ecology and Dynamics of the Ocean Floor. Four research vessels, large-scale seagoing equipment such as the manned submersible JAGO, the unmanned deep-sea robots ROV Kiel 6000 and AUV Abyss as well as state-of-the-art laboratories, analytical facilities, and a hierarchy of numerical models provide a unique basis for excellent marine research. With a number of internationally-based curricula the Institute actively contributes to educating young scientists in the field of marine sciences.

IFM-GEOMAR is a member of the Leibniz Association, the German Marine Research Consortium (KDM) and the Marine Board of the European Science Foundation.

KIEL INSTITUTE FOR THE WORLD ECONOMY

The Kiel Institute is one of the major centers for Research in global economic affairs, economic policy advice and economic education.

The Institute regards research into potentially innovative solutions to urgent problems of the world economy as its main task. On the basis of this research work, it advises decision makers in politics, the economy and society, and keeps the interested public informed on important matters of economic policy. As a portal to world economic research, it manages a broadly cast network of national and international experts, whose research work flows directly or indirectly into the Kiel Institute's research and advisory activities.

The Kiel Institute attaches particular value to economic education and further training and co-operates with the world's largest library in the economic and social sciences.

MUTHESIUS ACADEMY OF FINE ARTS AND DESIGN

Founded on 1st January 2005, the Muthesius Academy of Fine Arts and Design in Kiel is Germany's northernmost and youngest school of higher education devoted to the systematic study of art and design. Thanks to an innovative course structure, the Academy's concept features a diverse programme of curriculum options in the fields of art, spatial strategies and design. The history of the Academy began in 1907 with the founding of separate classes in artistic design at the School of Applied Arts, the Muthesius Academy. It is a story of constant, gradual change in both curriculum and academic structure. The newly founded Academy of Fine Arts and Design will offer approximately 400 places for students.

The Art Academy's size enables it to offer project-oriented and practical instruction in small groups - a tradition harking back to the days of the Muthesius Academy - as well as close contact between instructors and students. Modern media play no less important a role than that of the traditional canons of art and design.

ABOUT THE FUTURE OCEAN

MOTIVATION

The ocean hosts our planet's largest ecosystem, helps regulate the composition of the atmosphere and global climate, and provides mankind with essential living and non-living resources. Coastal regions are home to the majority of the world's population and the open seas are key to global trade and security and a source of major natural hazards. In short, the global ocean is vital for human welfare now and in the future. But mankind is altering the oceans in both direct and indirect ways and on a global scale. The alteration started with fishing which has already drastically changed the global marine ecosystem. Human impact now extends from regional changes, such as alteration of coastal and deep sea habitats, to global scale impact on marine life, ocean circulation and carbon cycling through emission of CO_2 and other pollutants.

The Future Ocean therefore is the recognition of mankind's increasing dependency on the ocean in the context of our increasing power to alter it. These two factors imply a need to understand our environment in order to be able to predict and manage. They also imply a need to educate, in order to make the next generation aware of the need for responsible and sustainable use of the ocean. We need tools to be able to decide, whether to adapt to, or to mitigate the changes that we have already set in motion.

IMPLEMENTATION

The Cluster of Excellence „The Future Ocean" was proposed in spring and funded in fall 2006, in response to a general call for proposals by the German Research Foundation (DFG) within the framework of the Excellence Initiative by the german federal and state governments. The visions formulated in the proposal were deeply affecting research, university structures, administration and science management in Kiel and demonstrated the firm commitment of the university and its partners, to advance to a new, modern level of science organization in Kiel. Since then many activities have been directed to implement the envisioned research framework.

To enhance the already existing research environment the Future Ocean comprises several components interlocked within each other to form a structure allowing scientists to perform at their best. It is designed around funding instruments promoting research in marine and related science in Kiel. Core of this structure are thirteen new junior research groups, all working at the interface between traditional scientific disciplines. These groups are bridging traditional marine sciences with its aspects in biology, chemistry, physics, geology, and previously loosely related subjects like economy, medicine, law, molecular biology and computer science. Secondly a platform concept was established, setting up four research platforms, supporting all researchers with the technical infrastructure needed to deliver world class

Figure 1 | Members and employees of the Cluster of Excellence „The Future Ocean".

results. Thirdly the Future Ocean fosters a fast-track funding concept, where money for start-up proposals, travel, conferences, and funds to invite renowned colleagues to Kiel can be applied for. The Future Ocean also issues its own scientific proposal calls in order to be able to quickly respond to the latest scientific developments in the most flexible way. All these proposals are fully reviewed externally to ensure the highest quality in science.

STRUCTURAL ELEMENTS OF THE FUTURE OCEAN

- The thirteen Junior Research Groups form the scientific core of „The Future Ocean". These newly established groups are funded to investigate bridging topics between classical disciplines. They are equipped with sufficient funds to support whole working groups for up to 6 years. The JRG leaders hold professorships which have a tenure option.

- The platform concept consolidates certain types of technical infrastructure under a single roof, enabling researchers to access available and needed instruments easily.

- Research projects, travel, visitors and conferences can be funded through a fast track internal proposal process. Project proposals undergo an external review process before funding.

- The Integrated School of Ocean Science supports graduate students with soft skill courses targeted to prepare for a future life in marine science, industry or at a non-governmental organization (NGO).

- The public outreach project promotes marine sciences to the general public, but also fosters exchange of internal information within the Future Ocean.

By spring 2008 all junior research groups have started operating. Within 2008 all groups successfully hired most of the required personnel and begun to work on their related scientific questions. Some initial results are already presented in this report. Also within 2008 the granted projects from the third proposal call 2007-2 began their work, while older projects were ongoing, pushing the number of active cluster projects from 27 to 41. Subsequently in summer 2008 the fourth proposal call was issued. By the end of 2008 the Future Ocean funded 57 cluster proposals. Overall it can be stated, that the Future Ocean has initiated a tremendous array of large and small initiatives, creating a positive forward orientated spirit in Kiel's research landscape. It has sparked several spin-off projects, like the marine oxygen focussed SFB 754 and the CO_2 Sequestration project SUGAR, both supported by „The Future Ocean" with seed-money funding to develop the research proposals. The Future Ocean is guided by the underlying principle to provide the most effective service and infrastructure, to support marine science to develop a thorough understanding of the future of our oceans.

FUTURE OCEAN PARTNER PROJECTS IN KIEL

- SFB 574 - The Collaborative Research Center (Sonderforschungsbereich) SFB 574, funded by the German Research Foundation, investigates the pathways and fluxes of fluids and volatile components (carbon, sulfur, halogens, and water) through subduction zones. Major aims include the evaluation of processes controlling subduction recycling, the effects of these volatiles on the climate and the geochemical evolution of the hydrosphere and atmosphere, as well as origin and causes of natural hazards.

- SFB 754 - The Collaborative Research Center SFB 754 addresses „Climate-Biogeochemistry Interactions in the Tropical Ocean". Since spring 2008 it is in its first phase which lasts until 2011. The key research of the SFB 754 includes subsurface dissolved oxygen in the tropical ocean and its response to variability in ocean circulation and ventilation, the sensitivity and feedback mechanisms linking low or variable oxygen levels and key nutrient source and sink mechanisms in the benthos and the water column, and studies on the magnitudes and time scales of past, present and likely future variations in oceanic oxygen and nutrient levels on various spatial scales.

- SUGAR - In summer 2008, the SUGAR project (Submarine Gas Hydrate Reservoirs) was launched in Germany. The project aims to produce natural gas from marine methane hydrates and to sequester carbon dioxide (CO_2) from power plants and other industrial sources as CO_2-hydrate in marine sediments. The project has 30 institutional partners from academia and industries and is coordinated at the Kiel-based Leibniz Institute of Marine Sciences (IFM-GEOMAR).

- KEI – Kiel Earth Institute: Kiel Earth Institute (KEI) is a virtual institution designed to research key issues of global change and its socio-economical consequences. Globalisation of economic activities, the scarcity of natural resources, and a changing environment are challenges all modern societies have to face. The idea for KEI emerged from an intensive cooperation between the Leibniz Institute of Marine Sciences (IFM-GEOMAR) and the Kiel Institute for the World Economy (IfW) within the scope of the Cluster of Excellence „The Future Ocean". Bringing together research and decision-making for societal needs in the area of global change is the main task for KEI.

SUPPORTING KIEL MARINE SCIENCES

Attracting students to study marine sciences is one of the central goals of the Future Ocean. To promote this, a multi-level strategy is applied, addressing all levels of society from the general public, to the education in schools and offering events for children, to the active support of masters- and graduate students. In 2008 the general public was addressed through various events and public displays of marine research. This was sometimes done in conjunction with state government organized events like the annual German reunion day on October 3, but also through special exhibitions like the display in the International Maritime Museum in Hamburg and on scientific congresses like the American Geophysical Union's Fall (AGU) meeting in December 2007.

The Future Ocean successfully addressed schools and teachers directly by providing marine science practice boxes to schools in Schleswig-Holstein, to enable teachers to integrate this topic into their classes in a practical and demonstrative manner. This activity is complemented by the organization of the 2008 Children University on marine sciences in Kiel (page 58), offering public lectures targeted at for children aged 8-14 and 12-16. Overall these activities have been very successful so far. It was recognizable that the public did indeed identify itself with the themes of the Future Ocean, and local citizens are proud to hear that researchers in Kiel and Schleswig-Holstein are actively providing research to tackle many of the critical environmental questions ahead. Monitoring the press and public expressions it was also realized that Kiel is more and more recognized as the leading location for marine science in Germany, a circumstance that is intended and which the Future Ocean strives to expand on. Last but not least an important goal of the Future Ocean is, to establish Kiel Marine Sciences as a trademark for highest class marine research not only in Germany, but on a global level, a goal that we pursue within the upcoming years.

RESEARCH THEMES

The mission of the cluster of excellence is, to address the future ocean in its entirety with respect to climate, ecosystems, resources and hazards. To achieve this, the scientific structure has been designed as two major research themes, subdivided into research topics (Fig. 1). The research themes are titled „The Ocean in the Greenhouse World" and „Marine Resources and Risks". Both themes document the future oriented approach of the research, aiming to predict and advise rather than to document and explain what has happened. This notion is also intended to be the glue between the projects as predictions rather require a completely different view of the earth, than documenting the current or historic state. The research themes are supported by several platforms, installations of infrastructure which in principle are open for use by any scientific member of the Future Ocean.

THE OCEAN IN THE GREENHOUSE WORLD

The oceanic response to anthropogenic greenhouse gas emissions is investigated under the theme „The Ocean in the Greenhouse World". The combined oceanic response to this forcing is complex and includes large-scale changes in ecosystem structure and ocean circulation. The internal cycling of carbon, nutrients and oxygen within the ocean and physical exchange of greenhouse gas, heat, water and momentum across the air-sea and ocean-seafloor interfaces are also affected by anthropogenic greenhouse gas emissions and global climate change. Internal oceanic feedbacks may amplify the external anthropogenic forcing with largely unknown consequences for oceans, global climate, and human society. „The Ocean in the Greenhouse World" encompasses basic and applied research into these roles and responses of the oceans in the Greenhouse World. The overarching questions of this research theme are:

- What are the biological and chemical responses of the ocean to changing atmospheric composition?
- How do ocean circulation and the ocean ecosystem interact with altered radiative forcing?
- What is the ocean's capacity for current and future mitigation of atmospheric CO_2 increase?
- What are the implications of these changes to the marine system for human welfare and greenhouse gas management?

Seven research topics have been defined as projects. „Ocean Acidification" is establishing new linkages between expertise in marine biology and geochemistry and related physiological and biochemical expertise at Kiel. It is intended to improve the mechanistic understanding of the response of marine organisms to elevated CO_2 and decreased pH. Warming of intermediate-depth waters has the potential to drive major changes in seafloor processes, including accelerated decomposition of methane hydrates and as yet unknown effects on benthic ecosystems. The „Seafloor Warming" project addresses this issue by combining expertise in benthic ecology and geochemistry with new observational technologies. „Oceanic CO_2 Uptake" builds on expertise in ocean modeling, marine carbon observations and synthesis in a new partnership with research on advanced numerical techniques. The goal is to improve our ability to quantify the current and future anthropogenic CO_2 uptake of the ocean. The „Ocean Circulation" project takes advantage of the existing expertise in past ocean climate proxy research and uses ocean and climate models in order to reconcile observational records from past climates with dynamically consistent climate scenarios. In „Sea Surface Chemistry" physical chemical structures and interactions at and near the air-sea interface are studied, including reactions important for understanding the ocean's response to the changing composition of the surface ocean and troposphere. Here, new linkages between physical and theoretical chemistry and marine science are being established. The changes predicted for the future ocean by the described projects have considerable implications for human welfare. Ocean carbon sequestration (on-going or deliberate) is important for an evaluation of carbon abatement strategies and global carbon management accounting. The economic and human welfare implications of future ocean change are the focus of a project titled „Valuing the Ocean", which takes advantage of the existing economic expertise at IfW and the scientific insight provided by other parts of the Future Ocean. This project is strategically placed at the interface between basic scientific insight, quantitative assessment, and socio-economic understanding to produce evaluations of the human-dimension implications of future ocean change.

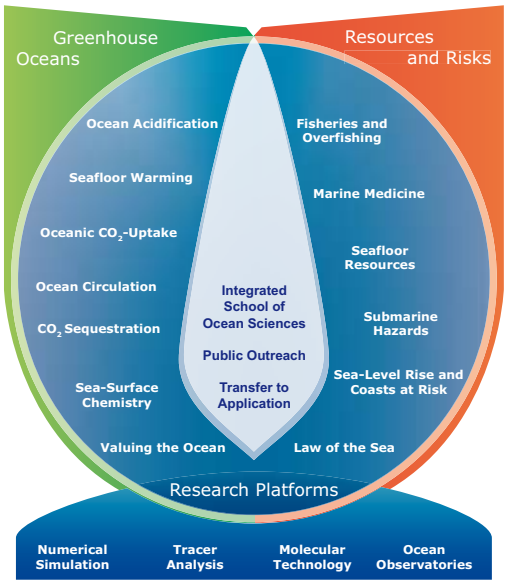


Figure 1 | Structure of the Cluster of Excellence „The Future Ocean" consisting of the research themes Greenhouse Ocean (green) and Resources and Risks (red), central services (light blue) and the infrastructure platforms (dark blue).

MARINE RESOURCES AND RISKS

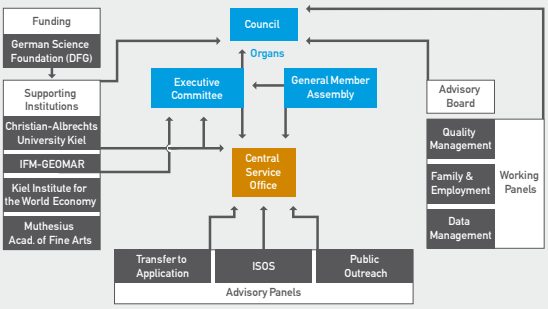
The second research theme of the Future Ocean deals with „Marine Resources and Risks". It focuses on the understanding and management of marine resources and the assessment of hazards. Oceans provide resources and services to mankind, such as fish and seafood, genetic resources for medical purposes, fossil fuels and minerals. However, the sea is also a source of hazards through tsunamis, storm surges and sea-level rise. These opportunities and risks pose several general questions:

- Which physical, chemical, biological, and geological mechanisms lead to the evolution of certain resources?
- What are the mechanisms that lead to marine hazards threatening coastal population?
- Are ocean organisms a model system for human diseases providing a new tool in medical research?
- How should ocean resources be managed in a sustainable manner and which institutional and legal frameworks are necessary for such endeavors?
- How can risks be assessed, how can damages from hazardous events be evaluated, and which countermeasures can be taken to mitigate these?

The „Fishery and Overfishing" project evaluates marine management with a special focus on multispecies interaction and the link between commercial species, non-commercial species, and the ecosystem. Marine life and fisheries are presently studied, but have not previously been linked to economic expertise. Building on this expertise, a research group was established to improve the management strategies of fish stocks and fisheries, incorporating economic, legal, and scientific aspects. Scientists from medical and natural sciences join in the „Marine Medicine" project to study marine organisms as model systems to gain a better understanding of the mechanisms triggering human diseases. The new JRG applies a genomics approach to investigate the evolution and function of orthologs to human susceptibility genes for barrier dysfunction in marine organisms from diverse phyla. This approach is possible because the genes causing barrier diseases have been conserved through evolution. As an ultimate goal, the knowledge required in the marine model organisms will be applied to develop novel therapeutic or preventive strategies for human barrier disorders. The study of the occurrence and formation of marine resources, such as gas hydrates and hydrothermal deposits, is an important focus of research in Kiel. Further expertise is needed in the area of fluid flow and coupled reactions, which are responsible for the formation of these deposits. This aspect is addressed by a modeling-oriented working group titled „Seafloor Resources" which serves as a link to existing research groups in this field. Despite growing concerns regarding submarine earthquakes, slumps and slides and their consequences, such as the triggering of tsunamis, marine seismology is not an established discipline in Germany. To close this gap, the „Submarine Hazards" research group was established, which addresses submarine hazards at continental margins. To strengthen the existing groups investigating sea-level change, coastal evolution and coastal zone management tasks, new expertise is needed to analyze physical-morphological changes in coastal seas and to develop new tools to assess the vulnerability and resilience of coastal zone communities. The socio-economic relevance of coastal change and risk assessment led to the establishment of two new research groups on „Sea-level Rise and Coastal Erosion" and „Risk Assessment in the Coastal Zone" covering these important fields. While the former concentrates on rapid physical and morphological changes at those coasts of the world being severely under stress by natural or anthropogenic impacts, the latter focuses on techniques to assess and evaluate risks and hazards in coastal areas under various stresses. Finally the „Law of the Sea" project strengthens the expertise in maritime law contributing to the development of new laws for the sustainable use of marine resources based on a sound understanding of the oceanic ecosystem. The link between the topics of „Marine Resources and Risks" is the focus on marine resources and risks for human society. Therefore, the economic and legal aspects bridge the six topics and create a unique scientific network being capable of developing innovative and comprehensive approaches in the investigation and management of marine resources and risks.

ORGANIZATION OF „THE FUTURE OCEAN"

The cluster's Executive Committee is responsible for the overall management of the cluster of excellence and is accountable to the Cluster Council and the General Assembly. It consists of the Chair, the Vice Chair, the two speakers of the research platforms and representatives from the research themes. The Council of the cluster of excellence gives advice to the Executive Committee on all strategic decisions, such as scientific priorities, yearly budget planning and monitoring criteria. The Council comprises the two leading proponents of each research topic and research platform, the leader of each JRG, the Presidents of Kiel University and Muthesius Academy of Fine Arts, the Directors of IFM-GEOMAR and IfW, as well as the Chair and Vice-Chair of the Executive Committee. An external Advisory Board acts as an independent quality-control and advice body to evaluate the progress of the project. It consists of ten leading scientists, both national and international, reflecting expertise of all cluster-relevant research fields. Additional members are appointed to evaluate the cluster's outreach to the general public, stake-holders and industries. The central service office provides necessary support for project management and monitoring activities. It also supports the public outreach and technology transfer activities and the Integrated School of Ocean Sciences (ISOS).



PROJECT STATISTICS

After little over two years, 2008 is the first year in the lifetime of the cluster of excellence where all working groups are completely staffed and running for the major part of the year. It can hence be assumed, that the current structure will more or less prevail for the upcoming project years. Although it is a little too early to compare performance data from several years, this is a good chance to take a look at some basic parameters of the Future Ocean project, which may give some indication for progress and performance. These parameters are staffing, funding, international networking through travel and visiting scientists, and publications.

PERSONNEL STRUCTURE

During 2008 the personnel structure of the Future Ocean has stabilized compared to the initial years. Staffing of the junior research groups and projects is complete. The Future Ocean experiences a significant but stable amount of fluctuation of employees due to new cluster projects being funded and at the same time projects expiring. Throughout 2008 the Future Ocean employed 120 people, 61 female, and 59 male. Some of them were not employed throughout the whole year 2008, but overall the Future Ocean maintains a basic personnel level of about 120 people. Scientific personnel falls into three main groups (Fig. 1):

- thirteen junior research group leaders (31% female)
- thirty-two post-doc scientists (38% female)
- fifty graduate students (58% female)

In addition technical and administrative personnel is employed, twenty-five people in total (64% female).

Overall the gender structure of the project quite accurately reflects the overall situation at the university. While there is an overall higher percentage of women at the graduate student level, the numbers decrease towards the post-doc and group leader levels. This is despite the cluster taking a number of measures for equal opportunity employment, to attract in particular qualified women into higher level positions. Among these are child-care facilities for children under three years and dual career options financed by the Future Ocean complemented by other measures undertaken by the university, which is itself is certified as a family friendly university. To evaluate and monitor activities in equal opportunity employment the Future Ocean maintains a panel dealing with related issues, collecting ideas and suggesting improvements where applicable. This makes us confident that the gender structure will change in the future reflecting effords towards an overall gender equality throughout the university and the marine sciences in Kiel.

BUDGET AND FUNDING

In 2007, when the Junior Research groups, the backbone of the Future Ocean, were just being formed, personnel costs have naturally been low, investments and expenses for equipment were comparatively high. In 2008, the level of expenses, personnel vs. material and administration has adjusted to the standard working level. In 2008 the projects running had access to first-class equipment through the technical platforms, they could pick from the most gifted scientists available and the Future Ocean supporting infrastructure strove to offer the best possible support available for any upcoming projects. The overall budget available was about 5.5M €.

The direct scientific costs fell into three major categories (Fig. 2):

- Junior Research Groups (2.56M €)
- Future Ocean Research projects (1.55M €)
- Technical platforms (0.15M €)

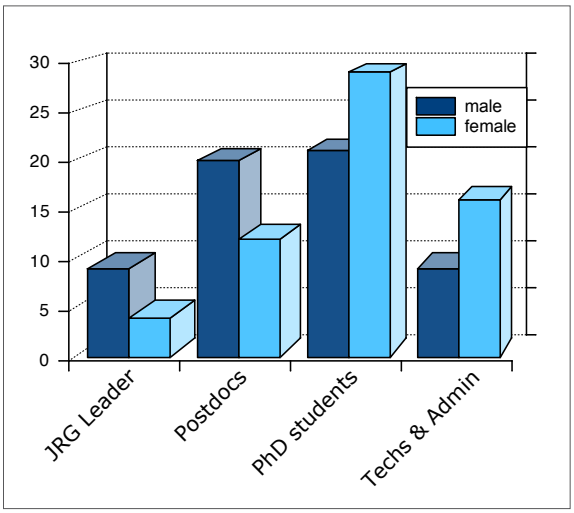


Figure 1 | Personnel structure of the Future Ocean in 2008.

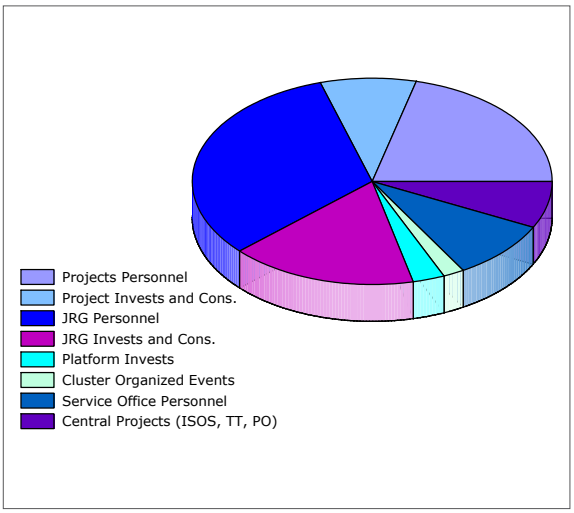


Figure 2 | Overview of cluster fund allocation.

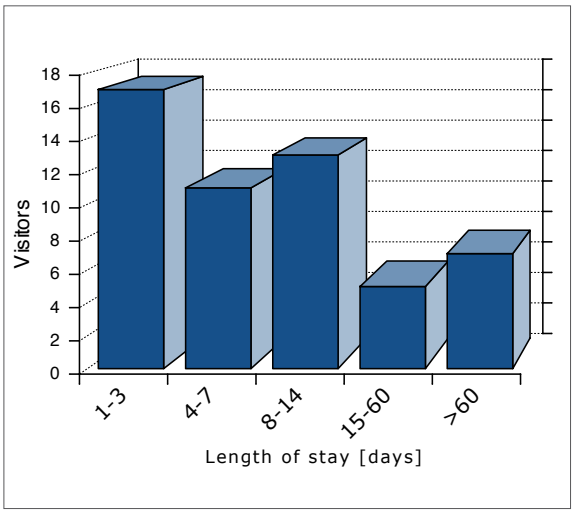


Figure 3 | Duration of visits from foreign colleagues.

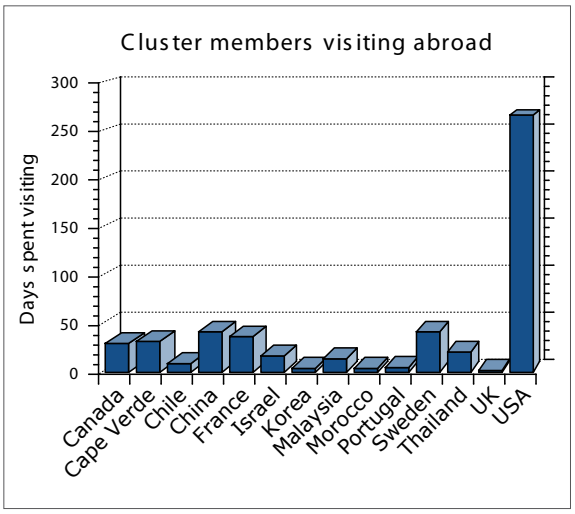


Figure 4 | Total days spent abroad for research visits by Future Ocean members and employees.

About 0.965M € were spent for miscellaneous structural and supporting expenses. These were i.e. project administration, public outreach activities, graduate education (Integrated School of Ocean Sciences), transfer-to-application projects, travel-, conference-, and visiting scientist support grants.

As some working groups were still built up within the first months of 2008, a significant amount of money was not spent within 2008. Therefore about 0.5M € were carried over into the FY 2009 budget with permission of the German Research Foundation (DFG).

INTERNATIONAL NETWORKING

Although the Future Ocean is a relatively new project, the ties into the international community in marine sciences are well established through the Leibniz Institute for Marine Science and the Christian-Albrechts-Universität zu Kiel. A simple measure of this is the amount of exchange that members and employees have with foreign scientists.

In 2008 the members of the Future Ocean had 53 scientific visitors in total. The term of their stay in Kiel is summarized in Fig. 3. Although about 50% of all visitors stay for a week or less, a significant number of colleagues stay for more extended research visits of two weeks or more.

Analysis of this data by country and visitor days shows, that the most intense collaboration exists with Israel, the USA, China and Russia. Overall the level of global collaboration is very divers and ties exist with over twenty different countries. Fig. 4 shows where Future Ocean members and employees went for research visits in 2008. Researchers spent time in twenty-two foreign countries. Most visits were at institutions in the USA, however, significant time was also spent in China, France and Sweden.

Overall these figures document, that the Future Ocean project is networking intensively within the global scientific community. The project is actively exchanging knowledge, experience and personnel with other institutions on a global level, an important prerequisite to deliver top level results in science.

PUBLICATIONS

Within the second year of the Future Ocean, simple publication statistics can be calculated on the Future Ocean relevant articles published. Overall cluster publications spanned the whole range of scientific journals, from geoscience to economic literature, from biogeochemistry to toxicology. Fig. 5 shows the numbers of articles for the eleven journals, Future Ocean researchers published most frequently in. Most of these are from earth science, geophysics, but also from Nature and Nature geoscience, illustrating the overall focus of the cluster of excellence on marine science. The statistics of the coming years wil show whether the focus wil stay within this field, or if the new research groups will shift the main publication venues towards a broader spectrum of journals.

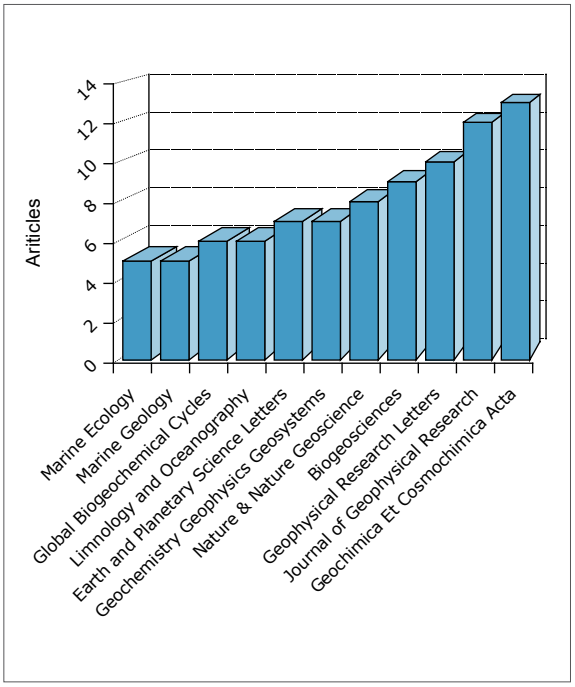


Figure 5 | The eleven most freqently used journals Future Ocean researchers published in in 2008.

THE RESEARCH

„Human beings, who are almost unique in having the ability to learn from the experience of others, are also remarkable for their apparent disinclination to do so.“

Douglas Adams

OCEAN ACIDIFICATION AND MARINE ANIMAL PHYSIOLOGY

The members of the ocean acidification group investigate basic mechanisms that contribute to marine animal sensitivity to future ocean acidification. Using ecological, physiological, biochemical and molecular biological methods, both, in laboratory and in field settings, they try to gain a cause and effect based understanding of crucial processes that define vulnerability to elevated seawater pCO_2. By comparing characteristics of more tolerant model groups like decapod crustaceans and cephalopods with those of more sensitive groups like echinoderms and bivalves they aim at identifying traits that promote sensitivity vs. tolerance. The current working hypothesis states that active animals with high metabolic rates evolved several traits as high ion-regulatory capacities, pH compensation mechanisms and tolerance of high blood / hemolymph / coelomic fluid pCO_2. These might make them less susceptible to future change in the ocean carbonate system than more hypo-metabolic taxa.

PROCESS AT VERY SLOW RATE

Anthropogenic emissions are changing the ocean's carbonate system speciation. By the year 2300, maximum decreases in surface ocean pH of up to 0.7 units (pCO_2 1900 µatm / 0.19 kPa) can be expected. Understanding the effects of these anticipated changes on marine animal performance/ fitness is difficult, as there obviously is much time to select for tolerant genotypes. Thus, the working group is following a dual strategy by carrying out (a) laboratory based CO_2 perturbation studies (days-months duration) to assess physiological responses and by simultaneously studying (b) physiological adaptations of animals exposed to naturally elevated seawater pCO_2 levels. Interestingly, a suitable naturally CO_2 enriched region could be identified in Kiel Fjord, with pCO_2 ranging between 1000-2000 µatm (0.1-0.2 kPa) during most of the year.

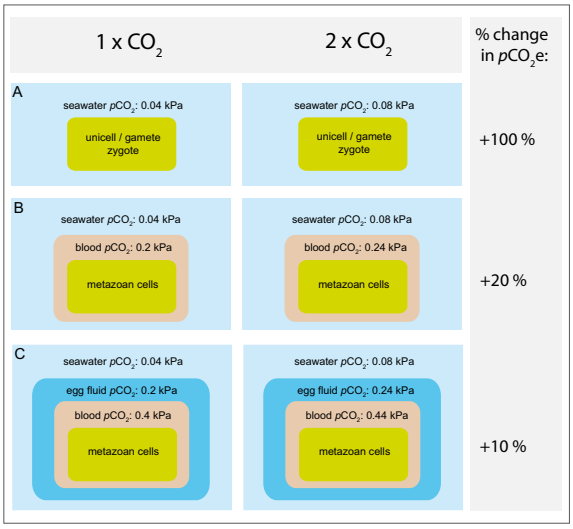


Figure 1 | Schematic illustration of changes in extracellular pCO_2 that a cell of a marine organism is encountering when ocean pCO_2 is increasing from 0.04 kPa (ca. 400 µatm) to 0.08 kPa (ca. 800 µatm). While unicellular organisms experience a 100% increase in pCO_2 (A), metazoan cells (B) and metazoan cells in eggs (C) experience less of a relative change in pCO_2. This might influence vulnerability to future changes in ocean pCO_2 (Melzner et al. in print).

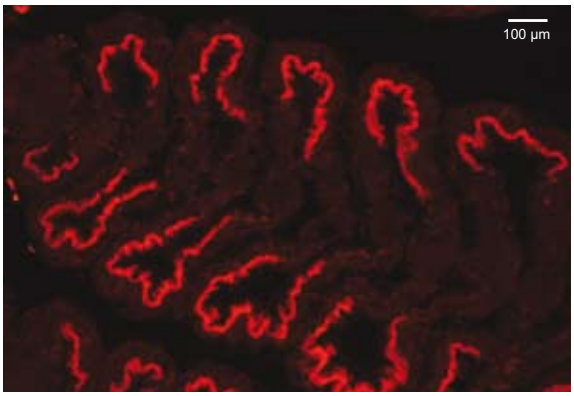


Figure 2 | High concentration of ion transporters in cephalopod gill epithelia – Na+/K+-ATPase, the motor of gill ion exchange, stained red with antibody and fluorescent dye (Hu, Charmantier, Melzner, in prep.).

TOLERANCE OF MARINE ANIMALS

In general, marine ectothermic metazoans with an extensive extracellular fluid volume may be less vulnerable to future acidification as their cells are already exposed to much higher pCO_2 values (0.1-0.4 kPa, 1000-4000 µatm) than those of unicellular organisms and gametes, for which the ocean (0.04 kPa, 400 µatm) is the extracellular space. A doubling in environmental pCO_2 therefore only represents a 10% change in extracellular pCO_2 in some marine teleosts (Fig. 1). High extracellular pCO_2 values are to some degree related to high metabolic rates, as diffusion gradients need to be high in order to excrete an amount of CO_2 that is directly proportional to the amount of CO_2 consumed. In active metazoans, such as teleost fish, cephalopods and many brachyuran crustaceans, exercise induced increases in metabolic rate require an efficient ion-regulatory machinery for CO_2 excretion and acid-base regulation, especially when anaerobic metabolism is involved and metabolic protons leak into the blood. These ion-transport systems, which are located in highly developed gill epithelia, form the basis for efficient compensation of pH disturbances during exposure to elevated environmental pCO_2 (Fig. 2).

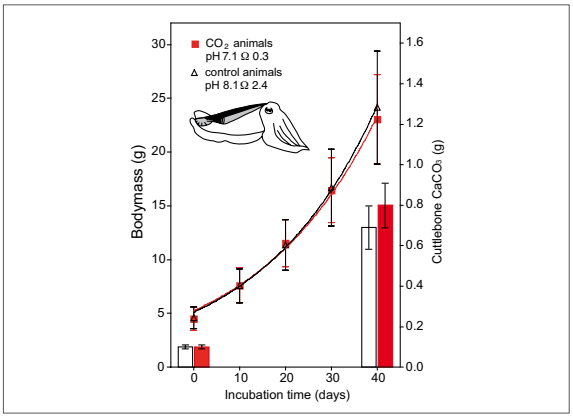


Figure 3 | Growth and calcification is not impaired by elevated seawater pCO_2. Animals grow exponentially during 40 day growth trials. Calcification (bars) even seems to be positively influenced by elevated seawater pCO_2 (Gutowska et al. 2008).

PH REGULATION, CALCIFICATION AND GROWTH

Work in 2008 mainly focused on the establishment of experimental- and animal holding facilities. In addition, important first experiments on acid-base and ion homeostasis, as well as on calcification were accomplished in the sea urchin *Strongylocentrotus droebachiensis*, the mussel *Mytilus edulis*, the sea star *Asterias rubens* and the cephalopod *Sepia officinalis*. Within these species, only the cephalopod is able to stabilize extracellular pH by means of rapid bicarbonate accretion. It also is the only one to maintain rates of metabolism, growth and calcification at seawater pCO_2 values of up to 0.6 kPa/6000 µatm (Fig. 3). In contrast, the sea urchin and the mussel suffer from decreased rates of calcification under similar conditions and are not (mussel) or only partly (sea urchin) able to control their extracellular pH (Fig. 4). Further work will mainly focus on biochemical and molecular biological mechanisms that are crucial for pH homeostasis and calcification.

EMBRYONIC-, LARVAL STAGE AND CO_2

While embryonic stages of some marine invertebrates with a prolonged embryonic development within egg capsules

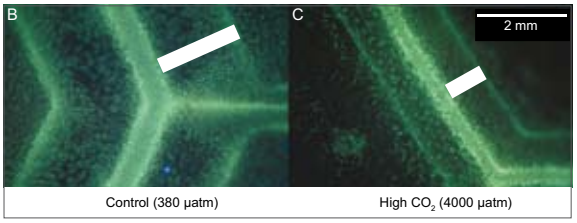


Figure 4 | Calcification in sea urchins (*S. droebachiensis*) is severely impaired by elevated seawater pCO_2. The sea urchin skeleton consists of numerous plates (A) that grow on their edges (B, C). Animals were marked with a fluorescent dye at the beginning of the experiment and after 54 days. The white boxes (B, C) indicate the newly formed shell portions (Syre, Stumpp, Melzner).

may be pre-adapted to coping with elevated pCO_2 values (they can encounter pCO_2 values of up to 4000 µatm in their egg fluid), pelagic larvae of many echinoderms have been shown to react very sensitive to moderately elevated seawater pCO_2. A decrease in pH by 0.4 units significantly reduces developmental speed and calcification rate in sea urchin (*S. droebachiensis* and *S. purpuratus*) larvae. Current activities in the ocean acidification group focus on the underlying molecular biological mechanisms that elicit these reductions in fitness.

COLLABORATIONS AND NETWORKS

The working group is collaborating with several other groups within the Cluster of Excellence „The Future Ocean", especially the marine medicine group (molecular biology, shared sequencing efforts), the ecology, geology and chemistry departments at IFM-GEOMAR, as well as the Institute of Physiology at Christian-Albrechts Universität zu Kiel. All work on echinoderm larval physiology and ecology is carried out in close collaboration with colleagues from the University of Göteborg, Sweden. Work on the characterization of ion-regulatory epithelia is performed in collaboration with Guy Charmantier's working group at the University of Montpellier, France. The research on ocean acidification is embedded into the European Project on Ocean Acidification (EPOCA) and national Biological Impacts of Ocean Acidification (BIOACID) projects.

WORKING GROUP

Martina Langenbuch, Rainer Kiko, Marian Y. Hu, Meike Stumpp, Agnes Heinemann, Frank Melzner, Jörn Thomsen, Julia Saphörster, Katja Trübenbach

SELECTED PUBLICATIONS

1 | Gutowska, M. A., Pörtner, H. O., and Melzner, F., (2008).
Growth and calcification in the cephalopod Sepia officinalis under elevated seawater pCO_2.
Mar. Ecol. Prog. Ser., 373, 303–309.

2 | Gutowska, M. A. and Melzner, F., (in print).
Abiotic conditions in cephalopod (Sepia officinalis) eggs: embryonic development at low pH and high pCO_2.
Mar. Biol., 156, 515–519.

3 | Melzner, F., Gutowska, M. A., Langenbuch, M., Dupont, S., Lucassen, M., Thorndyke, M.C., Bleich, M., Pörtner, H.O.
Physiological basis for high CO_2 tolerance in marine ectothermic animals: pre-adaptation through lifestyle and ontogeny?.
Biogeosciences Discussions, accepted ms.

WHAT HAPPENS WHEN THE GASHYDRATES ARE MELTING?

The global temperature rise affects gas hydrates in the Arctic Ocean. The Junior Research Group (JRG) „Seafloor Warming" investigates the consequences of temperature increases at the seafloor caused by global warming. One of our major topics is the potential destabilization of submarine gas hydrates in Arctic regions. In shallow Arctic shelf regions, hydrates are mainly stabilized by cold temperatures rather than by hydrostatic pressure. Here, only slight temperature increases could cause the destabilization of major hydrate reservoirs. Melting of gas hydrates could release large quantities of methane, a very potent greenhouse gas, into the atmosphere. Our research group aims at understanding the physical and biogeochemical processes that are connected with temperature-induced gas hydrate dissociation in marine sediments and to predict how much methane could be liberated.

MODELING GAS-HYDRATE DISSOCIATION

For the first time a one-dimensional reactive transport model was developed that considers multiple phases of methane (hydrate, gaseous and dissolved), heat transfer in each phase, and biogeochemical reactions in the sediment. In a first modeling approach we started with a sediment column, which had thickness of 100 m and contained initially only gas hydrates and sediment. Over the course of 100 years, temperature at the sediment-water interface was set to increase linearly by 3°C. Modeling revealed that heat transfer into the sediment will cause a steady temperature increase in the sediment column (Fig. 1A). After 20 years, gas hydrates situated below the sediment-water interface will start to dissociate (Fig. 1B). The melting process consumes heat and slows down seafloor warming. After 100 years, more than 30 m of the gas hydrates will be melted and large quantities of methane will be released (Fig. 1C). Half of the released methane will directly enter the hydrosphere in gaseous form (Fig. 1D). The rest of the methane remains in the sediment mostly as free gas. Only a minor fraction dissolves into the pore water and will be consumed by microorganisms. The model is a first theoretical attempt to simulate gas hydrate dissociation in sediments and will be modified for applications in natural systems.

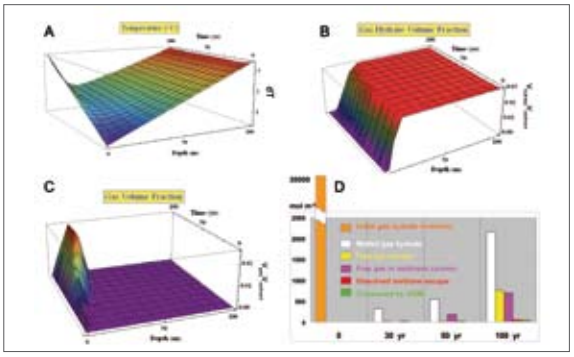


Figure 1 | Results of the gas-hydrate dissociation model. A-C: Changes in temperature, gas hydrate volume, and free gas volume over time and depth; D: Development of the gas hydrate inventory over time including free and dissolved gas as well as microbial consumption.

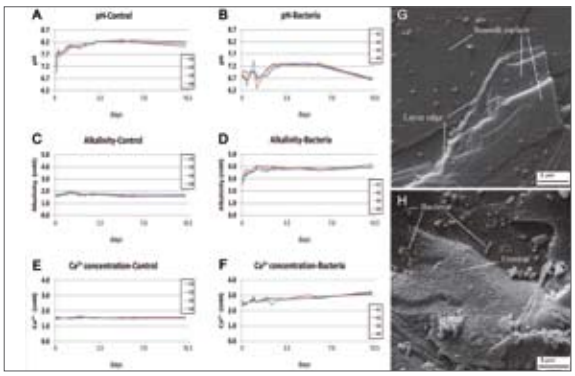


Figure 2 | Incubation of carbonate powder with methane and with (B, D, F, H) or without (A, C, E, G) aerobic methanotrophic bacteria. A, B: pH; C, D: alkalinity; E, F: calcium ions; G, H: surface of carbonate grains visualized by electron microscopy.

MICROORGANISMS AND CO_3 PRECIPITATION

When methane is released from dissociating gas hydrates it migrates through sediment and water towards the atmosphere. While traveling, dissolved parts of methane can be consumed by microorganisms. In anoxic sediments, a microbial process called anaerobic oxidation of methane (AOM) turns methane with sulfate into bicarbonate and sulfide. Bicarbonate usually precipitates as calcium carbonate – a long-term sink of methane. In the oxygenated water column a different group of microorganisms mediates aerobic oxidation of methane (MOx) by consuming methane with oxygen under the formation of carbon dioxide. The release of carbon dioxide causes a decrease in pH and could initiate carbonate dissolution. Our JRG investigates carbonate formation and dissolution processes connected to microbial methane consumption. Gained data will help to understand biogeochemical processes connected to gas hydrate dissociation. In a first attempt we focused on the effect of MOx on carbonate dissolution. Carbonate powder was added to seawater-solution with or without (controls) methanotrophic bacteria under a gas mixture of methane and air. Opposite to controls (Fig. 2A,C,E) treatments with bacteria revealed an increase in alkalinity (Fig. 2D) and Ca^{2+} ion concent-

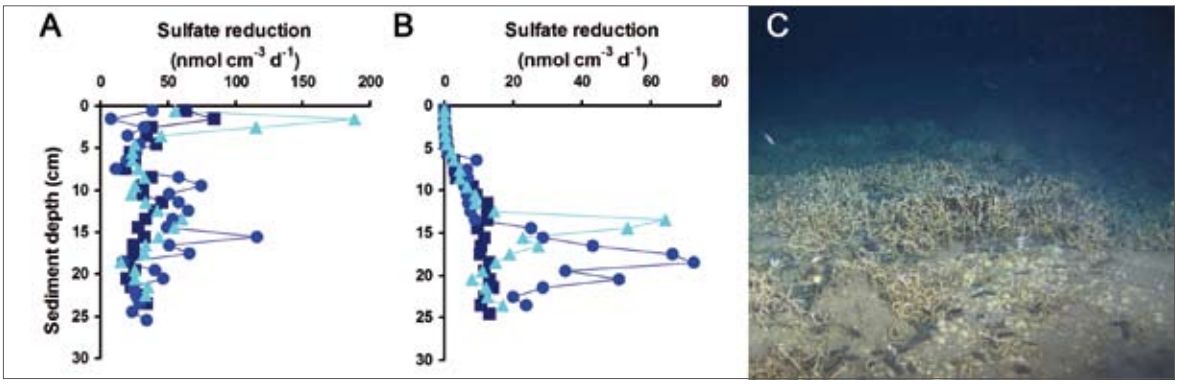


Figure 3 | Results from the North Alex Mud Volcano Expedition. A: Sulfate reduction coupled to methane oxidation (AOM) in the mud volcano center; B: Sulfate reduction in the vicinity of a tubeworm field; C: Picture of the tubeworm field with visible tubeworms, clams (white) and ray eggs (brown).

rations (Fig. 2F) - a result of carbonate dissolution in an acidified environment (Fig. 1B). Electron microscopic studies of carbonate powder exposed to bacteria revealed erosions on the crystal surface (Fig. 2H) compared to controls that remained unchanged (Fig. 2G), i.e. confirming carbonate dissolution via MOx. In a next step, a numerical model of methane-depended carbonate dissolution will be developed.

MUD VOLCANOES AND METHANE TRANSPORT

In November 2008 members of the JRG participated in an expedition to the North Alex mud volcano on the upper slope of the western Nile deep-sea fan in the Eastern Mediterranean (collaboration with the West-Nile-Delta Project). The mud volcano is characterized by an active seepage center transporting fluids and gases from deep subsurface sources to the sediment-water interface. Understanding at which rates microbes consume methane in the sediments of such active seeps will improve simulations of biogeochemical processes connected to gas hydrate dissociation. We sampled different locations between the center and rim of the mud volcano with ROV and multicorer and measured microbial methane consumption (AOM) in sediment cores. Highest rates (5-8 mmol m^{-2} d^{-1}, Fig. 3A) were found in the mud volcano center. High concentrations of hydrogen sulfide, a product of AOM, promoted chemosynthethic communities consisting of sulfur bacteria (*Beggiatoa spp.*) and symbiont bivalves (*Calyptogena* spp., *Acharax* spp). In the vicinity of the southern mud volcano rim a large tubeworm field (*Lamellibrachia* spp.) was discovered (Fig. 3C). The field was associated with authigenic carbonate precipitates and chemoautotrophic bivalves of the family Lucinidae. AOM rates were lower compared to the center (2-3 mmol m^{-2} d^{-1}) and increased with depth (Fig. 3B) indicating lower methane transport. Whole sediment cores taken from the different locations will later be connected to a sediment-flow-through system (an instrument developed within the SFB 574, B3), allowing the manipulation of methane flux and concentration of other solutes.

OUTLOOK: GAS HYDRATES IN THE BEAUFORT SEA

In September 2009 members of the JRG will participate in a research expedition with the US coast guard ice breaker *Polar Sea* to the Beaufort Sea to study the effect of temperature rises on the stability of gas hydrates. The cruise is organized by a consortium of international scientists, headed by Richard Coffin from the Naval Research Laboratory (USA). Field work will concentrate on biogeochemical analyses in sediment and water column.

WORKING GROUP

Lihua Liu, Hannah Weber, Julia Hommer, Dorothee Makarow, Johanna Schwers, Tina Treude
Missing: Stefan Krause, Phillip Steeb, Lars Bremer, Marion Liebetrau

SELECTED PUBLICATIONS

1 | Engelen, B., Ziegelmüller, K., Wolf, L., Köpke, B., Gittel, A., Treude, T., Nakagawa, S., Inagaki, F., Lever, M.A., Steinsbu, B.O. and Cypionka, H., (2008).
Fluids from the oceanic crust support microbial activities within the deep biosphere.
Geomicrobiology Journal, 25 (1), 56-66.

2 | Sommer, S., Linke, P., Pfannkuche, O., Treude, T. and Niemann, H.
Carbon flow through through a novel seep habitat dominated by dense beds of ampheretid polychaetes.
Marine Geology. doi:10.1016/j.margeo.2009.06.003.

3 |Treude, T., Smith, C.R., Wenzhöfer, F., Carney, E., Bernardino, A.F., Hannides, A.K., Krüger, M. and Boetius, A.
Biogeochemistry of a deep-sea whale fall: sulfate reduction, sulfide efflux and methanogenesis'.
Mar. Ecol. Prog. Ser. 382, 1-21.

CO_2 UPTAKE OCEANIC – OPTIMIZING BIOGEOCHEMICAL MODELS BY MATHEMATICS

The amount of CO_2 in the ocean is mainly determined by ocean currents and biogeochemical processes. The simulation of these processes is important to investigate the future behavior of the ocean as CO_2 buffer for the increasing emissions in the atmosphere. Models of CO_2 uptake consist of equations for different tracers such as nutrients, phyto- and zooplankton. These models use many parameters that are fitted to measurement data. For this purpose, methods of mathematical optimization and computer science are used. Main challenges are the huge computational effort to spin up 3-D models to steady seasonal cycles in order to optimize them, and the sparsity of the data. Among various different optimization techniques, the algorithmic generation of sensitivities, and Newton-like methods for the computation of states are used in the project.

THE ROLE OF CO_2 IN THE OCEAN

CO_2 is a main topic in the discussion about climate change and climate protection strategies. It is one of the main greenhouse gases, by holding back part of the radiation reflected from the earth's surface in the atmosphere. Thus, on one hand, CO_2 is responsible for the comfortable warm climate on earth allowing us to survive at all. On the other hand, the increase of CO_2 emissions in the last 200 years has caused a temperature rise with all well known consequences such as sea ice melting, changes in vegetation etc. Climate model simulations indicate that these effects, summarized as global warming, will continue and even become stronger.

Even though the atmospheric CO_2 is most discussed, its amount in the oceans is also very important. In fact, much more of this gas is dissolved in the oceans, and two thirds of the emitted CO_2 is taken up from the atmosphere via the sea surface. This effect thus mitigates the greenhouse effect, but, naturally also changes the chemical composition of the ocean water, leading e.g. to acidification. Moreover it is unclear how this mitigation property will change in the future due to global warming.

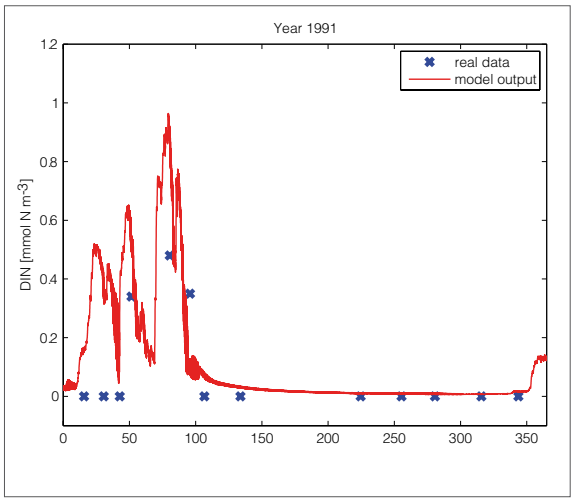


Figure 1 | This comparison of a NPZD model output (solid line) shows the sparsity of the data.

Figure 3 | Zooplankton (Image: MAR-ECO O. Paulsen GNUFDL).

MODELING THE CO_2 UPTAKE

The amount and distribution of CO_2 in the ocean is determined by the water circulation, by biochemical processes, namely the assimilation of CO_2 by phytoplankton (algae) and its mineralization by zooplankton (animals), and sedimentation. A well-accepted theory describes the relation of the amounts of CO_2 and nutrients that are converted to biomass by photosynthesis. Thus the CO_2 uptake is usually modeled in a system of transport (or advection-diffusion) equations for so-called tracers. One example is a model with the four tracers dissolved: inorganic nitrogen, phytoplankton, zooplankton, and detritus (NPZD model).

The coupling relations between the tracers in these models are more or less empirical, i.e. it is not clear what the coupling terms look like mathematically, and, moreover, how many tracers have to be taken into account. Many model parameters are used: They are chosen such that the model results remain feasible (i.e. tracer concentrations remain non-negative) and that given measurement data are matched by the model output.

PARAMETER OPTIMIZATION

The resulting problems belong to the mathematical disciplines of optimization, optimal control, and inverse problems: the aim is to minimize a least-squares type cost function, measuring the model misfit with respect to the data. The optimization variables are the unknown

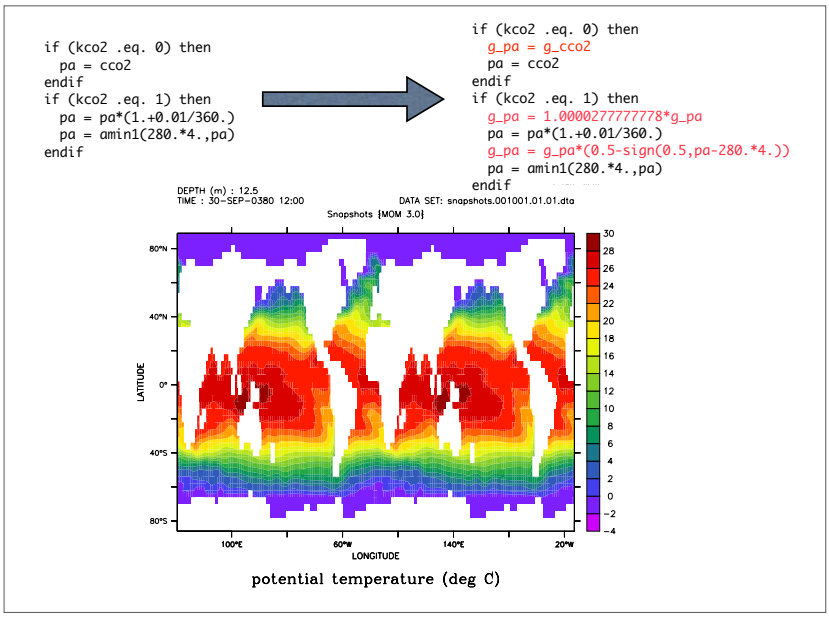


Figure 2 | Top: Transformation of model source code by Algorithmic Differentiation. Bottom: Typical ocean model output.

parameters in the nonlinear coupling terms in the system of tracer transport equations. They can be spatially and temporally constant or - in more sophisticated models - distributed functions. It is well known that this kind of problems are hard to tackle, even more since the models are high-dimensional, and the available data are not very dense with respect to space and time, and subject to uncertainty.

FAST SOLUTION ALGORITHMS

The mathematical algorithms used for parameter optimization work iteratively and require several model runs with different parameter values. Because it is necessary to run the models into a periodic state (corresponding to the annual cycle), the efficient computation of this so-called spin-up is crucial for a successful optimization. The often used technique to integrate the model in time until the periodic state is reached, is replaced in this project by a direct computation by a preconditioned Newton-Krylov method, a variant of the classical Newton method adapted to the huge amount of unknowns in global 3-D models.

SAND: SIMULTANEOUS ANALYSIS AND DESIGN

Another approach to deal with the huge computational effort when iterating the process cycle „model spin-up -> parameter update" was successfully applied to the Rahmstorf box model of the thermohaline circulation: the two iterations (simulation and optimization) are combined in the sense that a parameter (or model design) update is performed in every model iteration, and not only when the spin-up is complete.

FURTHER METHODS AND OUTLOOK

Linear-quadratic control theory is used to incorporate timely variant parameters. Linearizations of the full nonlinear models are obtained algorithmically by the method of automatic differentiation (AD), which has been applied to several biogeochemical models. This use of exact derivatives can be important since approximated gradients may destroy the convergence of the methods in some cases.

In this research field many models are in use, and some of them can be ordered hierarchically. Here the technique of space mapping or surrogate optimization is investigated. It aims at obtaining an optimal solution in an efficient way by optimizing with a cheap and simple model, while performing only some model runs with a more sophisticated and expensive one. The main immediate goal of the project is to extend some of the methods above to fully realistic 3-D biogeochemical models and to improve the used optimization methods.

WORKING GROUP

Thomas Slawig, Claudia Kratzenstein, Ines Niehaus, Mustapha El Jarbi, Malte Prieß, Johannes Rückelt

SELECTED PUBLICATIONS

1 | Kratzenstein, C., Slawig, T., (2008). One-shot Parameter Optimization in a Box Model of the North Atlantic Thermohaline Circulation. Preprint-Nr. SPP 1253-11-03.

2 | Rückelt, J., Bärwolff, G. and Slawig, T., (2008). An Alternating Approach for Optimal Control of a Pseudo-time Stepping Navier-Stokes Solver using Automatic Differentiation. Preprint-Nr.: SPP 1253-11-04.

3 | Neitzel, I., Prüfert, U. and Slawig, T., (in print). Strategies for Time-Dependent PDE Control With Inequality Constraints Using an Integrated Modeling and Simulation Environment Numerical Algorithms 50 (3) 241-269.

OCEAN CIRCULATION AND THE ATMOSPHERIC HYDROLOGICAL CYCLE: PAST, PRESENT, FUTURE

The Junior Research Group (JRG) „Ocean Circulation" located at the Institute of Geosciences, University of Kiel, investigates ocean circulation and the atmospheric hydrological cycle on time scales from the past over present into the future. Key activities are the combination of a coupled climate marine carbon cycle model with data from paleo climate reconstructions. The aim is to (1) test the flexibility of the climate model to reproduce climate conditions fundamentally different from today, and (2) to test the plausibility of paleoreconstructions derived from proxy records. A special focus is set on the climatic influence on marine organisms and their potential impact on paleoproxy reconstructions.

SIMULATING THE PAST

Paleomodeling provides a link between reconstructing the climate of the past and future climate prediction. Climate models, originally designed to simulate the present and future climate, play an important role in understanding mechanisms of the climate system, and their results are used for political decision making e.g. by the Intergovernmental Panel on Climate Change, IPCC. Validation of climate models by observations is restricted by the availability of data from instrumental records, which at maximum extends back over 150 years. For more reliable future climate predictions models should not only be able to reproduce the present day climate, but also internal variability and observed trends of climate change.

Marine sediments that accumulate at the sea floor consist of organic and inorganic detrital particles originating from the overlying water column, aeolian dust deposition and fluvial deposits from the continents. Such particles carry information of environmental conditions from their point of origin and time of deposition. Layer by layer, such proxy data can be used as climate archives from the past.

The JRG „Ocean Circulation" links model simulations and paleoreconstructions by the application of a complex prognostic climate model (KCMS) to climate conditions of the past. The aims are, on the one hand, to test the model's flexibility in representing climate conditions fundamentally different from today, and on the other hand, to test climate trends derived from proxy reconstructions against a physically consistent background as provided by the model (Fig. 1).

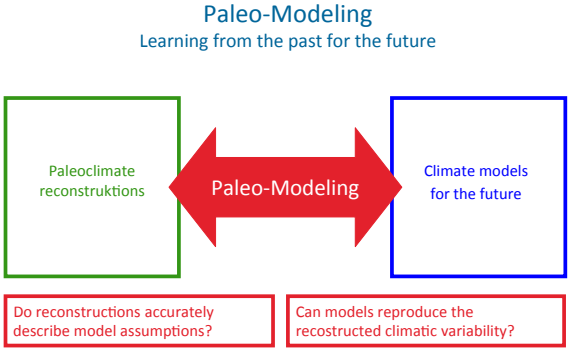


Figure 1 | The Junior Research Group's scientific approach.

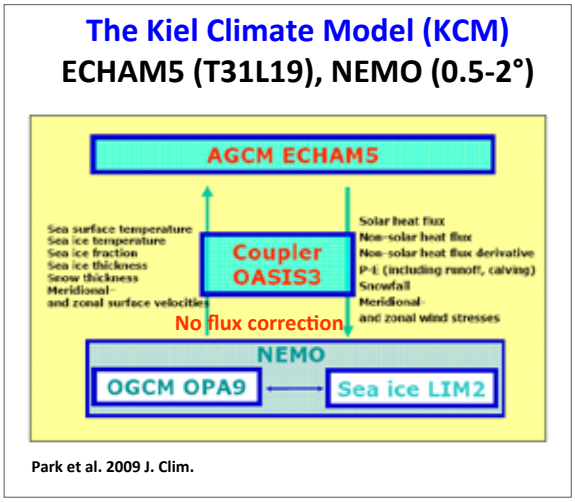


Figure 2 | Schematic diagram showing the components of the Kiel Climate Model System.

TESTING THE NEW KIEL CLIMATE MODEL

In order to assess the performance of the new coupled atmosphere ocean general circulation model KCMS (Fig. 2) for past climates, the model is adapted to boundary conditions of the present and last interglacial (Holocene: ≈ 0-10.000 yr BP; Eemian: ≈ 115.000-130.000 yr BP). The model has already been shown to reproduce a realistic present day ocean circulation, particularly in the tropical Pacific.

The application of boundary conditions from the Holocene and the Eemian is largely a sensitivity test of the model to changes in solar radiation, as induced by changes in the configuration of the orbital parameters eccentricity, obliquity and precession (Fig. 3). Six 1000-year long quasi steady-state simulations were performed for distinct time periods in the past. In particular, these are preindustrial (0 kyr BP), mid Holocene (6.000 yr BP), early Holocene (9.500 yr BP), late Eemian (115.000 yr BP) mid Eemian (122.000 yr BP), and early Eemian (126.000 yr BP). The Eemian often serves as an analogue for the Holocene as it experienced similar

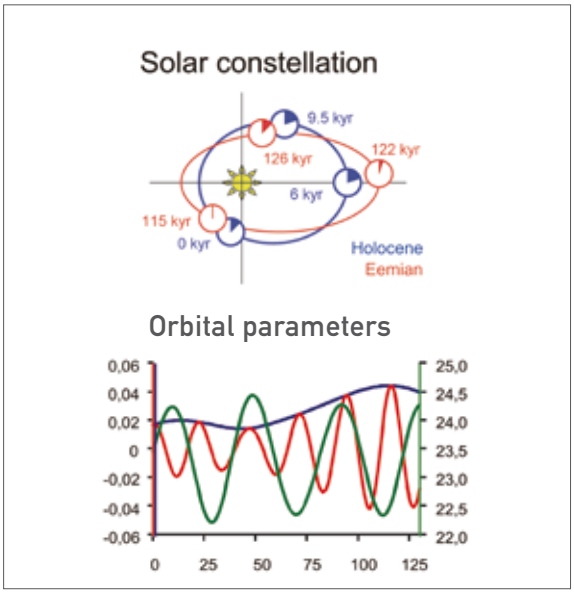


Figure 3 | Top: sketch of the orbital parameters for the different paleo time-slice simulations. Bottom: temporal variation of orbital parameters during the last 130 kyr: precession & eccentricity [°] (left scale), obliquity [°](right scale).

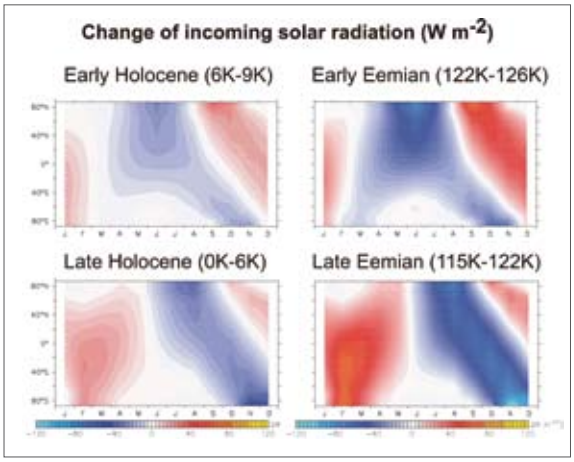


Figure 4 | Seasonal and latitudinal distribution of changes in the top of the atmosphere (TOA) incoming short wave radiation as resulting from the changes in the orbital configuration, red = positive anomaly (warming), blue = negative anomaly (cooling).

climatic conditions. Additionally, the trends in the orbital forcing over both periods have some similarities with a gradual decrease in obliquity and an increase in the precessional index (Fig. 3), although the Eemian has overall higher eccentricity and lower obliquity and the amplitude of insolation change is much more pronounced than during the Holocene (Fig. 4).

MODEL PERFORMANCE

The analysis of the very first model results has shown that the model response to changes in the orbital configuration is largely following obliquity forcing, with a slight cooling at high latitudes and a warming at low latitudes. This is also supported by data from paleoreconstructions based on alkenones. However, in some regions paleoreconstructions of sea surface temperature (SST) based on two different types of proxies (alkenones, Mg/Ca) give ambiguous results. With the help of the model results such discrepancies may be assigned to different sensitivities of the proxies to either annual mean or seasonal SSTs. In combination with modern data for SST and marine net primary productivity (NPP) we are able to highlight ocean areas where proxy records derived from marine phytoplankton are prone to be seasonally biased. Even more important is the discovery, that due to competition and interactions among different phytoplankton species, the same proxy may be biased differently in different regions.

El Niño Southern Oscillation (ENSO), one of the major modes of internal climate variability, is positively correlated with sea surface temperatures, particularly for the Western Tropical Pacific. Changes in precipitation patterns are in very good agreement with reconstructions from lake-level data, and the turnover time of atmospheric moisture is a function of the global mean temperature.

In a next step, a marine biogeochemical model will be included in order to investigate the climate impact on marine biological production and plankton dynamics, which has potential ramifications for the interpretation of marine proxy records.

WORKING GROUP

Birgit Schneider, Uta Krebs-Kanzow, Opeyemi R.S. Salau, Stefanie Maack, Vyacheslav Khon

SELECTED PUBLICATIONS

1 | Schneider, B., Bopp, L. and Gehlen, M., (2008). Assessing the sensitivity of modeled air-sea CO_2 exchange to the remineralization depth of particulate organic and inorganic carbon. Global Biogeochemical Cycles 22, doi:10.1029/2007GB003100.

2 | Schneider, B., Bopp, L., Gehlen, M., Segschneider, J., Frölicher, T.L., Cadule, P., Friedlingstein, P., Doney, S.C., Behrenfeld, M.J. and Joos, F., (2008). Climate-induced interannual variability of marine primary and export production in three global coupled climate carbon cycle models. Biogeosciences 5, S. 597–614.

3 | Gangstø, R., Gehlen, M., Schneider, B., Bopp, L., Aumont, O. and Joos, F., (2008). Modeling the marine aragonite cycle: changes under rising carbon dioxide and its role in shallow water CaCO3 dissolution in a biogeochemical ocean model. Biogeosciences 5, Nr. 4, S. 1057-1072.

PHYSICOCHEMICAL METHODS FOR OCEAN SURFACE RESEARCH

The biogeochemical coupling of the ocean and the atmosphere takes place at the air-sea interface and thus its characterization has to rely on a comprehensive understanding of these processes. In this context the group aims (1) to identify and study chemical structures and reactions at environmental interfaces, (2) to obtain a molecular level understanding of selected aspects by means of chemical kinetics and molecular modelling techniques, and (3) to provide modern optical detection instrumentation for marine research applications. A new laser laboratory has been set up providing sum-frequency generation spectroscopy (SFG) and cavity ringdown spectroscopy (CRDS). While SFG is used to investigate the organic nanolayer that is prevalent at the ocean surface and is known to play a significant role for air-sea gas exchange. CRDS is a valuable tool for gas phase detection as well as interface studies.

LOOKING INTO THE OCEAN NANOLAYER

The sea surface nanolayer represents a complex mixture of substances of biological and anthropogenic origin. Their properties as surface active agents determine the viscoelastic properties of the ocean surface and hence the gas exchange between ocean and atmosphere via wave formation dynamics. So far, detailed knowledge about nanolayer composition, dynamics, reactivity and molecular structure is scarce. The combination of sum-frequency generation spectroscopy (SFG) as a surface-sensitive tool and experiments on simple model systems as well as field samples provide novel insights into the properties of these films.

SFG spectroscopy is a second-order non-linear optical technique. The superposition of two short intense laser pulses at a surface generates a third background-free SFG beam. SFG is surface specific (only molecules located directly at the interface are measured), species selective (similar to IR spectroscopy, vibrational spectra are measured), and also orientation selective (due to the polarization dependence of the SFG signal). In a high purity water spectrum (Fig. 1a), the broad band centred at 3300 cm^{-1} corresponds to OH vibrations of the H-bond molecular network of interfacial water. Solvation of ions disturbs this network and result in lower SFG intensities. The narrow peak at 3700 cm^{-1} can be assigned to the stretch vibration of the free OH dangling bond at the water surface. As can be expected from simple reasoning and as it is illustrated in Fig 1b, with surfactant layers present at the air-water interface, these OH bonds are buried and disappear for higher film coverages. Next to the OH vibrations, the organic nanolayer also gives rise to strong signals in the CH stretch vibration spectral range. Most of the signals can be attributed to vibrations related to CH_3 and CH_2 groups of alkyl chains. Note that we also found indications for polysaccharides, which are commonly found in surface waters during phytoplankton blooms and – due to attached hydrophobic moieties – are expected to be at least weakly surface active.

Much work remains to be done in order to fully assess the analytic potential of SFG with regard to surface characterization of natural films. Currently, we continue to take time-series data in order to reveal seasonal trends of nanolayer abundance and composition. Moreover, laboratory work is focused on the investigation of structural properties of liquid-air interfaces of saccharide solutions and on the chemical reactivity of organic nanolayers. The latter can be studied by taking time-dependent spectra of surface composition while treating the sample with oxidizing gas phase compounds such as ozone.

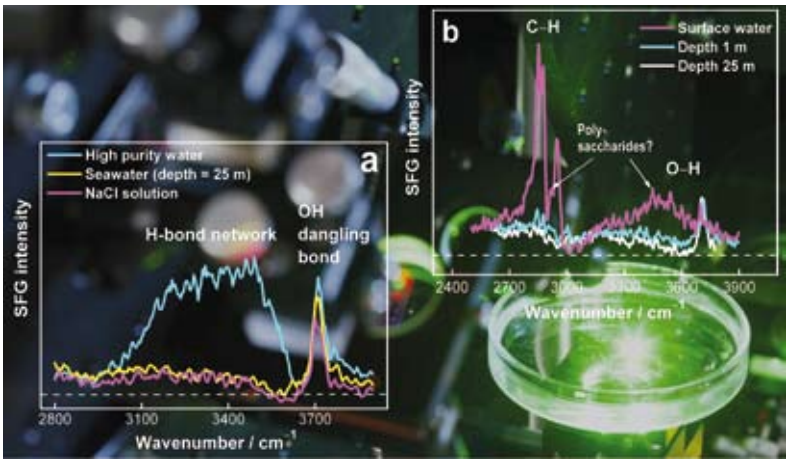


Figure 1 | Sum-frequency generation spectroscopy (SFG) sheds light on organic nanolayers. Example spectra: (a) high purity water, salt water and sea water without nanolayer present and (b) water from the Western Baltic Sea with organic nanolayer present.

ULTRASENSITIVE ABSORPTION SPECTROSCOPY

Cavity ringdown spectroscopy (CRDS) is an ultrasensitive detection method for molecular absorption. The high detection sensitivity is primarily based on a long absorption path length (>10 km) arising from a multiple reflection of a laser beam in a resonant optical cavity. We have designed a new modular spectrometer, which is based

on a continuous wave (cw) near-infrared (NIR) tunable diode laser light source (cw-NIR-CRD spectrometer) operating in the wavelength range λ = 1625 – 1690 nm. This wavelength range is especially well suited for trace gas detection in marine environments. In its gas phase detection configuration, the spectrometer can be used to detect several atmospherically relevant gas phase species such as CO_2, CH_4, N_2O and – due to CH-overtone vibrations – many halogenated hydrocarbons, which show strong absorption compared to the inevitable water background absorption. The spectrometer can be also operated in a surface sensitive mode by placing a specially designed quartz prism within the optical ringdown cavity (Fig. 2). Here, the so-called evanescent wave, which is formed upon total internal reflection of the laser beam, is used to measure absorption arising from molecules adsorbed at the reflecting surface. Since hydrophilic quartz surfaces are typically covered with water (wet quartz surfaces), they represent a suitable model system for environmental gas-solid interaction studies.

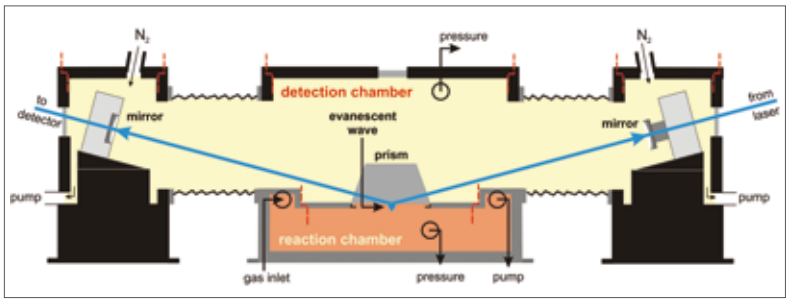


Figure 2 | Surface sensitive evanescent wave cavity ringdown spectroscopy: Reactor design.

OPTICAL ISOTOPEC RATIO MEASUREMENTS

Seasonal time-series of dissolved inorganic carbon (DIC) and its isotopic composition allow separation of physical and biological processes important for the surface layer carbon budget. In a joint project together with the marine chemistry department at the Leibniz Institute for Marine Sciences in Kiel and CONTROS GmbH we have started to characterize a commercial CRD analyzer for $\delta^{13}C$ isotopec ratio measurements of surface water CO_2. For example the analyzer was coupled to a conventional water/air equilibrator test setup and pH jumps were generated by adding acid or bases to a 130 L water tank. A full kinetic model of the carbonate system and the gas-equilibration processes reproduced the measured pCO_2 and $\delta^{13}CO_2$ signals, however, allowance had to be made for moderate air exchange with the laboratory environment. Excellent long-term stability and precision ($\delta^{13}CO_2$ < 0.1‰) of the instrument illustrates the potential of CRDS to complement conventional isotopic ratio mass spectrometry – in particular for in situ field studies.

FLUORESCENCE BASED BIOFILM DETECTION

In the sea, all submerged non-living (biofouling) and living surfaces (microepibiosis) are rapidly colonized by bacteria and unicellular alga. Being able to study biofilm formation dynamics with fine temporal and spatial resolution would help to unravel the underlying complex mechanisms. In cooperation with the marine ecology department of the Leibniz Institute for Marine Sciences in Kiel, a prototype submersible sensor head for quantitative detection of biomass has been developed (Fig. 3). Here, the output of a novel narrow-bandwidth UV-LED excites tryptophan fluorescence, which is efficiently collected by a bunch of optical fibres. The compact sensor has already been demonstrated to yield linear response for a dilution series of a bacteria suspension.

Figure 3 | Prototype of fluorescence based biofilm sensor head.

WORKING GROUP

Gernot Friedrichs, Johannes Dammeier, Carsten Fehling, Matthias Fischer, Joscha Kleber, Julia Bock, Kristian Laß

SELECTED PUBLICATIONS

1 | Friedrichs, G., (2008).
Review papers: Sensitive Absorption Methods for Quantitative Gas Phase Kinetic Measurements. Part1: Frequency Modulation Spectroscopy, Part 2: Cavity Ringdown Spectroscopy.
Z. Phys. Chem. 222, 1-61.

2 | Fehling, C. and Friedrichs, G., (2008).
Near-Infrared Cavity Ringdown Spectroscopy: From the Gas Phase to the Interface.
Bunsentagung Saarbrücken, Germany, May 2008

3 | Friedrichs, G., (2008).
CRDS and SFG based Concepts for Studying Coupled Gas Phase/Water Surface Kinetics with Applications in Ocean Surface and Aerosol Chemistry.
20th Symp. (Int.) on Gas Kinetics, Manchester, UK, July 2008.

VALUING THE OCEAN: THE ECONOMIC IMPACT OF OCEAN ACIDIFICATION ON CORAL REEFS

„Valuing the Ocean" aims at the economic role of the ocean in the carbon cycle and possible consequences for greenhouse gas management as well as climate change abatement and mitigation strategies. A slow-down of the oceanic pump would impose additional global costs in meeting a global greenhouse gas reduction target as more greenhouse gases remain in the atmosphere. Economic analyses of climate change mitigation strategies include the assessment of novel energy technologies such as carbon capture and storage as well as ocean fertilization. Another line of research is related to impact assessment. Economic consequences of ocean acidification are generally not considered in assessments of climate change. In this report details of a study estimating the economic impact of ocean acidification on coral reefs are provided.

IMPLICATIONS OF OCEAN ACIDIFICATION

Human activity is increasing the concentration of carbon dioxide in the atmosphere and in the ocean. In the atmosphere, carbon dioxide is a greenhouse gas causing climate change. In the ocean, carbon dioxide is an acid causing ecosystem change. While research on aspects of climate change has generated an enormous number of studies over the last few years, ocean acidification (OA) has only recently been recognised as a problem. Impact studies are still rare and estimates of the economic impact are absent. In our new publication (Brander et. al, 2009) we estimate the economic impact of OA on coral reefs which are generally considered to be economically as well as ecologically important ecosystems. It is a first step towards filling an important gap in the literature on the valuation of the impact of climate change and has serious implications for the type of policy interventions required.

For several reasons, OA has serious implications for the type of policy interventions required to control climate change. First, since OA is exclusively driven by carbon dioxide, as opposed to climate change which is also caused by other greenhouse gases, the additional cost associated with carbon dioxide emissions due to OA changes the trade-offs between the reductions of greenhouse gases. Second, the absorption of carbon dioxide by the oceans and the impact of OA occur over a short time scale, whereas the warming of the atmosphere substantially lags behind the build-up of greenhouse gases in the atmosphere. This changes the dynamics of optimal emission control. Third, the consideration of OA also has implications for the choice of policy instrument for the control of climate change. Climate change may be countered by geoengineering, but OA would continue unabated and may even accelerate if sulphur particles are used to cool the planet. Therefore, valuing the impact of OA will not only increase the estimates of the Pigouvian tax required to achieve efficient greenhouse gas emissions abatement, but it will affect other trade-offs and policies as well.

Ocean acidification has a range of impacts on biological systems. It will change the competition between marine plankton species in favour of those that rely less on calcium, it will negatively affect shellfish, it will impact on fish, it may benefit highly invasive non-native algal species, and it will reduce coral calcification. While the initial impact of OA is relatively clear, the eventual impact depends on the complex interaction of many species. The estimation of resulting changes in economic values, which generally derive from the higher trophic levels (e.g., top predator fish, marine mammals, sea birds), is therefore also pervaded by uncer-

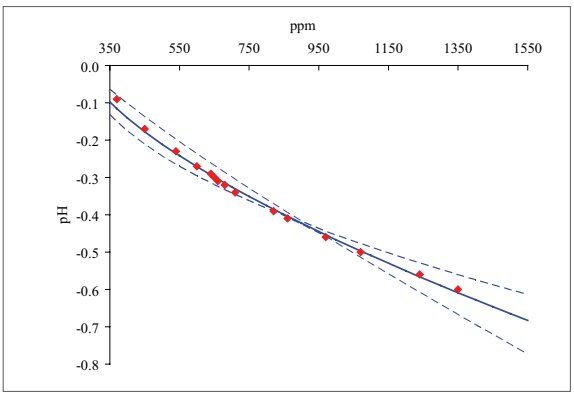


Figure 1 | Ocean acidity as a function of the atmospheric concentration of carbon dioxide as modeled by Caldeira and Wickett (2005) (red squares) and as approximated by Equation (1) (thick blue line; the 67% confidence interval is given the dashed blue lines).

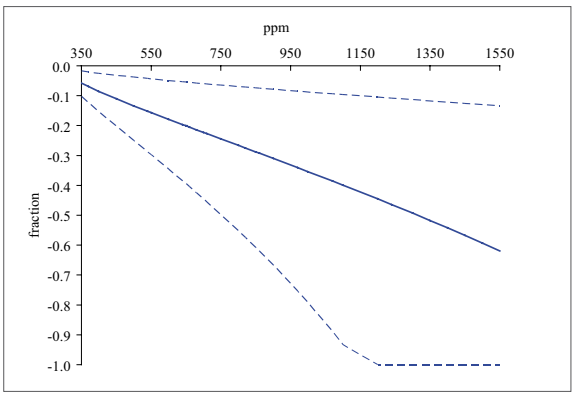


Figure 2 | Coral reef area as a function of the atmospheric concentration of carbon dioxide as according to Equations (1) and (2). The dotted lines are the 67% confidence interval.

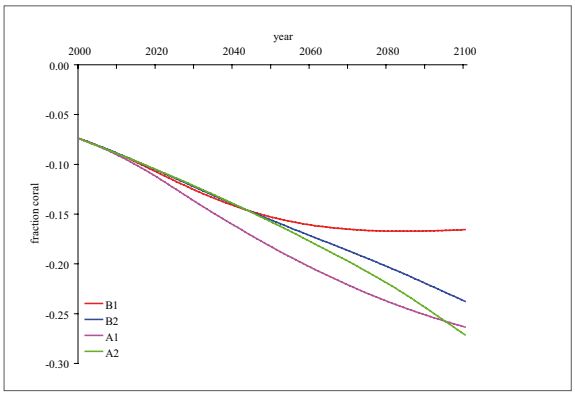


Figure 3 | The change in coral reef area according to the four SRES marker scenarios.

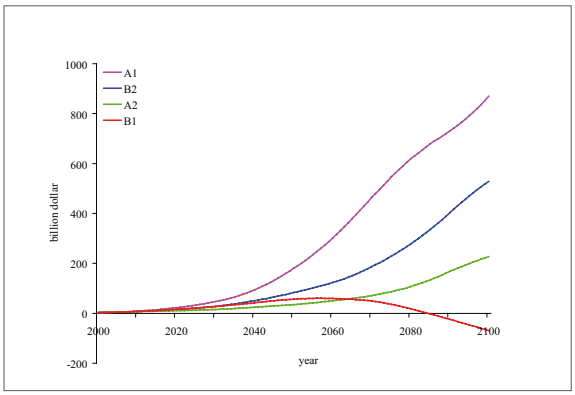


Figure 4 | The annual economic damage of ocean-acidification-induced coral reef area loss.

tainty. Coral reefs are an exception in that the impact of OA is relatively well understood and they have a range of direct and indirect use values for humans (e.g., coastal protection, fisheries, recreation, and amenity). It is for these reasons that our analysis is limited to assessing the economic impact of OA on coral reefs.

MODELLING OCEAN ACIDIFICATION VS. REEF AREA

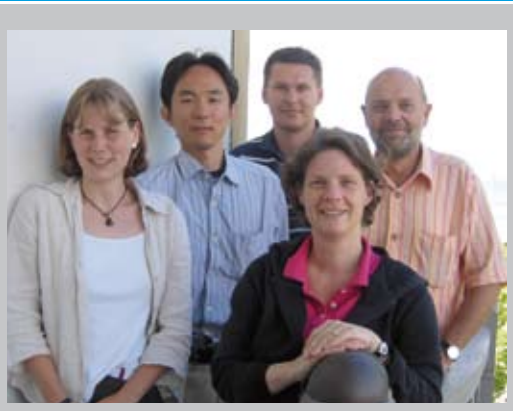
In our analysis we construct and calibrate simple models of OA and coral reef area loss, driven by the atmospheric concentration of carbon dioxide (Fig. 1 and 2). We extend an earlier meta-analysis of coral reef values to estimate a value transfer function for coral reefs, and apply an existing model of tourist numbers. The integrated assessment model FUND is used to estimate CO_2 emissions for the four Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES). Combining these models, we derive a number of scenarios of the annual impact of ocean-acidification-induced coral reef loss, and conduct a sensitivity analysis.

Assuming a conservative value of \$100,000/km^2/yr, the global economic value associated with reefs is in the order of \$30 billion/yr. Since OA is expected to impact a major part of these reefs within this century, it is plausible that the loss of coral reefs will amount to tens of billions of dollars loss per year. We find that the annual economic impact rapidly escalates over time (Fig. 3 and 4), essentially because the scenarios have rapid economic growth in the relevant countries and coral reefs are a luxury good. We estimate the economic value of damage to coral reefs from OA and find losses in the order of 0.18% of global GDP in 2100. This is one order of magnitude smaller than the estimated impact of climate change but still represents a substantial economic loss. Further research is required to refine these damage estimates and to extend the scope of analysis beyond coral reefs to other potentially impacted marine resources.

OUTLOOK

Next to analyses on consequences of ocean acidification, members of the project will continue investigating climate change mitigation strategies related to the ocean's role in the carbon cycle. This includes assessments of carbon capture with respect to, for example, different leakage rates and emissions allowance trading. In close collaboration with members of „Ocean Surface Chemistry" group and the „Law of the Sea" and „Living Resources" groups we will continue our analyses on economic aspects of ocean fertilization.

WORKING GROUP



Sonja Peterson, Daiju Narita, Thomas S. Lontzek, Katrin Rehdanz, Gernot Klepper

SELECTED PUBLICATIONS

1 | Brander, L., Rehdanz, K., Tol, R., van Beukering, P., (2009).
The Economic Impact of Ocean Acidification on Coral Reefs.
ESRI Working Paper, 282, Economic and Social Research Institute, Dublin.

2 | Narita, D., (2008).
The Use of CCS in Global Carbon Management: Simulation with the DICE Model.
Kiel Working Paper, 1440, Kiel Institute for the World Economy, Kiel.

SUSTAINABLE FISHERIES

Three quarters of all marine fish stocks worldwide are deemed fully exploited or overfished. Researchers expect that more stocks will collapse unless fisheries management and policy change substantially. The Junior Research Group aims at developing improved management strategies that promote a sustainable fishery. For this sake true interdisciplinary research is needed, taking into account both ecological and economic processes which are integrated into ecological-economic models. In 2008, specific models have been developed in order to study what role consumers' preferences for food fish diversity play for the potential collapse of fish stocks and to study fishery management using marine protected areas.

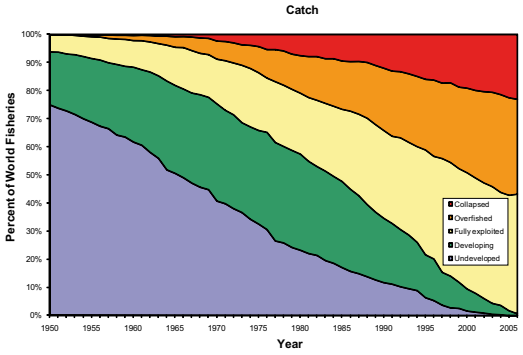


Figure 1 | Trends in the status of the world fisheries as reflected in FAO Production Data 1950-2007. In 2007, more than half of the stocks fished world-wide are overfished or collapsed (R. Froese).

FROM OVERFISHING TO SUSTAINABLE FISHERIES

The problem of overfishing has two aspects: firstly, overfishing means that, in the long run, fish stocks and fishing yields are lower than they could be. Secondly, overfishing leads to a loss of marine biodiversity, as more and more fish stocks are fished to collapse on a world-wide scale (Fig. 1), which means that even with very high fishing effort little fish can be caught from these stocks. Under better management the oceans could contribute much more to human food supply and generate much higher profits for fishermen than they presently do. The World Bank estimates in a report published in 2008 that, with better management, marine fisheries worldwide could generate a sustainable, additional benefit of roughly 50 billion US $ annually, which is substantial compared to 80-90 billion US $ total revenues from marine capture fisheries at present (according to estimates of the Food and Agriculture Organization of the United Nations (FAO)). The Junior Research Group (JRG) aims at developing novel fishery management concepts that promote a sustainable fishery. That means, stocks do not collapse and long-term yields increase to the benefit of the fishing business. Such improved management strategies require taking into account the whole fishery system including the relevant ecological and economic processes and interrelationships (Fig. 1). The methodical approach lies in the integrated interdisciplinary collaboration of marine ecologists and resource economics (Fig. 2). This is new, as the different aspects of the problem so far have predominantly been considered in isolation. New mathematical models are developed, which incorporate both, the ecological and economical interrelationships. Further relevant relationships are investigated in collaboration with other JRGs of the cluster of excellence. The problems studied in this group are continuously discussed with fishermen, politicians and representatives from non-governmental organisations. This transdisciplinary dialogue with stakeholders is crucial in order to develop management strategies suitable for practical implementation.

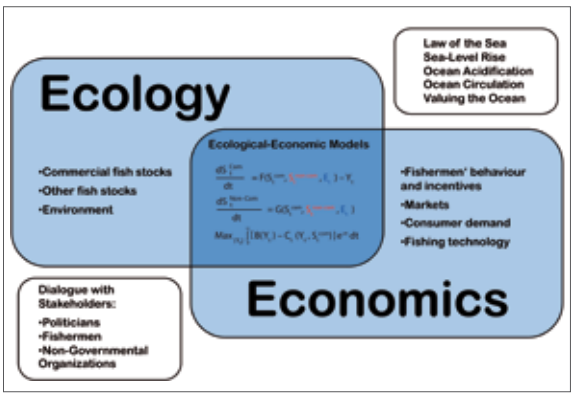


Figure 2 | Conceptual diagram on interdisciplinary ecological-economic research (M. Quaas, J. Schmidt, R. Voss).

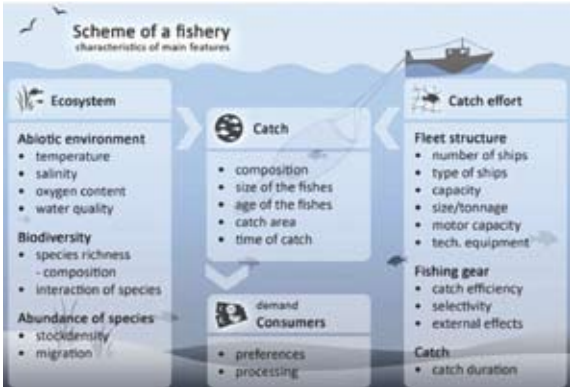


Figure 3 | Main features in analyzing a fishery (M. Bollmann, M. Quaas, J. Schmidt, R. Voss).

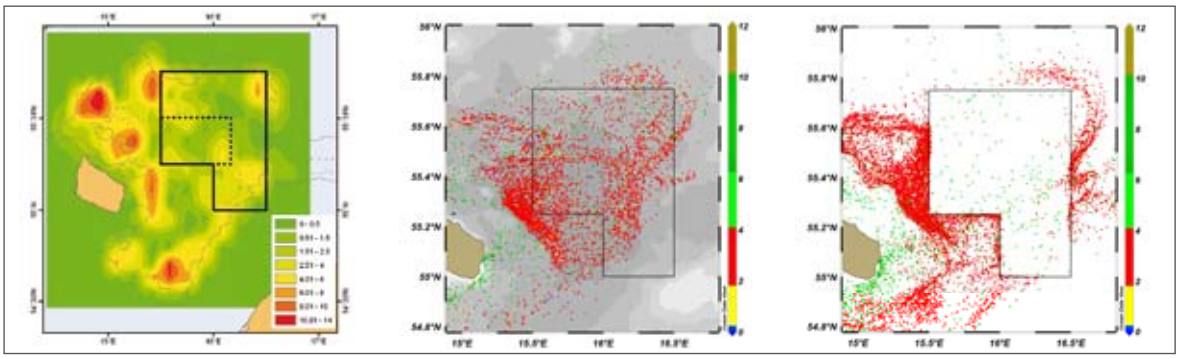


Figure 5 | Baltic cod Marine Protected Area. Origin of successful survivors (left; red areas); distribution of fishing effort before (middle panel) and after enforcement of the MPA (right). Color scale gives ship speed in knots, red points indicate trawling boats. Data according to B. Huwer, DTU-Aqua, Denmark & U. Böttcher, vTI-Rostock, Germany.

FOOD FISH DIVERSITY AND COLLAPSE OF STOCKS

How overfishing leads to inefficiently low stocks and yields has been extensively studied, and the fundamental principles are well understood. The second aspect, that overfishing leads to the collapse of more and more fish stocks (Fig. 3), has been recognized more recently and has become a focus of scientific interest and public concern in the last years. With a new bio-economic model of a multi-species fishery we have analyzed both aspects of overfishing. We have shown that consumer's preferences for food fish diversity may explain the cascading collapse of fish stocks in an unregulated fishery. In particular, our simulation experiments show that the depletion of one fish stock may lead to the collapse of other fish stocks with previously healthy stock sizes (Fig. 4). The economic reason is that consumers with strong preferences for food fish diversity have a high demand also for rare fish species with low stocks and yields, which makes it profitable to fish these stocks to collapse.

FISHERY MANAGEMENT USING MPAs

Marine protected areas (MPAs) can act as important tools in fishery management, as they are easy to implement and easy to control. They have proven to be effective in habitat preservation (e.g. coral reefs), but their value in economic terms and for management of mobile species is still under discussion. In the case of the Eastern Baltic cod stock, a MPA has been enforced in the central Bornholm Deep, the main spawning ground of cod, during the last years. Recent biological research, however, has shown that successful survivors are mainly originating from the slope areas outside the present extent of the MPA. Introduction of the MPA actually increased fishing mortality on these especially valuable spawning grounds, as effort was re-allocated to areas outside the MPA (Fig. 5). Inadequate formulation of MPAs, e.g. not accounting for biological and economic details, might therefore in some cases even be counterproductive.

INTEGRATING ECOLOGY AND ECONOMICS

Since early 2009 the JRG consists of five resource economists (one Juniorprofessor and four PhD students) and two fisheries ecologists (two Postdocs). In 2009 the collaboration between ecologists and economists will be deepened further in order to develop sensible management strategies for sustainable fisheries. Specific issues that will be addressed in 2009 include the modeling of age-structured fish populations, multi-species interactions in marine ecosystems, and spatial fisheries management.

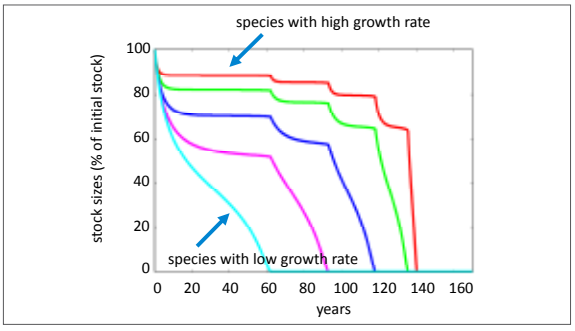


Figure 4 | Simulated stock sizes in a hypothetical multi-species fishery without management. After 60 years of fishing, the least resilient stock collapses, while others remain seemingly stable. After another 30 years the next stock collapses, and so forth. Ultimately all stocks collapse in this example. (M. Quaas, T. Requate).

WORKING GROUP

Martin Quaas, Rudi Voss, Jörn Schmidt, Ute Kapaun, Kirsten Ruckes, Frederik Noack, Max Stöven

SELECTED PUBLICATIONS

1 | Baumgärtner, S., Becker, C., Frank, K., Müller, B. and Quaas, M. F., (2008).
Relating the philosophy and practice of ecological economics. The role of concepts, models and case studies in inter- and transdisciplinary sustainability research.
Ecological Economics, 67(3): 384-393.

2 | Quaas, M. F. and Baumgärtner, S., (2008).
Natural vs. financial insurance in the management of public-good ecosystems.
Ecological Economics, 65:397-406.

3 | Voss, R., Dickmann, M., Hinrichsen, H.-H. and Floeter, J., (2008).
Environmental factors influencing larval sprat Sprattus sprattus feeding in the Baltic Sea.
Fish. Oceanogr. 17(3):219-230.

MARINE MEDICINE

Maintenance of the immunological integrity of organisms has been a driving force in evolution. Diversification of life forms has led to a vast number of heterogeneous non-self recognition strategies and defense effector mechanisms. However, selected principles of innate immunity seem to be molecularly conserved across animal phyla. The innate immune system has major functions: a) a controlled host/microbial crosstalk at epithelial barriers, b) the recognition of danger signals, c) clearance of intracellular pathogens by autophagy, d) the recruitment of mesoderm-derived professional immune cells and e) the secretion of local or circulating effector molecules such as antimicrobial peptides and simple opsonic forms of complement. (Fig. 1)

EVOLUTION OF ANCIENT GENES

The advances in our understanding of the evolution of the immune response are paralleled by a remarkable series of association findings of polymorphisms in the ancient genes with human chronic inflammatory diseases of epithelial barrier organs. Polygenic diseases associated with loss-of-function variations in NACHT domain–leucine-rich-repeat proteins (NLR), Toll-like receptors (TLR) and scavenger receptor cysteine-rich (SRCR) domains genes include Crohn disease (NLR, TLR and SRCR), atopic disease and asthma (NLR and TLR), which are characterized by chronic relapsing-remitting inflammation of barrier organs (intestine, lung, skin). Suggestive association of epithelial cancer entities (breast and colonic carcinoma) with germline mutations in NOD2 (nucleotide-binding oligomerization domain) and NOD1 supports the hypothesis that chronic inflammation induced by epithelial barrier dysfunction significantly contributes to the cause of malignant diseases.

Based on the hypothesis that many of today´s disease genes have an ancient evolutionary origin we focus on the following main topics:

- To describe components of the molecular and genetic risk map in human chronic inflammatory barrier diseases and to relate these genes back to their (marine) evolutionary origins
- To understand the conserved cellular programs elicited by host-pathogen interaction in simple model organisms
- To delineate the effects of selection pressure on genetic variability in barrier genes (e.g. NLRs)
- To employ evolutionary "old" model systems where the therapeutic augmentation of barrier function and epithelial drug delivery can be assessed

DECIPHERING THE MOLECULAR RISK MAP

It has become possible to systematically unravel the polygenic cause of complex human diseases by high density, Single nucleotide polymorphisms (SNP)-based association mapping in large samples of patients and controls. The introduction of genome-wide SNP mapping strategies, in particular using linkage-disquilibrium-based approach has been a breakthrough in the definition of disease genes with an unprecedented richness of findings. The group has contributed to the current understanding of the genetic underpinnings of several chronic inflammatory diseases, which are now followed up in selected marine animal models.

DEEP SEQUENCING OF MARINE TRANSCRIPTOMES

This unprecedented acceleration and resolution of findings with now more than 50 validated disease loci and genes awaits further functional characterization. Independent insights into the phylogeny of the pathways and transcriptomal signatures in response to environmental stimuli can be obtained by ultrafast sequencing approaches which enable a deep sampling of transcriptome sequence spaces of non-model organisms. This will result in a non-a-priori

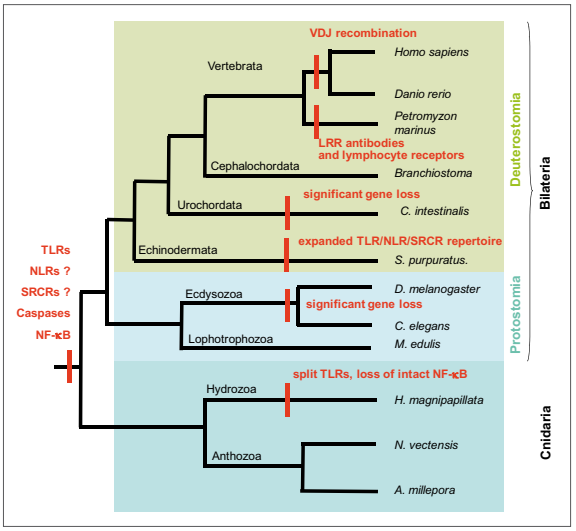


Figure 1 | Cheme of important immune-related events during animal evolution. The phylogenetic tree represents model organisms where genomic and/or transcriptomic data is available. Note that the immune-related changes in genome architecture in the diagram represent the current knowledge. The advent of ultra-fast sequencing and other genomic tools allows for a fast and systematic exploration of additional model organisms which may result in a comprehensive view on the origins and distribution of the immune gene repertoire in the animal kingdom. Abbreviation used: VDJ, variable (V), diversity (D) and joining (J) gene rearrangement for antigen receptor diversification. (from Rosenstiel et al., Journal of Innate Immunity in press).

based analysis of transcriptome signatures and will unveil complex alterations in transcriptomic patterns e.g. allelic imbalances, alternative splicing events and the detection of de novo somatic mutations on a genome-wide scale. We have established two different methods of ultrafast ribonucleic acid (RNA) sequencing (454/Roche and SoliD/Applied Biosystems) which serve as complementary technologies for different projects of the cluster. A special focus of the marine medicine group is a co-evolutionary understanding of host/pathogen interactions and their relevance for human disorders The technology is used to identify complete transcriptomal sequence spaces of three *Hydra* species and *Aurelia* (together with Th. Bosch), S. droebachiensis (together with F. Melzner) and *Mytilus edulis* in order to characterize the phylogeny of protective transcriptomal programs in response to bacterial challenges, the „Ur-defensome". Together with Thorsten Reusch, transcriptomal responses of Zostera spp. to environmental changes are characterized. The group was able to acquire the status of a central analysis platform of the DFG-funded priority program SP1399 „Evolution of Host-pathogen interaction" (together with H. Schulenburg).

INTESTINAL INFLAMMATION IN *M. EDULIS*

Induction of colitis using dextran sulfate sodium (DSS) has been successfully used in rats and mice to investigate acute and chronic inflammatory responses in the intestinal tract. Although the mechanism is not quite clear, DSS is thought to cause colitis through a toxic effect to the intestinal epithelial cells. Surfaces of marine multicellular host organisms are constantly exposed to a complex microflora and are subject to extensive attack and counter-attack processes. Thus, they are attractive model systems to understand the complex host-microbiota interactions that are also relevant to the human barrier organs and its microbiota. Aim of the study was to develop a model system for marine organisms which causes damage to the intestinal epithelium thereby inducing an innate immune response. We applied 5 days of 2-4% DSS on the marine mussel *Mytilus edulis* under different microbial conditions and investigated changes of hemocyte abundance and cellular integrity via histological measurements. DSS was found to effectively induce an immune response in the digestive gland of *M. edulis*. An increase in hemocyte concentration, and infiltration in the mucosa as well as in the intestinal lumen was found (Fig. 2). Granuloma-like structures appeared in the digestive gland tissue as well as ulcerations of the mucosal layer. The system thus proved suitable to induce an innate immune response and can now be used to investigate immune system responses under different environmental (temperature, food, microbial composition) and animal (age, injury, infection) conditions. Such investigations will help to elucidate the mechanisms which may alter innate immune system functioning and its effect on microbial-host interactions.

WORKING GROUP

Philip Rosenstiel, Eva Phillips

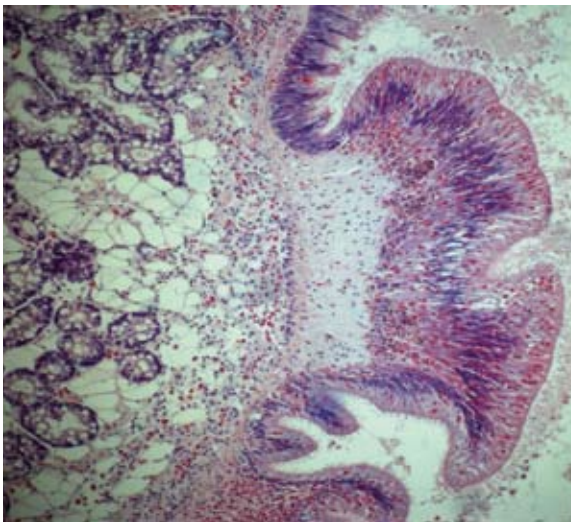


Figure 2 | Histological photomicrograph from the intestinal tissue of a DSS-challenged M. edulis individual. Please note the infiltration of immune cells (red dots) into the epithelial interface. Original magnification 200X.

OUTLOOK

The present insights into the evolutionary origins of the innate immune system in aquatic invertebrates may prove to be especially useful to understand how selective pressures form genetic diversity and sequence variability to cope with different immune challenges. Dissecting the primordial cellular programs of innate immunity, the „Ur-defensome", in simple eumetazoans is alleviated through transgenic technologies allowing for a stable genetic manipulation of these animals under laboratory conditions. We will try to further our understanding by addressing the following questions are: how does the interaction between mesodermal immune cells and the gut epithelium converge to maintain the homeostasis of a complex microbial ecology existing in the gut lumen? How are pathogens distinguished from commensals? What is the structure of the gene regulatory program that extends from the gut lumen through sensors in the gut epithelium to mesodermal immune cells and ultimately to effector functions?

SELECTED PUBLICATIONS

1 | Rosenstiel, P. and Schreiber, S., (2008).
Expression signatures, barriers and beyond: the role of oxidative stress in murine colitis and human inflammatory bowel disease revisited.
Eur J Gastroenterol Hepatol 20(6): 496-499.

2 | Rosenstiel, P., Derer, S., Till, A., Hasler, R., Eberstein, H., Bewig, B., Nikolaus, S., Nebel, A. and Schreiber, S., (2008).
Systematic expression profiling of innate immune genes defines a complex pattern of immunosenescence in peripheral and intestinal leukocytes.
Genes Immun 9(2): 103-114.

3 | Rosenstiel, P., Jacobs, G., Till, A. and Schreiber, S., (2008).
NOD-like receptors: ancient sentinels of the innate immune system.
Cell Mol Life Sci 65(9): 1361-1377.

SEAFLOOR RESOURCES

The global ocean hosts large natural resources of commercial interest. Theseare i.e. deep-sea ore deposits and offshore hydrocarbon occurrences. Deep-sea ore deposits form primarily as a by-product of hydrothermal activity at mid-ocean ridges when seawater penetrates into the seafloor along cracks and fractures. During venting of these hot fluids metals and other elements precipitate and deep-sea ore deposits form. Other important resources of the global ocean are offshore hydrocarbon occurrences that are mainly found in sedimentary basin provinces. Geological exploration tries to better understand the processes involved in forming these natural resources and make more reliable predictions on the occurrences of these resources. Key to this is a quantitative understanding of reactive transport processes in deformable porous media. The JRG Seafloor Resources actively develops and applies numerical simulations of reactive transport. This is an emerging exploration tool providing insights into fluid flow, heat transfer, multi species transport, chemical reactions and how these processes relate to rock deformation and geodynamics for a better understanding of the origin and nature of fluid-derived seafloor resources.

HYDROTHERMAL SYSTEMS AND SEAFLOOR AGING

The discovery of hydrothermal systems at mid-ocean ridges in the late 1970s was one of the most exciting achievements in oceanography - not least because of its importance for different fields of geosciences. Hydrothermal systems efficiently mine heat from the young ocean crust, thermal springs at the seafloor host unique ecosystems in extreme environmental conditions and commercially interesting high-quality ore deposits form as a byproduct of hydrothermal venting. Much has been learned from marine surveys of mid-ocean ridge segments and direct observations of vent sites at the ocean floor. The deep chemical and physical processes that control hydrothermalism remain, however, largely inaccessible to direct sampling and observations. Understanding those remote physicochemical processes requires interdisciplinary research including experiments, theoretical work, numerical simulations, detailed seafloor imaging and sampling, and studies of ophiolite complexes.

The JRG Seafloor Resources follows a cross-disciplinary approach to better understand fluid flow through oceanic crust in different tectonic settings (Fig. 1). Initial findings clearly confirm that fluid flow has a major control on the aging and alteration of oceanic lithosphere. At mid-ocean ridges, both numerical simulations and petrological studies of the Oman ophiolite show that seawater may reach and react with cold lithospheric mantle to make serpentine. Direct seafloor observations and structural data from Oman further suggest that fluid flow is focussed along fractures and faults. At ocean trenches, near the end of the lifetime of oceanic plates, bend-faults may again provide high permeability pathways for seawater to reach the cold oceanic mantle. Numerical simulations of the hydrological regime of the Cocos plate offshore Nicaragua suggest that the mantle may become significantly hydrated (i.e. serpentinized) around bend-faults as a consequence of deep sea-water circulation.

These new insights indicate that the crust-mantle boundary may not be a barrier to hydrothermal flow and that significant element exchange may occur not only between the global ocean and the ocean crust but also the lithospheric mantle. These findings will be integrated into improved budgets of element cycling between the global ocean and the solid Earth.

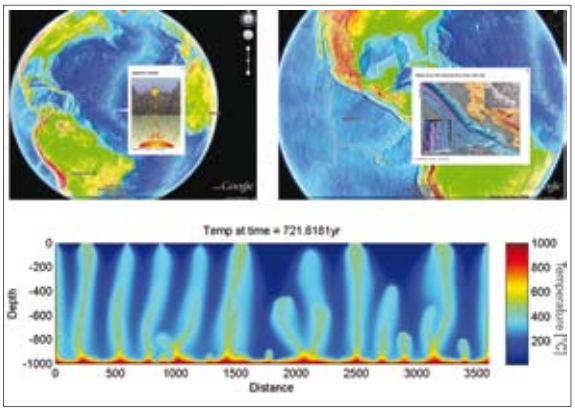


Figure 1 | Hydrothermal convection and seafloor aging.

CONTINENTAL BREAKUP AND NEW OCEAN BASINS

Continental break-up and the creation of new oceans is a fundamental yet poorly understood aspect of the plate tectonic cycle. Ever since the advent of plate tectonics geoscientist have strived for a better understanding of the geological processes that rupture the continental lithosphere and lead to the formation of new ocean basins. It is clear now that passive continental margins can be categorized into volcanic and non-volcanic rifted margins but the processes that control melting during lithosphere extension remain enigmatic. Likewise the structural evolution of rifted margins has not been fully understood. With the acquisition of new high-quality and high-resolution datasets it has become apparent that an increasing number of passive margins show subsidence histories that do not match our classic models

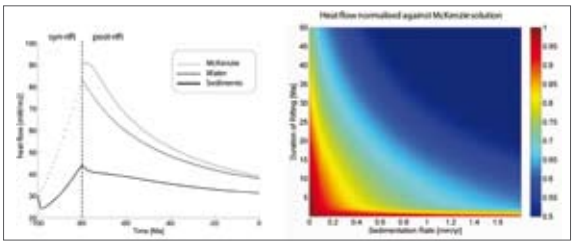


Figure 2 | Feedbacks of sedimentation on crustal heat flow.

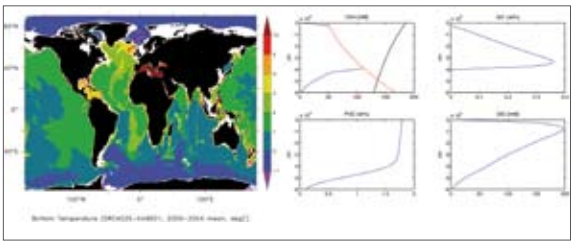


Figure 3 | Global bottom water temperatures (Biastoch et al. 2009) and gas hydrate modeling.

based on crustal thinning and local isostasy. The current challenge in passive margin research is to formulate novel concepts and ideas for the evolution of rifted margins and to test them with new numerical models. The academic effort is supported by what is sometimes called the „rift renaissance" in the offshore petroleum industry. The past years have seen record level oil prices and new exploration campaigns are set up worldwide that lead to the acquisition of state-of-the-art new datasets that will ultimately be of great benefit to the geoscientific community.

The Seafloor Resources group studies continental rifting and breakup with new numerical models. At present two main focuses are set: 1) quantification of the feedbacks between shallow sedimentary and deep lithosphere processes using kinematic basin models and 2) studies of strain localization, melting, and subsidence using fully dynamic finite-element models. A key finding from the kinematic basin modelling is that basement heat flow during rifting is a complex function of sedimentation, deposited rock type, and lithospheric stretching. Even for moderate sedimentation rates (>0.5mm/yr), basement heat flow is significantly depressed by the deposition of cold sediments (Fig. 2). These findings illustrate that first order feedback exists between shallow sedimentary and deep lithosphere processes and thereby make the case for integrated basin modelling.

A NEW GLOBAL GAS HYDRATE INVENTORY

Gas hydrates are ice-like structures, which can be found on the seafloor, in ocean sediments, and in permafrost regions. They contain gases, such as methane, that reside inside symmetrical cages of water molecules. The potentially significant amount of natural methane hydrate occurrences makes them of major interest as a potential energy resource. We are working on an improved global budget of methane hydrates that is based on reaction transport modelling. Building on the existing expertise at IFM-GEOMAR, we have developed a new 1-D reaction transport model that predicts the volume of gas hydrate in the sub-seafloor as a function of sedimentation rate, temperature/pressure, total organic carbon (TOC) content of deposited sediments, and kinetic parameters (Fig. 3). Unfortunately, well data is still sparse in the global ocean so that some parameters (e.g. bottom water temperatures, TOC content, and sedimentation rates) need to be extrapolated. To overcome some of these difficulties related to sparse input data, the Seafloor Resources group collaborates with colleagues from IFM-GEOMAR's ocean circulation and climate dynamics division. Global circulation models provide reliable global input data on bottom water temperatures, pressures, and salinities for reaction transport modelling. We are currently in the processes of applying our new gas hydrate model globally using the input data from oceanographic circulation models in order to compute a new map of worldwide gas hydrate occurrences.

WORKING GROUP

Sonja Theißen, Karthik Iyer, Volker Schenck, Dominique Lattard, Kaj Hoernle, Francoise Boudier, Lars Rüpke, Larry Cathles, Adolphe Nicolas (photographer)

SELECTED PUBLICATIONS

1 | John T., Medvedev S., Rüpke, L.H., Andersen, T.B., Podladchikov, Y.Y. and Austrheim, H., (2009).
Generation of intermediate-depth earthquakes by self-localizing thermal runaway.
Nature Geoscience, doi:10.1038/ngeo419.

2 | Iyer, K. and Podladchikov, Y.Y., (2009).
Transformation-induced jointing as a gauge for interfacial slip and rock strength.
Earth and Planetary Science Letters, 280, 159-166.

3 | Theißen, S. and Rüpke, L.H., (2009).
Feedbacks of sedimentation on crustal heat flow – new insights from the Voring Basin, Norwegian Sea.
Basin Research, in review.

4 | Rüpke, L.H., Schmalholz, S., Schmid, D. and Podladchikov, Y., (2008).
Automated thermotectonostratigraphic basin reconstruction: Viking Graben case study.
AAPG Bulletin, v.92, no.3 (March 2008), pp. 309-326.

SUBMARINE HAZARDS AT CONTINENTAL MARGINS

Earthquakes, submarine slope failures, and resulting tsunamis pose a major threat to coastal communities, which are home to over sixty percent of mankind and location of a large proportion of major industrial installations, increasingly including offshore installations. Scientists involved in this project focus their activities on the following two themes: (1) Assessment of the link between the structure and dynamics of subduction zones and the megaearthquake cycle, (2) Slope stability issues at continental margins. The main emphasis of the newly established junior research group (JRG) is the analysis of submarine slope failures and associated hazards. So far numerous slides in different tectonic settings were investigated, including active and passive margins, as well as lakes. This was done by means of hydro-acoustic, seismic, and sedimentological/geotechnical methods.

A GLOBAL PHENOMENON

Submarine landslides occur on continental margins worldwide. Fig. 1 shows the distribution of major slides though the figure is probably not complete and the distribution of landslides is biased by the density of available data. The largest known slides occur on passive margins, e.g. the Storegga slide off Norway and giant slides off NW-Africa. Slides might reach volumes of more than 20.000 km³, affect areas of more than 90.000 km² (about the area of Portugal) and show run-out distances of up to 800 km. Active margins are characterized by more frequent but generally smaller events.

Submarine mass wasting plays an important role during the evolution of continental margins. The main research focus, however, is related to the hazards associated with submarine sliding. Submarine slides are able to destroy offshore infrastructure (e.g., cables, pipelines, and platforms) and generate tsunamis. It is also discussed whether submarine slides can release large amounts of greenhouse gases bound in hydrates by the removal and liquefaction of the involved sediment. Today, the importance of submarine slope failure processes rises with increasing infrastructure on the sea-floor and near the coasts. A variety of socio-economical branches, including energy, communication, navigation, tourism, fisheries, military, and science extend their interest further offshore and deeper into the sea. In the view of a warming future ocean with rising sea-level and intensified human activities, the increasing significance of slope stability issues is evident.

MASS WASTING AT PASSIVE CONTINENTAL MARGINS

Submarine mass wasting at passive margins is investigated off NW-Africa, off Uruguay/Argentina, and in the Arctic Ocean. Sediment transport along the NW-African continental margin operates with different rates and styles including a significant transfer of land-derived terrigenous and hemipelagic sediments to the deep sea. Some sections show a large concentration of upper slope canyons but no indication for large scale mass wasting. Other sections are characterized by large scale mass wasting but no canyons and gullies were found (Fig. 2). These observations allow to draw several conclusions for mass wasting off NW-Africa, which are relevant for other passive margin settings as well. i) We speculate that the open slope areas without any major incisions allowed undisturbed rapid sediment build-up, which gave rise to sediment instabilities arising primarily from underconsolidation of the deposited sediments and widespread weak layers, while the canyons and gullies represent an effective pathway for „semi-continuous"

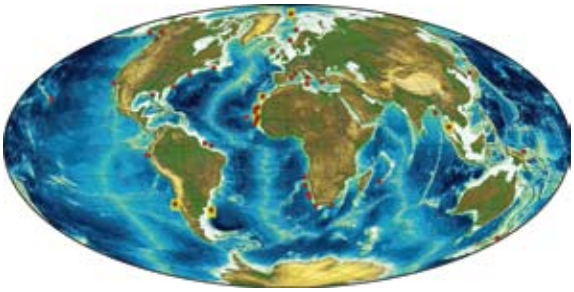


Figure 1 | Map showing the distribution of major slides along the continental margins. Note that the distribution of slides is biased by the availability of data. The yellow boxes show the main working areas of Submarine Hazards Group.

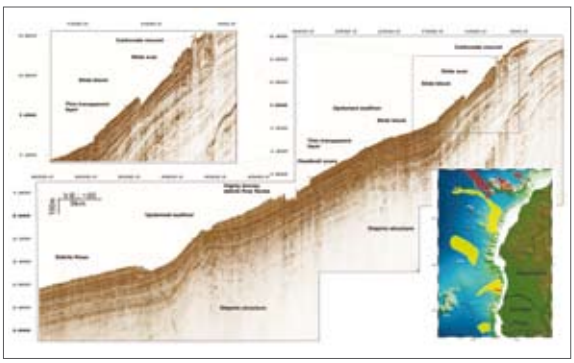


Figure 2 | Seismic section crossing the Mauritania Slide complex. Stacked debris flow deposits indicate a long history of mass wasting. The slide is located in an area of hydrocarbon exploration and probably triggered a major tsunami at ~10.5ka BP. The index map shows major slides off NW-Africa (yellow: slides on the open slope, red: volcanic slides around the Canary Islands). The thick red line marks the location of the seismic profile.

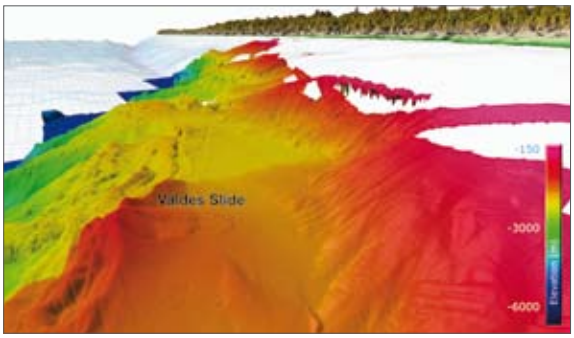


Figure 3 | 3D-view of the Valdes submarine slide and parts of the continental margin off Chile. Due to its position at the landward facing wall of a ridge, we consider the tsunami potential of this slide as higher than for other slides of similar size.

downslope sediment transport by turbidity currents. ii) Stacking of mass wasting events and the alignment of buried scarps with much younger headwalls suggest that sediments deposited above buried scarps are potentially unstable especially due to differential compaction and oversteepening, and therefore remain unstable after the initiation of land sliding. iii) The large size of the slides off NW-Africa is caused by high sedimentation rates but infrequent triggers.

MASS WASTING AT ACTIVE MARGINS

Submarine mass wasting at active margins is analyzed off Chile and in the Andaman Sea. The margin off Chile is characterized by slides of different sizes. The Valdes submarine landslide is a medium-sized landslide. In contrast to most other slides along the margin, it is located at the landward wall of a ridge, which terminates a sedimentary basin towards the steepening side of the continental slope (Fig. 3). This setting has important implications for the associated tsunami wave field (first arrival of positive amplitude). Taking the steep ridge flank with slope angles of 6°-7° into account, the potential trigger mechanism is most likely closely related to the formation and evolution of the ridge. Over-steepening of rapidly accumulated sediments (high sedimentation rate) and a weak layer acting as sliding surface seem to be the most important preconditioning factors of this slide. The most likely trigger mechanism is one of the frequently occurring strong earthquakes in this area.

LAKES AS MODELS FOR OCEAN

Lakes can be used to study mass wasting on small scales. Landslides in lakes show a lot of similarities to slides in the oceans, i.e. same physical principles and same societal relevance but are less complex and allow basinwide quantifications. Currently, we are investigating seismic data from Lake Ohrid (Macedonia/Albania, Fig. 4) and Lake Van (Turkey). Both lakes show numerous subaquatic landslides, which occur at specific stratigraphic levels. The occurrence of several slides at the same stratigraphic level suggests a joint trigger, most likely an earthquake. Hence, the ages of the slides can be used as proxy for paleoseismicity around the lakes. The scientific activities in both lakes take place in cooperation with the International Continental Scientific Drilling Program (ICDP). ICDP drilling at Lake Van is approved for 2010, while a proposal for drilling at Lake Ohrid is currently under review.

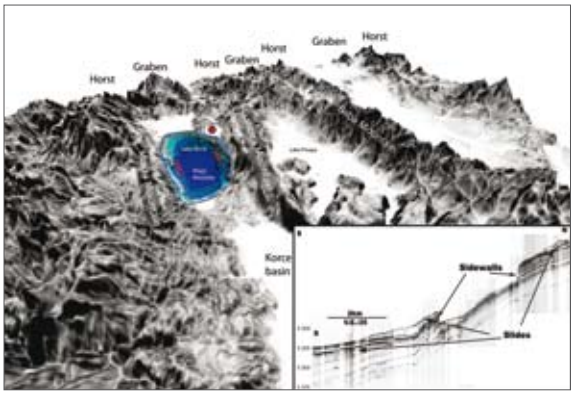


Figure 4 | Lakes, such as Lake Ohrid (Macedonia/Albania), are used as 'models for oceans' where mass wasting can be studied on small scales. The sediment echo sounder profile shows a typical example of a landslide in the lake. The main focus of the work is the interplay between earthquakes and slope failures.

WORKING GROUP

Katja Lindhorst, Daniel Winkelmann, Stephanie Kurschat, Mathias Meyer, Andrea Anasetti, Sebastian Krastel

SELECTED PUBLICATIONS

1 | Henrich, R., Hanebuth, T.T.J., Krastel, S., Neubert, N. and Wynn, R., (2008).
Architecture and sediment dynamics of the Mauritania Slide Complex.
Marine and Petroleum Geology, 25, 17-33.

2 | Winkelmann, D., Geissler, W.H., Schneider, J., Stein, R. and Schenke, H.-W., (2008).
Dynamic and timing of the Hinlopen/Yermak Megaslide north of Spitsbergen.
Arctic Ocean, Marine Geology, 250, 34-50.

3 | Wagner-Friedrichs, M., Krastel, S., Spiess, V., Ivanov, M., Bohrmann, G., Meisner, L., (2008).
3D seismic investigations of the Sevastopol mud volcano in correlation to gas/fluid migration pathways and gas hydrates occurrences in the Sorokin Trough (Black Sea).
G-cubed, 9-5, doi:10.1029/2007GC001685.

SEA BOTTOM INTERACTION IN COASTAL AREAS AND RIVER MOUTHS

The Junior Research Group „Sea-level Rise and Coastal Erosion" focuses on rapid physical and morphological changes at those coasts of the world, which are severely under stress due to natural and anthropogenic impacts. These are river-mouth systems in particular. Reliable prognoses of future coastal development must be based on a fundamental knowledge of the complex interrelated and interacting coastal processes. The understanding of these processes is still lacking for many coasts nearby and abroad. Modern measuring techniques with high temporal and spatial resolution are used in this research group to fill the gaps in current data sets and to improve our understanding of coastal processes.

WHAT IS IT ALL ABOUT

Coastal zones are widespread over the world. They are highly diverse with respect to geological composition, physical settings and morphological changes. Many of them are densely populated due to good living and working conditions. This includes in particular river mouth systems, where many mega cities and large harbor sites are located. Climate related sea-level rise, increase of storm intensity and duration, appearance of tsunamis or even manmade interferences by constructions force many coastal zones to adapt in an unintentional way. Often consequences such as flooding, erosion, decrease in water quality, or habitat change arise. Substantiated answers as well as reliable prognoses are strongly needed for high quality coastal zone protection and management. Prerequisite and focus of the group is to provide a detailed understanding of natural and anthropogenic influenced coastal processes and dynamics. Special interest is given to river mouth systems, which are hotspots in terms of economical and ecological value and risk potential. Most diverse, physical and sediment related interactions at the interfaces land – sea, water column - seafloor, and freshwater - seawater occur on various time scales, spanning seconds to thousands of years, and spatial scales ranging from centimeters to hundreds of kilometers. Therefore a multi-methodical approach is most promising to analyze these interactions in a qualitative and quantitative way. To achieve this, different highly sophisticated hydroacoustic and optical devices are simultaneously deployed. Acoustic Doppler Current Profilers (ADCP), Conductivity-Temperature-Depth probes (CTD), Optical Backscatter Sensors (OBS) and a Laser In-Situ Scattering and Transmissometry system (LISST) are used to measure water motion and condition as well as amount and sizes of suspended particulate matter (SPM) in the water column. The bathymetry is recorded by a multibeam echo-sounder (MBES), the constitution of the seabed surface by a side-scan sonar (SSS), and sub-bottom structures by a sediment echo-sounder (SES). Ground-truthing is done with various water and sediment sampling techniques. Some are specially adapted to retrieve material of boundary layers. A complete new laboratory has been established for modern sediment analytics, amongst others equipped with a new laser-based particle-size system. In the following two examples from ongoing projects are presented.

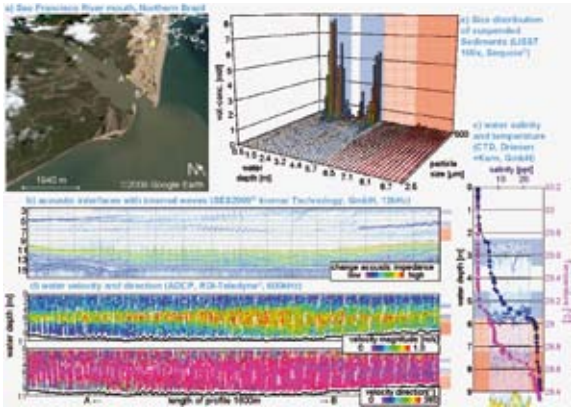


Figure 1 | a) Satellite image of the São Francisco River mouth (Northern Brazil) with location of a longitudinal profile A-B, b) acoustically prominent interfaces between water layers of different temperature and salinity, topped by internal waves c) ground truthing by CTD measurement, d) varying flow conditions within the water column, e) particle-size distribution, indicating large aggregates on the interfaces (new, unpublished data).

COASTAL CHANGE CAUSED BY WATER RESERVOIRS?

The demand on freshwater for domestic and industrial use increases worldwide. Thus, many rivers are nowadays dammed. This reduces discharge and related sediment transport to the adjacent coastal regions. Deltaic systems originating from high riverine sediment input, now often face estuarine conditions. Coastal erosion and land loss can arise, as observed at the mouth of the São Francisco River in Northern Brazil (Fig. 1a). Villages have been extinguished within a few years. A new research project, funded by the German Research Foundation (DFG), has been set up with international partners from Salvador (Brazil), Natal (Brazil) and Kiel (Germany), including the participation of the Sea-level Rise and Coastal Erosion group. Coastal changes caused by damming of the São Francisco River will be identified during various expeditions. Focus is set on the sediment- and hydrodynamics at the river mouth, whereof hardly any information is currently available.

New data reflects abrupt vertical changes of salinity and temperature in different water depths (example: 2-3 m, 5-6 m), documenting a pronounced saltwater intrusion into the estuary up to 7 km (Fig. 1a-d). Water masses of different physical characteristics and flow conditions appear, interacting at their interfaces, as indicated by internal waves (Fig. 1a-c). This water stratification strongly influences the fine-grained sediment dynamics, as shown by abrupt increase of large particle aggregates at the interfaces (Fig. 1e). These new findings do not only reflect the already assumed adjustment of estuarine conditions, but also indicate changes in sediment dynamics. Based on this information, significant ecological and economical consequences can be expected.

IMPACT OF DREDGING ACTIVITIES

Substantial deposits of fine cohesive sediments and subaqueous dunes of several metres in height are well known features of many tidal estuaries. They can considerably reduce the navigable depth. Facing the fact of a growing demand on ship-based cargo transport worldwide, most navigation channels need intensive maintenance and further construction by dredging to guarantee vessel access. In this context, questions arise on expanding economical side effects, e.g. dredging costs, and on ecological side effects, e.g. habitat changes. Fundamental knowledge of estuarine sediment processes and dredging induced impact is needed, which is actively worked out in cluster-related projects of the Sea-level Rise and Coastal Erosion group.

One project focuses on the impact of a special dredging technique, which triggers sediment dispersal by water injection (WI) to reduce heights of subaqueous dunes (Fig. 2a). The investigations are motivated by distinct advantages of this new method compared to conventional techniques. Firstly, dredging costs are tremendously reduced, because expensive vessel-based transport of dredged material from dredging to the dumping sites is avoided. Secondly, the WI-dredging vessel can remove small structures more precisely, leading to a much smaller ecological environmental impact to the sites. The latter still has to be verified.

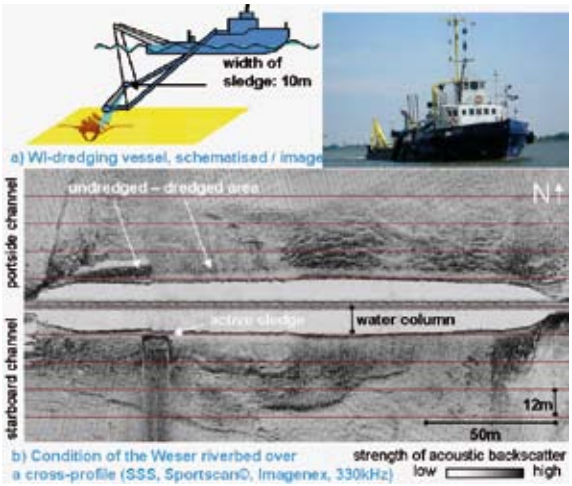


Figure 2 | a) schematic view and image of a WI-dredging vessel, c) acoustic image of the riverbed over a cross-profile in the inner Weser estuary (German North Sea Coast), reflecting the process of WI-dredging, which is the height reduction of a subaqueous dune. Fluidised sediment is transported southward with the tidal current (new, unpublished data).

The Weser tidal estuary (German North Sea coast) belongs to the most engineered waterways of Germany and abroad. Further riverbed adjustments are planned to expand capacity for increasing vessel sizes, involving further dredging. Effects of WI-dredging were monitored in the inner Weser estuary during a joint campaign with participation of seven partner institutions in June 2008. Detailed insight into the dredging process and related sediment transport is exemplarily shown by new side-scan sonar data (Fig. 2b). While dune crests are precisely removed by jets of water, injected directly into the riverbed to fluidize surface sediments, material is then either transported as bedload or in suspension, congruent with the direction of the tidal flow. A pronounced dredging related impact on estuarine sediment processes within the selected river stretches decreases exponentially with increasing distance from the dredging site.

WORKING GROUP

Rik Tjallingii, Andreas Jacobsen, Henning May, Kerstin Schrottke, Svenja Papenmeier, Christian Schiffer, Sarah Ohlemacher

SELECTED PUBLICATIONS

1 | Bartholomä, A., Schrottke, K. and Winter, C., (2008). Sand wave dynamics: Surfing between assumptions and facts.
Parsons, D., Garlan, T. & Best, J. (eds) Marine and River Dune Dynamics, p. 17-24.

2 | Schrottke, K., and Bartholomä, A., (2008). Detaillierte Einblicke in die ästuarine Schwebstoffdynamik mittels hochauflösender Hydroakustik. – Tagungsband zum Seminar „Ultraschall in der Hydrometrie: neue Technik – neuer Nutzen?"
FgHW / DWA, 3-4 Juni, Koblenz, 75-82.

3 | Schrottke, K., Becker, M., Bartholomä, A., Flemming, B.W. and Hebbeln, D., (2006). Fluid mud dynamics in the Weser estuary turbidity zone tracked by high-resolution side-scan sonar and parametric sub-bottom profiler.
Geo-Marine Letters 26, 185-198.

RISK ASSESSMENT IN THE COASTAL ZONE

Climate-induced pressure on coastal areas is resulting in a range of impacts, which include submergence and flooding, erosion, saltwater intrusion and the loss of wetlands. At the same time, human pressure is increasing as population along the coast is growing up to three times faster than the global average. The extent of potential impacts is significant but uncertain. Actual impacts will depend on the degree of change of various climate-related factors as well as on human response. Our research focuses on assessing the magnitude of these impacts and on understanding how coastal systems respond to natural forcings as well as the ways in which human development affects this response. Particular emphasis is given to the ways in which sea-level rise, one of the more certain impacts of global warming, will exacerbate potential impacts and increase coastal vulnerability.

THE DIVA MODEL

The adverse implications of climatic- and non-climatic-related changes in coastal systems are anticipated to increase in the next years. Such changes may include alterations in storm patterns and in sediment balance, increased erosion, saltwater intrusion and salinisation, loss of wetlands and subsidence. Furthermore, rising sea levels, one of the more certain impacts of climate change, will exacerbate the impacts of these threats. The slow response of sea level to warming suggests that the sea levels will continue to rise beyond the 21st century, even if mitigation measures were to take place with immediate effect. Besides the anticipated increase in physical exposure, the vulnerability of coastal systems will continue to increase as a result of the existing trends in the utilisation of the coastal zone by humans. The predicted rates of population increase and the current patterns of coastal development make imperative the design of adaptation measures in order to reduce the risk for population. Hence, assessments must look beyond 2100 and should take into account the different ways in which humans will respond to those changes. The Junior Research Group (JRG) „Coastal Risk Assessment" employs novel modeling tools for exploring the various mechanisms that drive coastal change and for evaluating the influence of alternative policies and management regimes on coastal development. In co-operation with the University of Southampton, the Potsdam Institute for Climate Impact Research and the Free University of Amsterdam it is working on the development and application of the DIVA model, an integrated-assessment model that consists of: (i) a global coastal database of physical and socio-economic parameters; (ii) a series of interacting modules that represent the different natural and human coastal subsystems. Work focuses on the further development, updating and maintenance of the coastal database that underlies the DIVA model and on the application of the model for different socio-economic and climatic scenarios. Current work on the application of the model includes an assessment of risk and adaptation to sea-level rise for the EU27 region in the 21st century. The impacts of sea-level rise are assessed in terms of: the number of people that are affected by annual flooding and that are forced to migrate due to coastal erosion; monetary damage costs; and adaptation costs. Initial findings of the JRG suggest that socio-economic development along the coast is the principal driver of the impacts in the first half of the century while the effects of sea-level rise become more apparent in the second half. However, adaptation measures substantially reduce the impacts and look affordable in relation to the size of the economy.

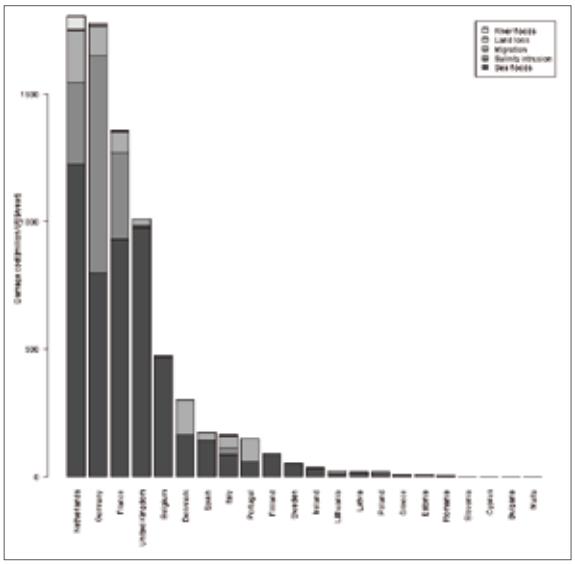


Figure 1 | Distribution of damage cost under A2 without adaptation (A2+NO) in 2100

HUMAN IMPACTS IN THE VENECIAN COASTAL ZONE

The rapid development of the shipping industry is a typical example of the challenges posed by the utilization of the coastal zone by humans. Shipping in coastal areas leads to sediment resuspension events, having several detrimental effects in shipping channels and lagoons. Many of these channels are located in important estuarine systems. Resuspension increases turbidity, thereby blocking sunlight and decreasing biological productivity. The sediment can

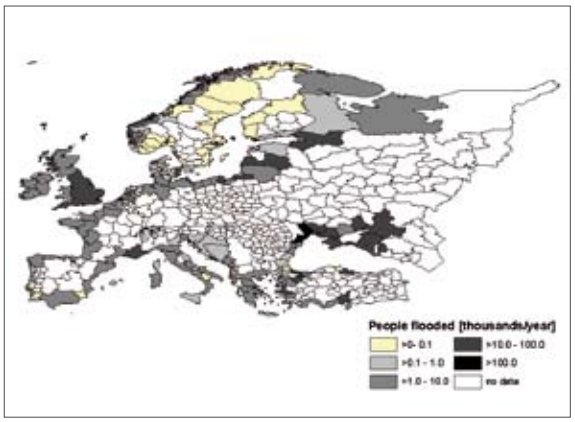


Figure 2 | People flooded under the A2 scenario without adaptation 2100.

represent navigational hazards and re-suspension can serve to remobilize previously isolated contaminants. Large ships in shipping channels often re-suspend sediments through the motion of their propellers, however where deep shipping channels are found adjacent to extensive shoals a powerful forced solitary long wave can be produced creating massive re-suspension events of long duration (Fig. 3). The JRG is investigating sediment re-suspension in the Venice Lagoon. Over the course of three sampling campaigns a bevy of geophysical instruments has and will be utilized to capture and record the re-suspension events caused by the production of these special waves in the Venice Lagoon. We hypothesize that the majority of sediment re-suspension in the Venice Lagoon is caused by the formation and propagation of these waves, which can be prevented by reducing the speed of ships as well as limiting navigation to the period from medium to high tide. Though Venice serves as a case study for similar ports around the world, the situation there is particularly dire as most of the sediment in the vicinity of the port is highly contaminated. These large events can remobilize large concentrations of pollutants and allow them to spread to more pristine areas of the lagoon. This serves as a potentially devastating problem for the health of the lagoon's ecosystem, which is critically important, both physically and economically, to the denizens of Venice. As the shipping industry increases and more channels and harbours are created throughout the world, the understanding of shipping-induced sediment mobilization is necessary to protect vital ecosystems.

OUTLOOK FOR 2009

Impacts, risks and vulnerability to coastal hazards and how these will be exacerbated by sea-level rise constitutes the primary research focus of the Junior Research Group. Ongoing work on the above topics will continue while, following the arrival of new group members, the range of coastal processes that is being studied has been expanded. Current topics in the group's research agenda include: the monitoring and modelling of the response of coastal wetlands to accelerated sea-level rise in the Wadden Sea; the development of coastal typologies and databases for impact and vulnerability analysis; and forecasting the impacts of coastal hazards in land use development.

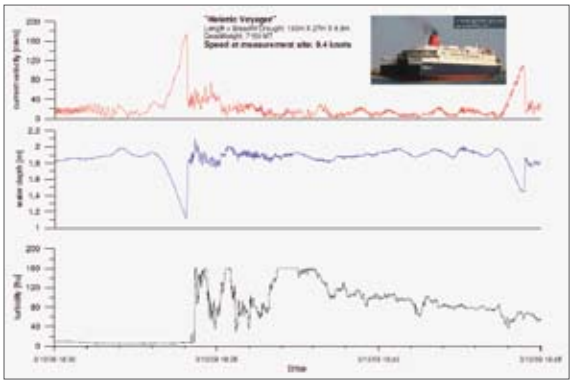


Figure 3 | This figure shows data collected from an S4 electromagnetic current meter on March 10th at 6:30 pm. After the ship passes there is a long decrease in the water level with a corresponding increase in water velocity. The water returns to its original height in less than a second signifying the passing of a wall of water. This passage leads to a major re-suspension event of long duration. The total turbidity is so high it extends beyond the maximum detection limit of the S4 sensors. This type of resuspension event is particularly detrimental to the health of the Venice Lagoon.

WORKING GROUP

Daniela Arp, Morgan Gelinas, Nassos Vafeidis, Michal Lichter, Mark Schürch, Tina Geisler, John Rapaglia
Missing: Jana Koerth, Eva Papaioannou, Juliane Zimmermann

SELECTED PUBLICATIONS

1 | Nicholls, R.J., Tol, R.S.J. and Vafeidis, A.T., (2008).
Global estimates of a collapse of the West Antarctic ice sheet: an application of FUND.
Climatic Change, Vol. 21 (1-2), pp. 171-191.

2 | Stieglitz, T., Rapaglia, J., and Bokuniewicz, H.B., (2008).
Estimation of submarine groundwater discharge from bulk ground electrical conductivity measurements.
Journal of Geophysical Research.-Oceans, C8 (15).

3 | Vafeidis, A.T., Nicholls, R.J., McFadden, L., Tol, R.S.J., Hinkel, J., Spencer, T., Grashoff, P.S., Boot, G. and Klein, R.J.T., (2008).
A new global database for assessing the vulnerability of coastal zones to sea-level rise.
Journal of Coastal Research, Vol. 24 (4), pp. 917-924.

INTERNATIONAL LAW OF THE SEA

Almost every ocean activity, be it maritime traffic, fishing, resource exploitation, the laying of pipelines and sea cables, marine scientific research or the protection of the ocean, involves the legal question whether at all and, in case of affirmation, under what circumstances it may be undertaken. With a view to the international plane, the answers to that question are enshrined in the international law of the sea, which constitutes one of the oldest and most practically relevant areas of public international law. The Junior Research Group (JRG) „Law of the Sea" strives to comprehensively analyze the existing legal framework in the light of current challenges deriving from climate change, increasing energy resource scarcity and overexploitation of the seas.

METHODOLOGY: A COMPREHENSIVE APPROACH

The work conducted within the JRG is based on the premise that attention should first of all be directed at the existing law before asking what international law should say. Such a 'realistic' approach involves an identification of the pertinent legal rules and their interpretation based on a strict application of the accepted methods of interpretation (primarily wording, context, object and purpose). It takes the rules contained in the United Nations' Convention on the Law of the Sea of 1982 (UNCLOS), which is sometimes referred to as the „constitution for the oceans", as the starting point. This treaty was concluded „to settle, in a spirit of mutual understanding and cooperation, all issues relating to the law of the sea […]" (preamble), and has, since its entry into force in 1994, received almost universal acceptance. Based on the regulatory requirements contained therein, the JRG comprehensively examines the legality of individual ocean activities and measures their impact against the prerequisites of the concept of sustainability. To achieve this goal the JRG is closely collaborating with other research groups of the cluster. For instance, an evaluation of the effectiveness of the international and European law of fisheries cannot be undertaken without including aspects of marine biology (stock developments) and economics (stock values). The same is true with regard to almost all other ocean activities: Whether or not a certain project (such as, e.g., storage of CO_2 below the seabed) may lawfully be undertaken in the light of a risk assessment based on the precautionary principle depends on an in-depth analysis of the probability and gravity of the dangers which might result from the activity concerned. The need to cooperate in a multidisciplinary manner naturally also affects the dialogue with state authorities, non-governmental organizations and other stakeholders. The JRG is actively cooperating with the Federal Maritime Agency on

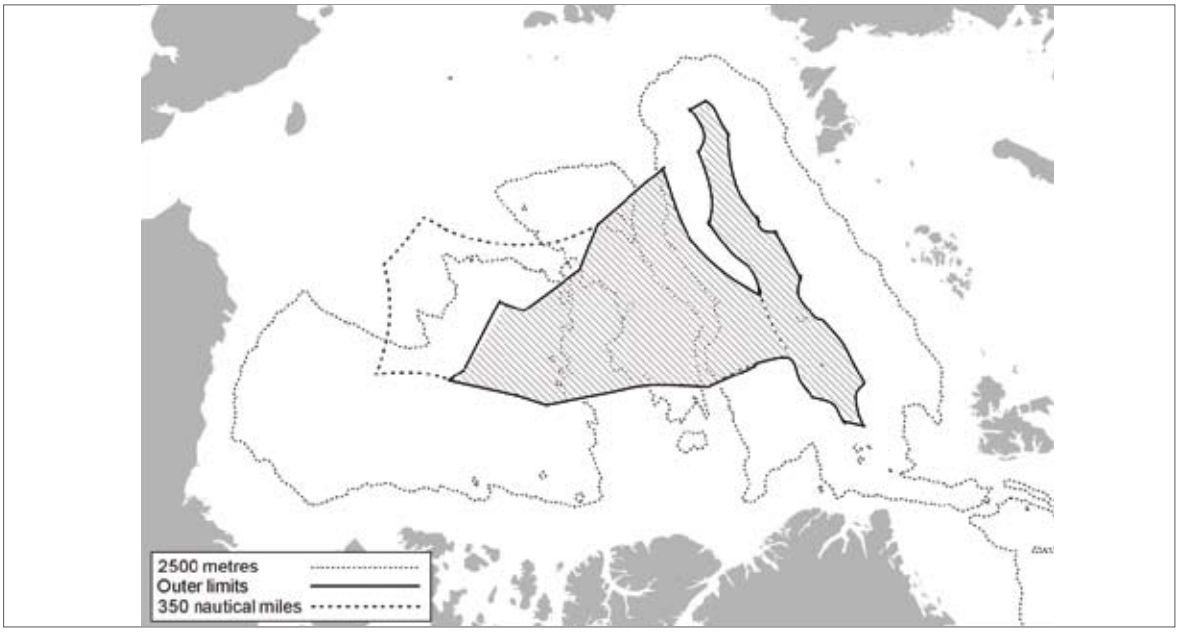


Figure 1 | New evaluation of the outer limits of the continental shelf in the Arctic Ocean according to A. Proelss and T. Müller (2008). Under this view, a cut-off of the continental shelf areas applies 350 nautical miles from the coast, whenever the coastal state's shelf area would be determined by the existence of the ridge. This definition results in a substantially larger and continuous unassigned area that would fall under the international regime of the deep seabed. Most of the combined outer limit of Canada and Greenland consists of the 350 nautical miles cut off line while the Russian outer limit remains a combination of both.

issues such as the legal regime relevant to ship emissions. In early 2009, Alexander Proelss delivered a legal opinion on the legality of iron fertilization experiments, on which the German Federal Ministry of Education and Research based its decision to approve the undertaking of the Indo-German iron fertilization experiment „LOHAFEX" in the Southern Atlantic Ocean. The members of the JRG are also participating in a working group on the future common fisheries policy of the European Community (EC), which includes stakeholders from all relevant branches, and it plans to submit a comment to the EC´s green paper „Reform of the Common Fisheries Policy."

INTERNATIONAL COOPERATION

International cooperation constitutes the third pillar of the work conducted by the JRG as evidenced by the recent appointment of Alexander Proelss as one of the two German members to the newly established Committee on „Baselines under the International Law of the Sea" of the International Law Association. He is also the co-organizer of the international law lecture series of the Walther-Schücking-Institute for International Law and has repeatedly invited world leading experts on the law of the sea (Alan Boyle, Kari Hakapää) to Kiel. The existing cooperation with the Scandinavian Institute of Maritime Law (Oslo) was deepened by initiating an informal PhD-student exchange programme. Under this programme, the Scandinavian Institute as well as the JRG will mutually fund research visits of PhD students to Oslo and Kiel respectively. The programme is addressed to students who wish to broaden their research by including certain aspects of maritime law (in Oslo) and international law of the sea (in Kiel) respectively. The collaboration between the Institutes will be further advanced by a scientific series entitled „International Law of the Sea and Maritime Law", which will jointly be edited by Doris König (Hamburg), Trine-Lise Wilhelmsen (Oslo) and Alexander Proelss (Kiel). Recent activities also include a workshop on „Marine and Coastal Resources: Risks and Law" which was jointly organized by the Cluster of Excellence „The Future Ocean" JRGs „Seafloor Warming" led by Tina Treude and „Law of the Sea" in October 2008.

RESEARCH: PROTECTION AND USE OF THE OCEANS

Research activities undertaken in 2008 comprised several talks and publications on, inter alia, the legal regime of the Arctic Ocean, the management of marine genetic resources under UNCLOS, the fight against piracy, the protection of marine mammals (together with the research group of Ursula Siebert, Research and Technology Centre Westcoast, Büsum / Germany) and the legality of iron fertilization activities. In an article published in the Heidelberg Journal of International Law („The Legal Regime of the Arctic Ocean"), Alexander Proelss and Till Müller addressed the issue of continental shelf delineation in the Arctic, the competences of the UN Commission on the Outer Limits of the Continental Shelf, the question of passage through the North West Passage, and the protection of the Arctic environment in a comprehensive manner. They concluded that the dispute over the control of the North West Passage as well as the struggle over the resources of the Arctic seabed are adequately addressed by the rules contained in UNCLOS. In particular, contrary to what has been argued to date, a rather large portion of the sea-bed underlying the Arctic Ocean cannot be claimed as extended continental shelf and is, as it forms part of the deep ocean floor, subject to the regime of the Area (Fig. 1).

GOVERNING THE FUTURE OCEAN

The members of the JRG (one professor, one secretary, one post-doc, three PhD students) will continue to undertake research on all pertinent aspects of the law of the sea. Primary attention will be paid to a 1.500 pages commentary on UNCLOS, which will be edited by Alexander Proelss and published by C.H. Beck in collaboration with Hart Publishing in 2011. The treatise will be the first systematic, element by element analysis of the provisions of the Convention and will involve the cooperation of the majority of law of the sea experts worldwide.

WORKING GROUP

Monika Krivickaite, Petra Gnadt, Alexander Proelß, Kerstin Güssow, Ursula Blanke-Kießling, Killian O'Brien

SELECTED PUBLICATIONS

1 | Proelss, A. and Müller, T., (2008).
The Legal Regime of the Arctic Ocean, Zeitschrift für ausländisches öffentliches Recht und Völkerrecht (=Heidelberg Journal of International Law), 68, pp. 651-88.

2 | Proelss, A.
Marine Mammals
R. Wolfrum (ed.), Max Planck Encyclopedia of Public International Law, http://www.mpepil.com/.

3 | Proelss, A., (2008).
Marine Genetic Resources under UNCLOS and the CBD.
German Yearbook of International Law, 51, 31 pp. (in print).

TECHNICAL INFRASTRUCTURE PLATFORMS

To provide technical infrastructure and resources for all scientists within the Future Ocean, a platform concept has been established. Platform P1, Numerical Simulation, recognizes that many aspects of research require access to high performance computing facilities and modern numerical techniques. This expertise and support is offered by a network connecting the Interdisciplinary Center for Numerical Simulation, the Seismic Processing Center and the ocean and climate modeling groups with the Computing Centers at Kiel University. Platform P2, the Tracer Analysis Center, supports research through highly specialized and accurate isotope and trace metal analysis instruments. Advanced techniques have been integrated to offer a comprehensive analytical support. Platform P3, Molecular Technology, comprises high throughput molecular techniques. It greatly benefits from the new Center for Molecular Biosciences (ZMB) recently established in Kiel and pursues improved understanding of human diseases by the study of marine organisms and mechanistic studies of pH-sensitive processes in plankton at the molecular level. Platform P4, Ocean Observatories offers support for in-situ observations of current conditions and on-going trends in the ocean. These require an array of oceanographic sampling and observing platforms. The Technology and Logistics Center for Ocean Observations at Kiel serves as the nucleus for cutting edge technology to explore the ocean over space and time and in remote regions from the oceanic crust to the air-sea interface (P4). The platforms set up in the Future Ocean allow for an efficient use of resources and will be extended according to the needs of the working groups.

P1 | NUMERICAL SIMULATION

Numerical Simulations play a key role in the Cluster of Excellence. They require an infrastructure for high-performance computing, development of interfaces for algorithms and software from different areas, in particular marine science and numerical mathematics, the ability to store and manage data in an efficient way, and to provide expertise from mathematics and computer science for large-scale numerical problems.

The computing infrastructure comprises of a vector machine NEC SX-8 located in the computing center (Rechenzentrum, RZ) of the university which was extended by an additional node for applications computed in cluster projects. The numerical simulation platform also extended the Opteron-Parallel Machine in the computer center, acquired a dedicated server for the processing of Seismic Data together with various hardware upgrades to high performance computer facilities. The platform also provided Software for Algorithmic Dataassimilaton. Platform P1 is predominantly used by the groups investigating Oceanic CO_2 uptake and Ocean Circulation.

P2 | TRACER ANALYSIS

Tracer analysis provides analytical infrastructure for the use of isotopes, trace elements, and trace compounds, which are the basis for marine research. It plays a key role in the research of ocean conditions of the past and has an important role in guiding our understanding of the future ocean. This research requires highly specialized and accurate isotope and trace metal analysis.

Currently the platform comprises a Broadband Laser Light Source consisting of two main components, a mode-locked ps-Nd:YAG pump laser with harmonic frequency conversion unit (EKSPLA, PL2241A), and an optical parametric generator/amplifier (OPG/OPA) with difference-frequency generation (DFG) option (EKSPLA, PG401/DFG2-10P). The laser system combines good spectral resolution (band width <6 cm^{-1}) with very wide detection wavelength coverage (VIS – IR spectral range) and thus acts as a versatile light source.

The platform also maintains a gas chromatograph-coupled isotope-ratio-mass-spectrometer (GC-IRMS) MAT 253 with Gaschromatography-Interface. The instrument enables measurements of H(D), C, and N stable isotope ratios in

organic molecules that are characteristic for certain marine algae or derived from land plants and can be extracted from marine sediments. Stable isotope ratios of D, C, N from long-chained fossil hydrocarbon molecules provide very sophisticated paleoenvironmental indicators for the marine and terrestrial biosphere.

Other instruments are i.e. a quadrupol Mass spectrometer, an ultra-sensitive mass spectrometer for stable isotope analysis in carbonates, a 193 nm Excimer Laser Ablation-Inductively coupled plasma mass spectrometer, a gas chromatography combustion system for an Infrared mass spectrometer. Research platform P2 is mainly used by groups researching the sea surface chemistry, ocean acidification, mineral seafloor resources, seafloor warming and gas hydrate formation.

P3 | MOLECULAR TECHNOLOGY

This platform provides high-throughput molecular technologies to marine biology projects. It was founded in an interdisciplinary approach by three faculties (Medicine, Mathematics & Natural Sciences and Agriculture/Nutrition) to concentrate automated technologies in life sciences.

The platform offer in particular (i) (ultra)high-throughput analyses of genetic diversity, (ii) systematic expression profiling, (iii) robot-assisted cell-based assays including automated genome-wide siRNA transfection protocols, (iv) competitive proteome analysis techniques and (v) high-throughput live imaging facilities.

The infrastructure of platform P3 currently comprises of a Qiagen BR8000 as a workstation capable of high-throughput, walk-away DNA purification from a variety of biological specimen. It is complemeted with a 96-capillary 3730xl DNA Analyzer from Applied Biosystems. These large-scale sequencing capabilities are important for all cluster scientists that work with biological material.

The Biacore X100 System uses a label-free surface plasmon resonance (SPR) based technology which allows to study biomolecular interactions in real time. Protein-protein interaction, protein-ligand interaction or any biomolecule of interest interacting with a specific binding partner can be studied with high sensitivity. This allows understanding biological processes at the molecular level and gains insights into binding events that drive them.

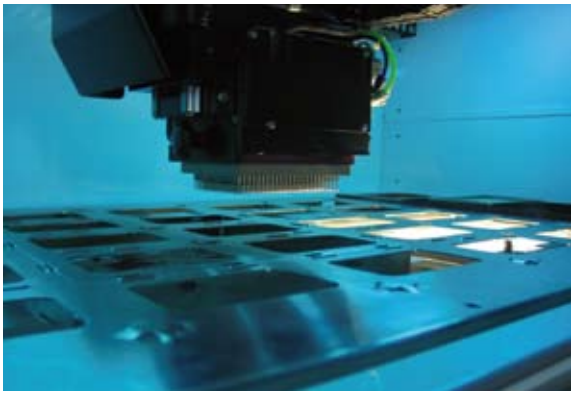
To allow for the nucleic acid extraction step in the processing of field samples for normal and qPCR „sea-going molecular biology equipment" has been acquired for on-board use. The Maxwell™ 16 System is a small automatic purification system for genomic DNA, RNA and protein that can process up to 16 samples in 30 minutes that can be taken into the field, for example, on board a ship. It processes DNA/RNA samples as they are collected, and includes a metagenomic filtration system to rapidly collect size fractions of planktonic organisms.

Platform P3 is mainly used by the Ocean Acidification, Seafloor Warming and Marine Medicine groups of the Cluster of Excellence.

P4 | OCEAN OBSERVATORIES

The Ocean Observatory platform has the mandate to provide multi-facetted observational capabilities that meet the wide range of requirements for research to be carried out within in the Kiel Future Ocean Network. The platform holds instruments deployed at the sea floor, traveling the water column, swimming on the surface or observing from various distances.

Available instruments are i.e. 300 L Mesocosms for replicated shipboard plankton studies with manipulative experiments, benthic mesocosms with oxygen exchange systems for integration into existing bottom landers, an „Ocean Tracer Injection System" (OTIS) for injection of artificial tracer into ocean interior, a continuous imaging flow cytometer (FlowCAM) for real time monitoring of particles in fluids, a controlled aeration system for CO_2 manipulation of seawater in laboratory, mesocosm and field experiments, a shallow-water side-scan-sonar and low-voltage mini-boomer for hydroacoustic imaging in coastal applications, a parametric sub-bottom profiler (SES-2000) for shallow water applications, an optical instrument for in-situ measurement of particle size spectra (LISST-100) for characterisation of suspended matter, a 600 kHz Acoustic Doppler Current Profiler (ADCP) for shallow water applications, seismometers with 8000 m depth capability, Benthos C3D side-scan-sonar for seabed mapping. The platform also applied various special upgrades to the ROV „Kiel 6000" in order to support the cluster's working groups. Platform P4 is mainly used by the research groups working on Sealevel-rise and coasts at risk, submarine hazards, and seafloor resources.



PARAMETERIZATION OF NEAR SURFACE VERTICAL MIXING PROCESSES BY MULTISCALE METHODS

Selected Projects

The project aims to improve the parameterization of near surface vertical mixing processes by applying a 3-D non-hydrostatic Large-Eddy Simulation (LES) model to the surface ocean to explicitly resolve spatial scales ranging from 500 m down to 1 m. The results are compared with different state-of-the-art parameterizations of vertical mixing as used in the existing global ocean circulation models to optimize parameters associated with the parameterizations of vertical mixing and, subsequently, to examine the sensitivity of modelled carbon uptake on the optimized parameterizations.

PROJECT GOALS

The biotic uptake of carbon of the ocean crucially depends on near surface vertical mixing processes. Vertical mixing transports the essential nutrients from the aphotic to the euphotic zone where photosynthesis can take place. This upward flux of nutrients is (in steady state) in turn balanced by the export of organic materials down to the aphotic zone, i.e. it is directly related to the biotically induced carbon drawdown in the ocean (the biological carbon pump). In ocean models these processes have to be parameterized since not all spatial scales can be resolved. These parametrizations are still a source of large uncertainties concerning the carbon uptake of the oceans. State-of-the-art global ocean general circulation models, as used e.g. in the cluster of excellence's working groups to predict future oceanic carbon uptake, resolve at the smallest spatial scales approximately 10 km in the lateral and 10m in the vertical direction due to computational limitations. The effect of important smaller (sub-grid) scale processes on the resolved scales in the model has to be parameterized. Such a parameterization is non-trivial and is one of the main problems in today's attempts to model the ocean circulation and its biogeochemical cycles.

COMPARING APPROXIMATIONS

As a common platform for comparison to the full Navier-Stokes equations project the hydrostatic approximation was implemented as the first task in this project. Subsequently (a) a quantitative comparison of these two models, (b) an assemblage of statistical data of velocity fluctuations for different characteristic ocean situations including temperature and salinity fluctuations were conducted.

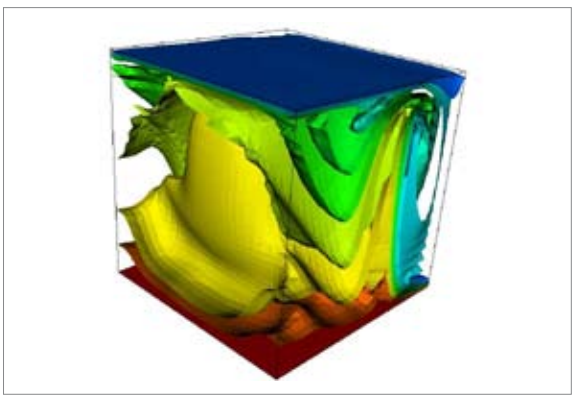


Figure 1 | Temperature field for a variable density flow. A cold fluid is located at the surface while warmer fluid is at the bottom. This configuration leads to instabilities due to higher density fluid above lower density fluid.

The use of the hydrostatic approximation is justified only for the case of a very anisotropic geometry, i.e. the horizontal length L_x, L_y of the computational domain Ω are much larger than the vertical length L_z. Therefore, for a quantitative comparison of the two flow models, we studied the impact of the anisotropy of the computational domain to the relative error in the L^2-norm

$$e(t) = \left(\int_\Omega \|v_{hsa}(t) - v_{nse(t)}\|^2 dx\right)^{1/2} \left(\int_\Omega \|v_{nse}(t)\|^2 dx\right)^{-1/2}.$$

Here, $v_{hsa}(t)$ denotes the velocity solution for the hydrostatic approximation and $v_{nse}(t)$ the velocity of the full Navier-Stokes equations at time t. The mesh size was small enough so that the influence of mesh was negligible.

For the enhancement of the turbulent parameterization, Reynolds stresses of the velocity fluctuations, e.g. $\rho u_i' u_j'$, should be statistically evaluated for the full Navier-Stokes model and compared with the used parameterization of the hydrostatic approximation. To this end, software routines for the evaluation of those terms have been written.

Finally, as an extension of the Navier-Stokes equations an additional equation for the temperature and a variable density was implemented in the local model. The density variations enter into the momentum equation via the gravitation force (Boussinesq approximation). In Fig. 1 the temperature is visualized for a flow with a colder fluid at the top and a warm fluid at the bottom, leading to instabilities and mixing.

OUTLOOK

Upcoming work includes more detailed analysis of the difference of hydrostatic flow and Navier-Stokes flow for higher aspect ratios (> 1000) and for non-constant density flows. Furthermore, the developed routines for monitoring statistical quantities (e.g. Reynolds stresses) will be applied and their results will be compared to the parameterizations of a global ocean model in order to improve them.

PROJECT TEAM

Malte Braack, Heiner Dietze, Carsten Eden, Ulrike Löptien and Madlen Kimmritz (PhD Student)

MODELLING CHEMO-SENSOR AIDED FORAGING IN ZOOPLANKTON

Selected Projects

In many models used to investigate the role of plankton in marine ecosystems, zooplankton predation, which can govern the simulated plankton dynamics, is oversimplified. Moreover, plankton biodiversity is not well captured, although it might enhance the ability of ecosystems to adapt to climate change. From preliminary studies it became apparent that different predation formulations can significantly improve plankton dynamics. Can they also facilitate biodiversity in plankton models?

A NEW MODEL FRAMEWORK

In an introductory study on fitting a formulation for chemo-sensor aided feeding to literature data of feeding experiments it became apparent that capturing the complexity of the feeding process of zooplankton requires a more detailed model. In particular, feeding strategies vary with predator and prey size, and both size-dependent source and sink terms need to be accounted for. In this new model framework, body size of prey and predator should play a central role in governing the feeding behavior.

In the new model, predator and prey abundances are described by size spectra (Fig. 1). Each predator can choose a feeding strategy from a range of possible options, including chemodetection of prey. The different strategies are distinguished by their effect on the prey size spectrum (size signature). Their benefits are compared using the predator's energy budget, where the size-resolved ingestion rates constitute the source terms. Sinks are costs for maintenance, production of structural material and motility. The optimal feeding strategy for a predator of given size is the one giving the highest ingestion at lowest cost in the current prey environment. At every instant, a predator can adapt its strategy and thus react to changes in the prey environment.

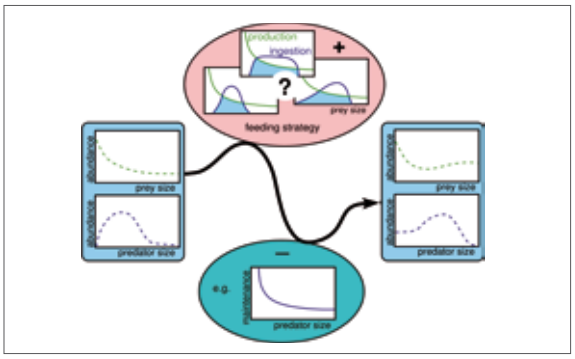


Figure 1 | Schematic of the proposed model. Predator and prey are described by abundance size spectra (blue boxes). The predator's energy budget consists of source terms (pink box) and sink terms (turquoise box). Energy sources are feeding strategies differing in their effect on the prey size spectrum, and their net yield (blue areas under ingestion curves). Energy sinks are e.g. size-dependent maintenance costs.

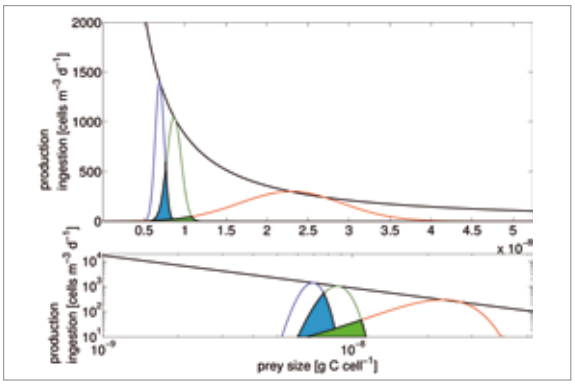


Figure 2 | Ingestion size spectra of three predators (body sizes 410 µm Equivalent spherical diameter ESD, blue; 440 µm, green; 610 µm, red), assuming a gaussian ingestion spectrum. Black line: oligotrophic production from field observations. Blue and green areas indicate ingestion shared between predators due to overlapping prey size ranges.

PRELIMINARY RESULTS

A steady state calculation was conducted to investigate the potential effects of implementing different feeding strategies in a size-resolved plankton model. With the assumptions that a) all prey production is consumed and that b) feeding strategies can be represented by Gaussian or log-normal curves, ingestion size spectra were calculated for predator and prey of different sizes, and for different feeding strategies. Input parameters were total and maximum ingestion from literature data as well as a fixed optimum prey size.

The resulting curves demonstrate that while large predators occupy wide ecological niches on the prey size spectrum, small predators have narrower prey size ranges. Thus, large predators dominate a wide niche and lead to low predator diversity, whereas a greater number of small predators can coexist on a given prey size range and allow for higher predator diversity. Here, whether predators compete or coexist, depends on the available production that needs to be shared between the predators.

Different feeding strategies, here Gaussian vs. log-normal distributions calculated from the same total and maximum ingestion, affect different prey sizes, and differ in the total prey size range. In this way, a particular feeding strategy can be better suited to a given prey environment than another. The size signature of the feeding strategy can impede the invasion of the ecological niche for other competing predators. The choice of feeding strategy can also shape the trophic structure of the ecosystem by targeting a different size class.

PROJECT TEAM

Andreas Oschlies, Markus Pahlow, Ulf Riebesell

EFFECT OF INCREASED CO_2 ON CELLULAR ION TRANSPORT MECHANISMS

Selected Projects

The long term consequences of anthropogenic CO_2 rise in the ocean hit all marine organisms from the starting point of the nutritional chain to complex organisms. Protists, for example, suffer in respect of the formation and calcification of shells. Marine worms exhibit only limited tolerance to chronically elevated CO_2 and react to this impairment with a substantial decrease in synthesis of function proteins. To monitor the state of ion transport and homeostasis in organisms, organs or at the level of single cells we provide different techniques established in mammals that will be adapted to new organisms and cells.

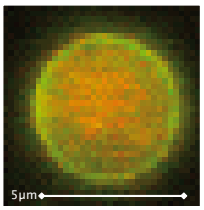


Figure 1 | Microfluorimetric measurement of cytosolic pH. Confocal image of *Emiliania huxleyi* protoplast after fluorescent dye loading.

This project investigated the effects of changes in ambient pH and pCO_2 on marine model organisms at the cellular level. Membrane transport and compensatory mechanisms for cellular pH homeostasis are measured by electrophysiological and microfluorimetric techniques. The selected two marine calcifying organisms *Emiliania huxleyi* and *Coccolithus pelagicus* were continuously cultured in the lab and the respective conditions haven been optimized to obtain highly viable cells in a regular fashion. The original cell preparation for measurement of cytosolic pH (pHi) has been modified to obtain protoplast preparations with improved dye loading and which can be used in parallel for patch clamp investigations. Cells were loaded with the dye BCECF-AM (Bis-(carboxyethyl)-5(6)-carboxyfluoresceinacetoxymethylester) and fluorescence intensities are recorded by video imaging and confocal microscopy (Fig. 1). Calibration and dye loading were optimized for time constancy.

Out of equilibrium solutions for the isolated measurement of cell membrane permeabilities for CO_2, HCO_3^- and H^+ were generated and applied. Immunofluorescence was observed in coccolithophorids with antibodies against transporters and carbonic anhydrases.

RESULTS

Ambient changes in pH directly influence pHi values significantly as shown in Fig. 2. Data is comparable for both *C. pelagicus* and *E. huxleyi* and in the investigated time frame no obvious compensation by cellular mechanisms could be observed. The data shown in Fig. 2 strongly suggested the existence of an H^+ transport pathway across the plasma membrane. In the next experimental series we investigated whether this pathway was depending on extracellular Cl^- or K^+ concentration. Changes in pHi were most prominent for Cl^- in *C. pelagicus*. The measurements in *C. pelagicus* and *E. huxleyi* indicate that H^+ uptake is either directly or indirectly coupled to the concentrations of K^+ and Cl^-. The coupling could be either via Cl^- or K^+ dependent membrane voltage, or via Cl^- coupled acid/base transporters. To distinguish between these pathways it became necessary to change the ambient concentrations of CO_2 / HCO_3^- /H^+ out of equilibrium. We adapted the respective methods and focused on *E. huxleyi*.

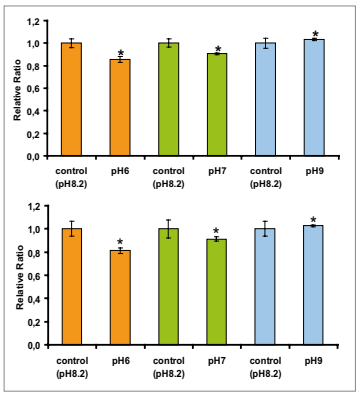


Figure 2 | pHi depends on ambient H+ concentrations. Relative changes in fluorescence ratio in C. pelagicus (top) and E. huxleyi (bottom). A decrease in ratio corresponds to acidification.

In addition to the H^+ permeability, experiments with out-of-equilibrium solutions (OOE) for CO_2 / HCO_3^- /H^+ revealed a surprisingly low CO_2 permeability of E. huxleyi and a permeability for HCO_3^- (Fig. 2). Interestingly, influx of HCO_3^- resulted in an acidification of the cell. Based on these findings we were able to design a first draft of a cell model to generate hypotheses on the transporters and ion channels involved (Fig. 3).

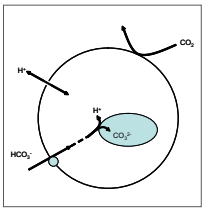


Figure 3 | Draft model of putative pathways for HCO_3^-, CO_2 and H^+ in E. huxleyi. Experiments indicate a direct H^+ pathway, probably via ion channels, acidifying the cytoplasm as well as the chloroplasts. CO_2 permeability seems to be tightly controlled over the plasma membrane, an external application of high CO_2 showing no detectable effect on pHi. External application of HCO_3^- acidified the cytoplasm and chloroplasts. The acidification could be explained by immediate metabolism of HCO_3^- and compartmentalisation of CO_3^{2-} leaving H^+ in the cytosol. Golgi-derived vesicles or the coccolith vesicle itself are likely compartments. Experiments with ion replacements suggest either a Cl^- coupled HCO_3^- uptake step or the presence of anion channels permeable for HCO_3^-.

OUTLOOK

Future projects will concentrate on the search of candidate transporters and channels in *E. huxleyi* genome. Permeability data will be introduced into *E. huxleyi* computer model for ion fluxes. Finally pharmacological and functional profiling of membrane permeability will be combined with electrical measurements.

PROJECT TEAM

Markus Bleich, Ulf Riebesell, Kerstin Suffrian

3-D MODELING OF SEAFLOOR STRUCTURES FROM ROV-BASED VIDEO DATA

Selected Projects

Underwater objects and structures like black smokers, ship wrecks, or coral reefs, which can only be observed by diving personally or operating a ROV, are difficult to study. Among the data providing information about such objects are often image sequences. The goal of this project is to analyze the feasibility and limitations of structure from motion (SfM) algorithms for 3-D reconstruction based on underwater images. 3-D models computed by this approach are detailed visualizations of the object or scene in question and can be used for volumetric measurements, documentation, and presentation to the general public. In this project video data of black smokers recorded by the ROV Kiel 6000 (Fig. 1) is analyzed.

Figure 1 | ROV Kiel 6000

FIRST RESULTS

So far, the algorithm can be applied to rigid local seafloor structures and it has been possible to reconstruct several parts of the black smoker. In order to accomplish that, the ROV's HDTV camera has been calibrated. Fig. 2 shows the general structure of the algorithm. Images are related to each other by 2D-2D correspondences. The algorithm is initialized by estimating the epipolar geometry between two frames. Triangulation results in a sparse 3D point cloud, which allows reconstructing the remaining camera path by adding camera poses through 2D-3D camera tracking. Via computing dense depth maps, the sparse 3D point cloud is filled further, finally resulting in a 3D surface model. Some adaptations to the special underwater imaging environment have been made: a segmentation step detects the background containing only water and allows filtering erroneous 2D correspondences and entries in the dense depth maps. A color correction approach based on a physical model for light propagation underwater allows the correction of the bluish or greenish hue always present on underwater images. Figure 3 shows some results of the algorithm: a reconstructed camera path, a resulting model, and the same model with corrected colors.

OUTLOOK

During the next months a new set of image sequences that has been recorded in January this year will be analyzed. In addition, the algorithm will be expanded to enable merging several subsequences into one large 3-D model. The color correction routines will be tested on the new image sequences.

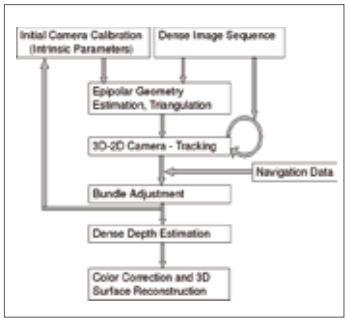


Figure 2 | Overview SfM algorithm.

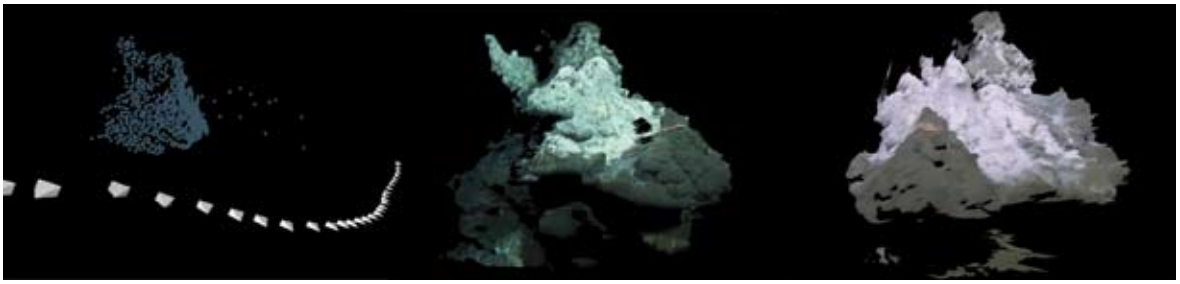


Figure 3 | 3D point cloud with camera path, middle: 3D model, right: 3D model with repaired texture colors.

PROJECT TEAM

Reinhard Koch, Colin Devey, Thomas Kuhn, Lars Rüpke

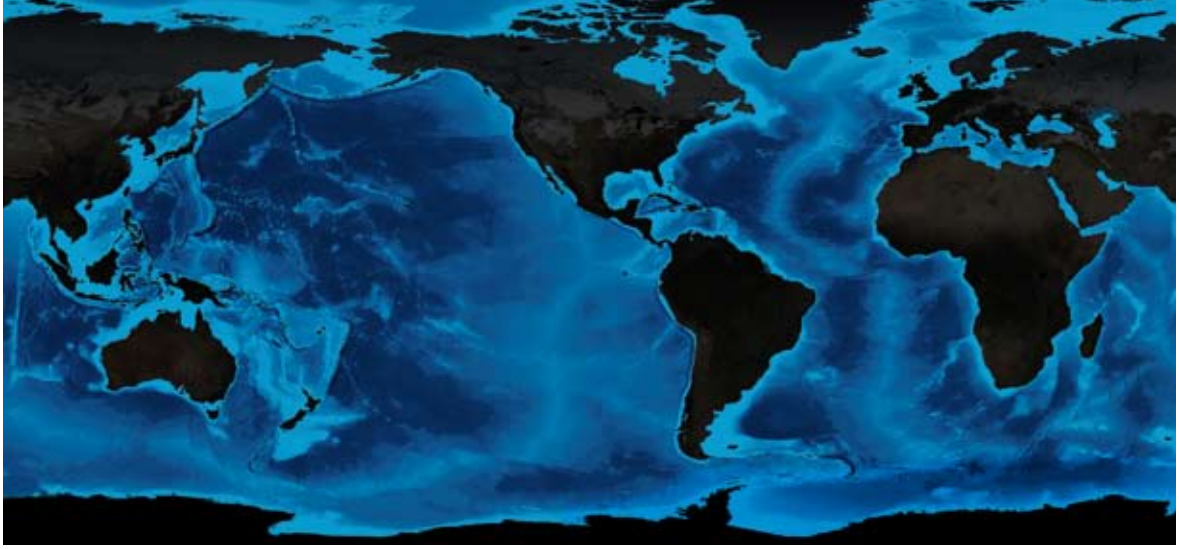
SELECTED PUBLICATION

Anne Sedlazeck, Kevin Koeser and Reinhard Koch (2009): 3D Reconstruction Based on Underwater Video from ROV Kiel 6000 Considering Underwater Imaging Conditions IEEE OCEANS Conference 2009, Bremen, Germany.

THE SERVICES

„The system of life on this planet is so astoundingly complex that it was a long time before man even realized that it was a system at all and that it wasn‘t something that was just there.“

Douglas Adams



INTERNAL AND EXTERNAL COMMUNICATION IN PUBLIC OUTREACH

Scientific topics are well-established in the media, visitor numbers at science festivals like on the scientific outreach vessel Jenny are on the increase and out-of-school learning facilities, such as science centres, experimental sessions or universities of the first age, are growing in popularity. Therefore, the Public Outreach group in the Cluster of Excellence „The Future Ocean" is pursuing the aim of directing public interest in science to maritime and interdisciplinary research subjects as well as promoting a dialogue between science and society over the long term (Fig. 1).

INTERNAL NETWORKING AS A PRECONDITION TO EXTERNAL COMMUNICATION

The more than 140 scientists of The Future Ocean research network are based in various locations on campus as well as at the four individual institutions in Kiel. Research is carried out within working groups, who themselves often bridge more than one location. Exchange of information either in person or via specific media did not take place in a formalised manner. The challenge for the public outreach project was therefore to create tools for internal communication that, on the one hand, provide information for all members and, on the other, contribute to the new working group leaders, members of staff as well as principal investigators, being able to identify themselves with the goals of the research network and thereby invigorating the spirit of the project.

A number of measures have been adopted in this respect:

- An internal monthly newsletter (named INTERN) was drafted. The newsletter mainly serves to disseminate inter disciplinary academic publications relating to the cluster, to introduce new members and employees, to announce visiting academics, events or news that contributes to building the network. Eleven newsletters were published in 2008.
- The internal lecture series „Blaue Stunde" was launched which serves as a platform for the Junior Research Groups (JRG) to introduce their main areas of research (Figure 2). The aim is to improve networking amongst the members of the working groups. Four events were held by JRG heads in 2008: In May, Alexander Proelß presented an introduction to international maritime law and its significance for the exploitation of resources in the deep sea. In July, Gernot Friedrichs reported on his research group's current project „Ocean Surface Chemistry and Reaction Kinetics" and offered a guided tour in the new laser laboratory. In August, Kerstin Schrottke reported on new measuring equipment and methods used on the research vessel Littorina. In December, Tina Treude presented the current research projects being carried out by her research group at the Technical and Logistics Centre of IFM-GEOMAR.

BRANDING THROUGH UNIFORM PUBLIC IMAGE

In 2008, teachers and students at the Muthesius Academy of Fine Arts created a specific corporate design for the cluster of excellence which was used in the production of cluster

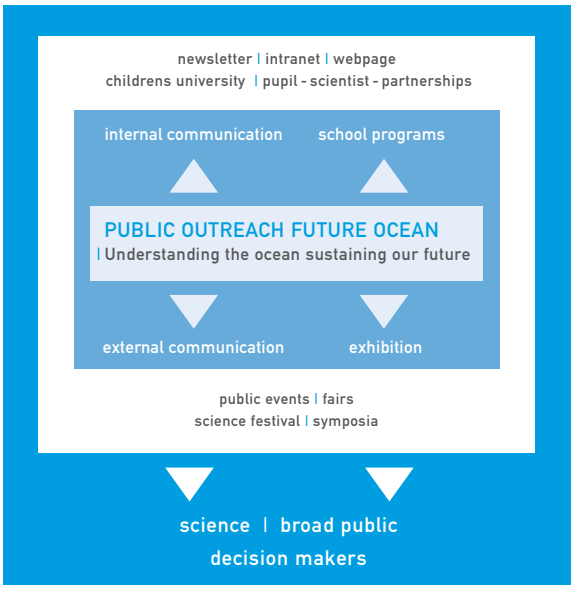


Figure 1 | Public Outreach: Science communication.

Figure 2 | "Blaue Stunde": Kerstin Schrottke reports on new measuring equipment.

Figure 4 | About 200 Participants attended the panel discussion "The Future Ocean" which was chared by Gerald Traufetter, Science editor of Der Spiegel, europes largest news magazine.

flyers, the www.ozean-der-zukunft.de website, as well as posters and presentations. Thanks to this corporate design contributions of the Cluster of Excellence „The Future Ocean" made at conferences and events are clearly distinguished as being part of the cluster. Thus the profile of the cluster of excellence in both the scientific community and public is raised. A large number of printed products such as posters or flyers have been produced. The recent image film produced by the Land Schleswig-Holstein entitled „Sea - Our Future" on marine and maritime beacon projects included sequences on the laser laboratory of Gernot Friedrichs and networking in the cluster of excellence. In the fall of 2008 the German Research Foundation (DFG) launched a campaign for an online video portal which was designed to introduce all of the organisations funded within the framework of the Excellence Initiative with a short film. Against this background the Public Outreach group produced a draft for a short film on the future ocean and casted the suitable actors. The film was shot in one day in fall 2008 (Fig. 3).

PUBLIC EVENTS

The public outreach team organises lectures and panel discussions on topics of the cluster of excellence for the interested public. The cluster of excellence, in conjunction with the Leibniz Institute of Maritime Sciences (IFM-GEOMAR), has organised the public „Kieler Woche" lectures within the framework of the world's largest sailing event and the largest public festival in northern Europe. The subjects spanned topics from ocean observation systems to marine medicine and the dispute on the situation in the Arctic region concerning international law. The lectures were well-attended with an average of 60 participants. Under the title "The oceans and global climate change – a challenge to society and economy", the cluster of excellence organised a public panel discussion during the 2nd Bi-Annual Symposium "The Future Ocean". In the Kiel University's Museum of Art Professor of meteorology Mojib Latif (IFM-GEOMAR) and Professor for economy Till Requate (Kiel University) highlighted the consequences of oceanic and climate change from different perspectives (Fig. 4).

Figure 3 | Making of the Cluster Image film: Interview with Speaker Martin Visbeck.

FUTURE OCEAN EXHIBITION

The exhibition „Future Ocean“ - a travelling exhibition with modular exhibits - communicates the scientific topics pursued by the Cluster of Excellence „The Future Ocean“ in Kiel. Guided by questions such as „Who owns the ocean?“, „Can we still eat fish tomorrow?“ or „How can we store greenhouse gas in the ocean?“, visitors are given more information on marine research and on how apparently disparate topics like the „Law of the Sea“, „Fisheries“ or „Seafloor Resources“ are interconnected. The exhibition „Future Ocean“, was the highlight of knowledge communication in 2008.

Figure 1 | The floating science centre MS Wissenschaft: Prof. Dr. Ing. Matthias Kleiner, President of the German Research Foundation (DFG), Thomas Rachel, Parliamentary State Secretary of the Federal Ministry of Education and Research, Annika Wallaschek and Martin Visbeck next to the Cluster exhibit.

After a number of successful presentations in 2007, the Muthesius Academy of Fine Arts in collaboration with the marine scientists designed a permanent exhibition entitled Future Ocean in the International Maritime Museum of Hamburg. The museum in the historical dock warehouse B in Hamburg's Hafencity guides the visitor through more than 3,000 years of maritime history. Located on deck seven, the maritime science floor, the „Future Ocean” exhibition covers some 120 m² and is supposed to spark visitor interest in maritime research. At the exhibition visitors can i.e. learn more about the dynamic of ocean currents, the origin of tsunamis, the consequences of acidification of the oceans or about maritime law. Three exhibits stand out in particular: The three-dimensional world map „Kiel world relief” from the Institute for Geosciences at Kiel University, a digital globe that projects images and films through a fish eye wide-angle lens and an ocean observatory that shows modern maritime research equipment in a scale of 1:10. As part of the official opening on 25 June 2008 by Federal President Horst Köhler, Prime Minister of the state of Schleswig-Holstein Peter Harry Carstensen and Hamburg Mayor Ole von Beust, particular attention was paid to the area of „the Future Ocean” (Fig. 3). 90,000 people had visited the museum by the end of 2008. The maritime science floor is one of the main attractions and demonstrates the high national and international standing of the Kiel maritime sciences.

Individual modules and subjects of „The Future Ocean” exhibition were also displayed in 2008:

- on the scientific outreach vessel Jenny - Subject: Year of mathematics. Exhibit: Ocean current and mathematics. Date: May to September, exhibited in 30 towns and cities throughout Germany (Fig. 1)
- at the Schleswig-Holstein Day in Neumünster (Germany). Exhibits: Overfishing (AquaMaps/FishBase), ocean currents. Date: 11 to 13 July 2008;
- at the „German Unification Day”, Hamburg (Germany). Exhibit: Future Ocean Explorer and research equipment. 3 to 5 October 2008; (Fig. 4) and
- at the XVIII Malente Symposium „More than Water - Oceans and Global Responsibility”, organised by the Dräger Foundation, ZEIT Foundation and the Cluster of Excellence „The Future Ocean”, 12 to 14 October 2008 (Fig. 2).

All in all, the target groups of political decision makers, the scientific community, the wider public and school classes were successfully reached through the Future Ocean public displays.

Figure 2 | Presentation of the Future Ocean at the XVIII Malente Symposium "More than Water".

Figure 3 | Federal President Horst Köhler, Hamburg Mayor Ole von Beust and Schleswig-Holstein Minister-President Peter-Harry Carstensen paid special attention to the Future Ocean exhibition in the International Maritime Museum in Hamburg.

Figure 4 | Presentation of the Future Ocean Explorer at the „German Unification Day"

FUTURE OCEAN EXPLORER

New pathways of transmitting information on marine science to the wider public have also been taken. To achieve this public outreach strove to set standards in communication technology. The goal was, to place the visitor in the role of an active researcher. For this purpose, the Muthesius Academy of Fine Arts combined a number of concepts, centering around the idea of the development of a multi-touch table, called the Future Ocean Explorer. Technological and interactive options, including a multi-user interface, were used in the Future Ocean Explorer to represent the interaction of scientific issues in the cluster of excellence. Moreover, an intuitive interactive concept was also developed. Issues come to the surface from the depth of a „water basin" in the form of little fish from a swarm. The observer has a free choice of four sets of special topics, such as „Oceanic change" or „CO_2 and climate". The development was a joint project between professors of communication and interior design from the Muthesius Academy of Fine Arts as well as freelance media designers. The scientific content material for the Future Ocean Explorer was developed jointly by designers, scientists and the Public Outreach team. It was implemented as films, interviews, informative texts and animations.

FUTURE OCEAN ON THE GERMAN UNIFICATION DAY

The Future Ocean Explorer was first introduced to the general public at the state presentation of the state of Schleswig-Holstein at the „German Unification Day" in Hamburg from 3 to 5 October 2008. The digital exhibit was set in the deep sea environment and shown in conjunction with maritime science research equipment. More than 10,000 visitors saw the presentation of the cluster of excellence in Hamburg, which showcased Schleswig-Holstein as a leading region for maritime research.

The close cooperation with the state government of Schleswig-Holstein at representative events documents the strategic significance of public relations work as part of the Cluster of Excellence „The Future Ocean". It is clearly aimed to establish a specific public image of the state of Schleswig-Holstein throughout Germany, focusing on marine and maritime research. The Future Ocean contributes to the profile of the State of Schleswig-Holstein and its capital city Kiel far beyond the borders of the region.

WORKING GROUP

Annika Wallaschek, Friederike Balzereit, Mette Lüning, Katrin Knickmeier

Public Outreach activities are jointly organized by the PO-Group (see above), Gerd Hoffmann-Wieck (IFM-GEOMAR), and Manfred Schulz, Tom Duscher, Stephan Sachs from the Muthesius Academy of Fine Arts.

SCHOOL PROGRAMS

To address the next generation of science students and to transfer the latest scientific knowledge directly to schools, „The Future Ocean" together with its partners offers various opportunities for joint experiments for pupils/students in the laboratory, at sea, and through public lectures. In 2008 the emphasis on practical work within the existing network of ten partner schools was continued and extended. To reach a wider audience of younger pupils the Childrens University „The Future Ocean" was started. Major activities in 2008 were:

CHILDRENS UNIVERSITY 2008

The Childrens University „The Future Ocean", at the University of Kiel is the first Childrens University in Germany with an exclusive focus on marine topics. Six professors from different fields of marine science of the Future Ocean introduced children into their research. The scientists reported on the relation of ocean and climate, global warming, robots in ocean science, molecular mechanisms in marine organisms, the ocean and the human anatomy, overfishing, and marine mammals. Three lectures were targeting pupils aged from 8 to 12, the other three aimed at students aged 12 to 16. During these lectures the potential future scientists experience the excitement and fascination of marine sciences. Each lecture is complemented with handouts in order to allow the audience to review the content at home. Videos of each of the lectures are produced as well. Handouts and videos are made available for download from the Future Ocean website (www.ozean-der-zukunft.de) for the interested public. All content is made available online free of charge, in order to enable students, parents and teachers to learn more about marine systems and the latest scientific findings. During the 2008 lecture series more than 1,500 students visited the Childrens University in Kiel.

In order to evaluate success and impact of the Childrens University teachers are asked to provide feedback on the lectures and the handouts, as well as their success to communicate marine science into the classroom. The general response was extremely positive. The first Childrens University „The Future Ocean" generated a very high attention by the public media, mainly in newspapers, but also on TV, radio and the internet. The event is listed on the German Children University directory (www.die-kinder-uni.de) and is a member of the European Children's Universities Network (http://eucu.net/).

The Childrens University „The Future Ocean" at Kiel University communicates latest research topics to school kids. The goal is, to established the activity as a permanently recurring event at the University of Kiel with changing topics.

Figure 1 | More than 1500 school kids were listening to the lectures at the Children's University „The Future Ocean".

Figure 2 | Tammy and Lisa high school pupils at Gymnasium in Heikendorf on their first research cruise.

RESEARCH CRUISES

„The Future Ocean" organizes participation of pupils on research cruises. In 2008 the project supported three pupils from Kiel and two pupils and a teacher from Cape Verde to join a research cruise on the german research vessel *Maria S. Merian*. The expedition started from Mindelo, Cape Verde Islands into the equatorial Atlantic. The pupils worked as part of the scientific team and reported on their activities and experiences in public talks and interviews after their return.

THE OCEAN IN A BOX

„The Ocean in a Box" is a compilation of twelve boxes containing marine science books targeted on students for long-term loans to Future Ocean partner schools. Two boxes are placed in the public libraries of IFM-GEOMAR for loan by interested schools and parties.

STUDENTS PARTNER RESEARCH PROGRAMME

Students work together with teachers and marine scientists on special research projects. The work can take place individually (special learning achievements) or in groups (e.g. enrichment courses, visits to institutes, interviews with scientists). The results of the project are presented on various opportunities, i.e. NaT-Working symposia, science festivals for students, or open days in schools.

EXPEDITION BOXES

For schools interested in further studies on marine sciences, five expedition boxes on the subjects of hydrology, marine chemistry, plankton, benthos, and climate change (CO_2) are provided. The boxes are set up as a modular system. The plankton box i.e. contains everything necessary for plankton research: plankton nets, water sampler, boxes for plankton cultures, books for species determination, a teaching manual for teachers. If the teachers are additionally interested in nutrient analysis, tools of the marine chemistry box can be added. The manuals of all boxes have been written by scientists and teachers. The content of the boxes is described on the website and can be ordered upon consultation by any teacher interested in marine research. Teachers can borrow these boxes for use in their schools for project work, for biology, chemistry, and physics. The boxes were first used to train teachers at the 2nd Symposium NaT-Working Marine Research at IFM-GEOMAR in November 2008.

Figure 4 | Expedition Box Benthos and invasive species.

OUTLOOK

The plans for school programme outreach activities for 2009 are:

The Childrens University on marine sciences at the University of Kiel for kids aged 8 to 16 will be continued. In cooperation with the Cornelsen-Verlag, Berlin, the Future Ocean coordinates the publication of a small school book (64 pages) on marine sciences. The book puts a special focus on Future Ocean topics. We plan to continue the cooperative projects for students and scientists on relevant research issues. The cooperation with Federal Environmental Award (BundesUmweltWettbewerb, coordinated by IPN) shall be furthered. A special price was awarded for the best „Future Ocean – too high, too warm, too acidic" project in 2008/2009. The project „research holidays" (Forscherferien by IPN), half-day excursions to the beach carried out for 3rd and 4th grade pupils, shall make the children familiar with the flora and fauna of the sea in their immediate vicinity. Future Ocean plans to organize a four day excursion with the research vessel Littorina on the baltic sea for pupils. This will include a one-day training course in marine sciences for teachers.

Figure 3 | Ursula Siebert (left) works with pupils.

ORGANISATION AND SUPPORT

The school programs are organized by the Cluster of Excellence „The Future Ocean" and the project „NaT-Working Marine Research" at the Leibniz Institute for Marine Sciences (Joachim Dengg). The Childrens University is a collaboration of the former and the Leibniz Institute for Science Education at the University of Kiel (IPN), with technical support from the computer center of the Kiel University. It is actively sponsored by the Foundation „Stiftung 200 Jahre Sparkasse Kiel" and promoted through a media partnership with a major local newspaper ***Kieler Nachrichten*** and ***Geolino***, a nationwide popular science journal for kids.

SUPPORTING FUTURE OCEAN SCIENTISTS: THE INTEGRATED SCHOOL OF OCEAN SCIENCES

What comprises excellence in graduate education – how can the cluster bring together PhD students from marine disciplines as diverse as law, natural sciences and economics on a common platform? How best to establish a structural base for marine science education that reflects and supports marine sciences as a thematic focus of the Christian-Albrechts-Universität zu Kiel?

What comprises excellence in graduate education – how can the cluster bring together PhD students from marine disciplines as diverse as law, natural sciences and economics on a common platform? How best to establish a structural base for marine science education that reflects and supports marine sciences as a thematic focus of the Christian-Albrechts-Universität zu Kiel?

To address these issues the Integrated School of Ocean Sciences (ISOS) was set up within the Cluster with the goals of a) implementing a research-driven and career-focussed PhD programme, b) implementing an e-learning platform for marine science education, c) supporting proposals for research and training to national and EU funding agencies and d) initiating and coordinating cooperation in graduate education with national and international partners.

From the start, the ISOS concept for a high-level PhD programme was based on the provision of tangible additional benefit for each participant. With participants from very diverse fields, we decided to shape the programme as it developed by offering courses tailored to the specific needs of the participants, by experimenting with new, innovative components and by continually orienting ourselves on feedback from PhD candidates and Cluster members. Since participation is entirely voluntary (i.e. PhD candidates "vote with their feet") the explosion of the programme from a projected 30 to – at the time of going to press – over 100 participants suggests that we have tapped a large, and previously unfulfilled, need. ISOS is open to graduates irrespective of their funding sources (fig. 2) – over half are funded by projects outside the Cluster – and thus functions as a graduate center for marine sciences at the University.

As a graduate school, ISOS has built up course offers in all aspects of marine sciences, with input from Cluster members and particularly profiting from the multidisciplinary network and enthusiasm of the 13 new cluster professors. A strong aspect of the programme involves harnessing key players from outside the University – many of them alumni eager to contribute – from marine consultancies, NGOs, scientific publishers, policy-making organisations and other Universities. The broad spectrum of scientific topics, career paths, the opportunity to discuss at a personal level and the laying of a broad network are important aspects at the ISOS.

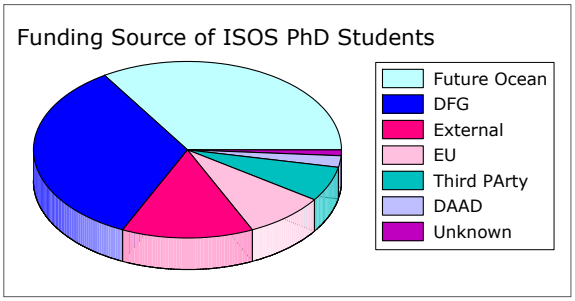


Figure 2 | Sources of funding for the ISOS PhD students. By far most of the students come from DFG funded projects (incl. Future Ocean.

Figure 1 | Hands-on experience at sea is a major attraction for marine scientists.

Figure 3 | Learning from ones peers: interdisciplinary networks start at the early career stage.

PhD RETREAT

Discussing common themes in a socially conducive atmosphere – the ISOS PhD retreats are two-day events providing an opportunity for PhD candidates to address a theme of common interest, network with other PhD students and pick up new idesas. Invited experts give input and insights into their fields, and share personal experiences. For these retreats a group PhD-organisers work with the ISOS office to choose the theme and the invited guests.

In May 2008 doctoral candidates from all the natural science disciplines, informatics, medicine, law and economics met for the second ISOS PhD Retreat. The chosen location at the Nordkolleg Rendsburg with its open gardens offered a great opportunity for an informal get-together. Building up on previous only partly successful communication efforts – e.g. how can a modeller enthuse a lawyer for her/his topic? – the theme chosen was "Communication". We devoted the first session to communication at the public stakeholder level, the second session to communication for a broad-based scientific peer group. Below is a short report from the PhD-organisers!

Figure 2 | Getting together across the disciplines: ISOS PhD Retreat.

Figure 1 | Communication: an integral part of science

Figure 3 | Learning about the evolution of popular science articles.

NO SCIENCE WITHOUT COMMUNICATION

To be a scientist is to be a player in different leagues - increasingly it is important for us to communicate our work to peers and prospective employers, but also to the public, family and friends. To be introduced to these leagues and to get insights into the "rules" of the communication within them was the main focus for this retreat. It is the responsibility of scientists to use different communication ways in order to get "the news" to "the people" with quite different background knowledge. This task is very challenging but also enjoyable.

Nikolaus Gelpke, chief editor of the German culture and feature magazine MARE (www.mare.de) gave insights into the "evolution" of a popular science article. Furthermore in a subsequent workshop and under his tutelage the participants had a lively discussion on some very interesting topics from current research. The PhD. students had prepared outlines beforehand with the objective of producing an interesting "suite" for publishing in MARE. So we might be surprised to read one of these in a future MARE-issue.

Foremost, however, publications in original research journals are an important part of scientists' every day life. Thus, the retreat was accompanied by Matthias Seaman and Hans-Heinrich Janssen from Inter-Research, a German scientific publishing house. Both editors gave very good advice and an insiders view on how to prepare manuscripts for publication and how the review process is conducted.

But written communication is not the only communication. To complement the theme for this retreat, a session of communication within the PhD group was planned. Participants were asked to introduce the others to their research in a limited amount of time. The challenge was to get the "message" through and not to loose the audience. This exercise was very good and benefited everyone. Clearly, we all have a lot to learn and practice in this area!"

WEB-BASED LEARNING

e-Learning activities at ISOS focused on the consolidation and extension of the e-learning base for Kiel marine science education and the accompanying e-learning strategy and services established in 2007. A portal website gives access to the e-learning base offering course materials and e-learning content at the master and graduate levels (Fig. X-a). By the end of 2008, 60 courses and up to 800 active users were registered with participants from each cluster relevant discipline.

Services for members of the Cluster of Excellence include individual consulting and trainings in the use of the e-learning system and in the development of e-content units. The overall strategy is to extend existing learning resources with dynamic and interactive e-content of different types (Fig. X-a) on a course-by-course basis. This extension strategy, which is is widely accepted and extensivley used by teachers, allows to stepwise increase the interactive e-content parts in their courses and, hence, to add educational value.

The production of e-content will be organized in small temporary satellite teams (Fig. X-b) consisting of teachers/authors, student assistants and members of the ISOS e-learning group. Teams are organized by the ISOS e-learning coordinator. Following this approach, ten content-related projects have already been realized and several more are in development. Techniques used range from interactive video lectures and online tests to discipline specific media production (like video recordings and high-end animal photography as educational resources for an online course on the identification of marine animals) or complex educational simulations (e.g. in fishery ecology and economy). Even complete courses have been extended to open online resources with connection to scientific data bases (i.e. Fish Base).

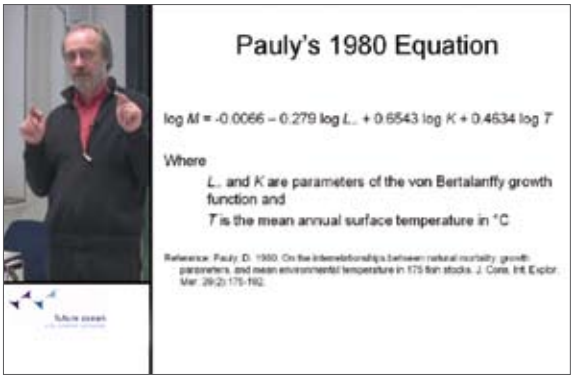


Figure 4 | Screenshot of the video lecture project „Biodiversity of fishes" by Rainer Froese, IFM-GEOMAR. Talk and slides are combined in a video including a slide to slide navigation

On university level, the ISOS e-learning strategy and networking has led to the constitution of a service center for e-learning and new mediat o be established in 2009. This service center will take over some administrative activities concerning platform and users, which will reallocate resources within the ISOS e-learning for new activities directing to social learning and networking and knowledge sharing.

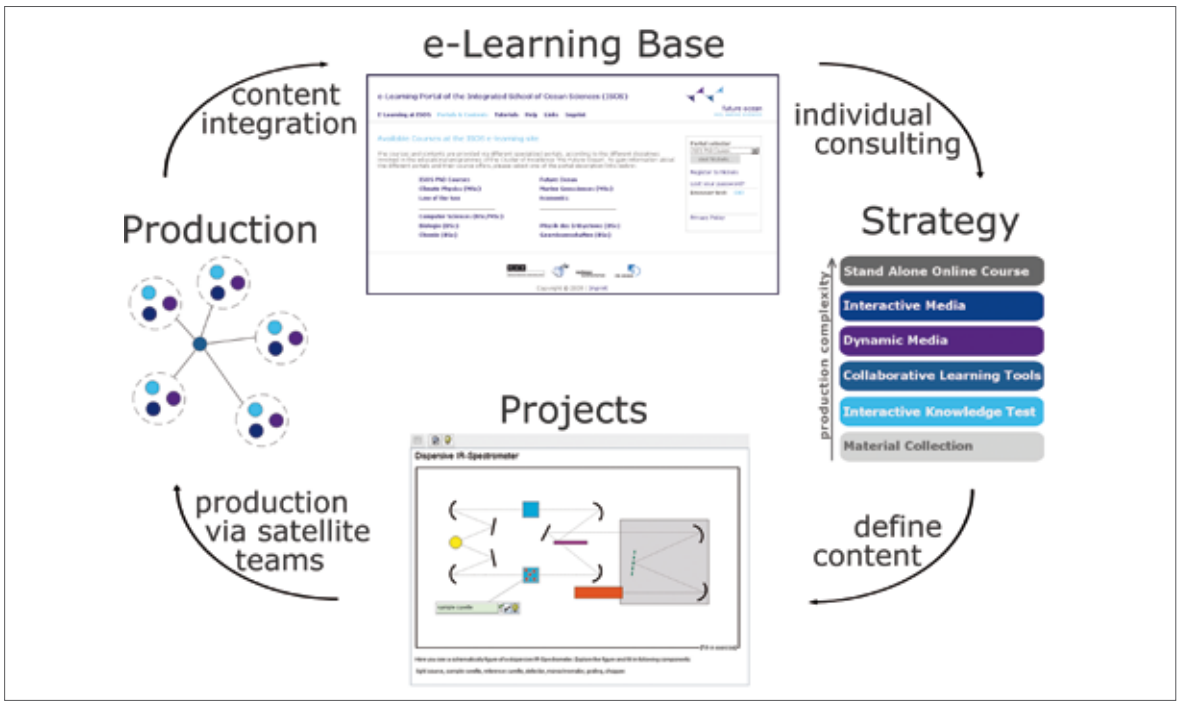


Figure 3 | Illustration of the ISOS e-learning extension strategy: In close cooperation with the ISOS e-learning team cluster members can develop, produce, disseminate and share specific educational resources and integrate web based strategies for teaching and learning in their courses.

VISITING SCIENTISTS

RALPH KEELING

Prof. Dr. Ralph Keeling from Scripps Institution of Oceanography in San Diego, USA, is spending a one-year sabbatical with the Cluster of Excellence „The Future Ocean" at the Leibniz Institute of Marine Sciences from summer 2008 to summer 2009. Ralph Keeling is one of the worldwide leading experts in the area of atmospheric gases, in particular oxygen. His research has focused primarily on atmospheric processes but he has recently turned also to studying oxygen in the ocean. Here in Kiel he will work in particular with the Cluster of Excellence „The Future Ocean" and the Collaborative Research Centre 754 „Climate-Biogeochemistry Interactions in the Tropical Ocean" at the IFM-GEOMAR. Thus, Prof. Keeling gratefully accepted the invitation to spend a one-year research sabbatical in Kiel.

„Since 20 years my measurements show a continuous decline of oxygen in the atmosphere", Keeling stated. „The same thing is happening in the ocean. But there, oxygen is more difficult to measure because of its inhomogeneous distribution. My colleagues here in Kiel study quite intensively the so-called 'oxygen minimum zones' in the ocean. Here, I can learn a lot and on the other hand I am able to bring in my own experience from my atmospheric studies", Keeling continued. „We were very pleased to get Ralph Keeling for a sabbatical to Kiel", Martin Visbeck, speaker of the Cluster of Excellence „The Future Ocean" stated."

Figure 1 | Ralph Keeling spent one year visiting the Future Ocean in Kiel.

CHELAPILLA PATVARDHAN AND GOR SARAN ADHAR

Figure 2 | C. Patvardhan (University of Agra, India) and G.S. Adhar (University of North Carolina at Wilmington) visited the Future Ocean in Summer 2008 for research and teaching

From mid of May to the mid of June two guests from India and the USA visited the cluster of excellence for research and teaching. Prof. C. Patvardhanfrom the University of Agra, India, teaches a course in parallel computing with the OpenMPI on the Opteron computing cluster in the computing center in Kiel. This computing cluster was recently bought from Future Ocean funds. Prof. G.S. Adhar from the University of North Carolina at Wilmington teaches „Design of quantitative evolutionary algorithms". The hybrid evolutionary algorithm developed by Prof. Adhar is supposed to support the parameter optimization tasks researched within the CO_2 uptake focus within the Future Ocean. Both researchers were invited by Anand Srivastav and gave additional talks as part of the ISOS lecture series.

In total 57 foreign scientists from 22 countries visited researchers for purposes and themes related to the Future Ocean. Among them were i.e. Prof. R.J. Nicholls, Head of School of Civil Engineering and the Environment, University of Southampton, UK, Prof. Jason Phipps Morgan, Cornell University, USA, Prof. Keith Kvenvolden USGS Menlo Park, CA, USA, Prof. Alan Boyle, University of Edinburgh, UK, Prof. Dr. Hucai Zhang, Nanjing Institute of Geography and Limnology, China and others. See pages 16-17 for additional statistics on the international exchange of scientists with the Cluster of Excellence „The Future Ocean".

TRANSFER TO APPLICATION

The Transfer to Application project aims to communicate innovative knowledge and new technologies developed by the Future Ocean into industry and governmental and non-governmental organizations. Many university and industry related organizations are already active in this field. Some try to secure patents potentially developed in university labs, some establish connections between scientists and industry partners, some help local companies to become internationally visible, some strive to disseminate the latest research to spark new ideas and investment opportunities with potential investors. The Future Ocean cooperates with all of them through its Transfer to Application project.

Together with various partners we start knowledge and exploitation projects, in order to communicate our science to the public and to the benefit of our local industry and stakeholders. Most initiatives have just been started in 2008 as test balloons, in order to evaluate where the potentials of success lie. This process is still ongoing. The Transfer to Application project is a testbed for measures, whose outcome is not always known in advance. In the end, however, these measures are evaluated to determine, which parts of this project shall be continued and which ones do not apply to the marine science community. Scientists were contacted through a general survey to identify their expectations, demands and needs in terms of transfer of knowledge into applications. The information gained through the survey governed our activities supporting the link between science and economy.

TOPICAL INFORMATION MEETINGS

The Future Ocean organized the „Science meets Industry" marketplace conversations on marine technology together with the Maritime Cluster Schleswig-Holstein. The Maritime Cluster is a local network of over 1200 companies from all areas of the maritime industry. Selected high-level researchers presented their work and reported on the relevance about possible industrial application. They also presented their visions on the future of marine research and possible collaboration and developments with industry. These led into bilateral discussions during the following forum meeting where corporate representatives could discuss the presented ideas with the scientists in greater detail.

In 2009 Future Ocean plans a series of lectures with the Det Norske Veritas (DNV). DNV is one of the world´s leading ship classification societies. The lectures will deal with maritime themes circulating around commercial topics like risk assessment, resources and transport.

SCIENCE-INDUSTRY COLLABORATIVE PROJECTS

Endocrine disruptors increasingly problematic for the environment as to date they cannot be filtered out through regular water treatment techniques. Several of the endocrine substances can interfere with the reproduction and development of fish, amphibians and potentially also mammals. A member of the Future Ocean discovered bacteria able to degrade endocrine substances in wastewater. To further explore possibilities for an industrial application of these organisms additional research is necessary. Meetings with science and industry representatives resulted in two collaborative research proposals on the application of endocrine substance degrading bacteria for wastewater treatment.

SCIENCE MARKETING

Fairs and conferences are important forums to transfer knowledge and technologies into economic use. The project „Fair-Marketing" aims at young scientists, PhD students and postdocs of the Future Ocean. They are given the opportunity to exhibit newly developed technologies at international leading fairs. The Transfer to Application project will support and fund selected participants. In May 2009 the Offshore Technology Conference (OTC), the world´s largest show of the offshore industry, will take place in Houston, Texas. The Future Ocean prepares to present an in-house developed ocean bottom seismometer (OBS) at the OTC

Figure 1 | The Future Ocean will present an ocean bottom seismometer (OBS) at the Offshore Technology Conference in Houston in 2009 (OTC). This seismometer was developed at the institute for Geosciences at the Christian-Albrechts-Universität zu Kiel.

Figure 2 I ISOS PhD Kilian O'Brien and his 'Messe Mentor' Prof. Dr. Ernst Flüh attend the ship building and machinery fair (SMM) in Hamburg (Germany). They are the first participants of the "Industrial-Fair-Mentoring"-program, aiming to initiate contacts between offshore industry and research.

(Fig. 1). The seismometer is a low-budget high frequency sea floor solution which can be used for shallow water seismic measurements like e.g. foundation soil analysis for offshore constructions for water depths of up to about 60 meters.

SCIENCE AND INDUSTRY NETWORKING

Visiting a commercial or scientific fair can be overwhelming because of the vast new impressions as well as well as the completely different attitudes in research and industrial environments. Therefore the Fair-Mentoring project for postgraduates was developed together with the Integrated School of Ocean Sciences (ISOS). A senior scientist – „Mentor"- assists a „Mentee", who typically comes from a different research area then the mentor. The purpose is, to train students to deal with industry partners, meet people and start to socialize with industry contacts, while at the same time reflect on these experiences with the scientific mentor. Contacts made on industrial fairs may sometimes develop into a job offer. They certainly sharpen the profile of the mentee, as well as keeping the Future Ocean visible on industrial exhibitions. The Fair-Mentoring has started at the Ship building and Machinery fair (SMM) 2008 in Hamburg, Germany.

Figure 3 I On the „Science meets Industry" marketplace forum Prof. Dr. R. Schneider presents results and visions on possible collaborations with industry to representatives of the regional maritime industry.

The Future Ocean also supports networking between hig-profile research initiatives („Leuchtturmprojekte") within Schleswig-Holstein. The plans for these science-politics-meetings are underway.

PATENT SCOUTING AND PATENT AWARENESS

Most group leaders and principal investigators were interviewed until early 2008 to identify the potential of their research to make commercially interesting developments, but also to sensitize scientists on this topic. This was carried out together with the Patent and Exploitation Agency (PVA SH) for Scientific Institutions of the state Schleswig-Holstein. To educate researchers on opportunities, challenges and legal aspects of patents informational events were organized. Conversations and discussions with the junior research group leaders were arranged. Professors were encouraged to implement short presentations about patents and industrial exploitation of scientific results in their lectures.

THE BI-ANNUAL FUTURE OCEAN SYMPOSIUM

The bi-annual symposium organized by the Future Ocean took place from 8-9 October 2008 in Kiel. The symposium was organized to inform international and national colleagues and the general public about ongoing research in the marine sciences in Kiel. Two days of talks were organized around three important topics within the scope of the Future Ocean:

Figure 1 | A view of a plenary talk during the Future Ocean Symposium 2008.

SEAFLOOR MATTERS!

The surface area of the Earth is dominated by seafloor. This gigantic submarine areal is cut into shelf regions, continental margins, deep-sea plains, trenches, and ridges as well as subduction and spreading zones. In some regions, kilometers of sediment accumulate in millions of years through deposition of organic matter from the overlying water column, whereas in other regions liquid magma hardens into rocky basalt to form new seafloor. Seafloor means more than the lower boundary of the ocean. It is home to organisms, an important reactor for nutrient recycling, and most likely the place where life has once begun. The seafloor comprises a predominant percentage of global fossil energy resources as well as the largest amount of total biomass on Earth. During the session we will take you on a journey to some amazing discoveries the seafloor has in store for us.

MARINE LIFE AND BIODIVERSITY

Marine life and biodiversity are maintained by complex ecological processes and interactions between populations along these food webs and with the marine environment. On top, humans exert a major impact on most marine ecosystems: each year fisheries harvest nearly 100 million tons of food fish. In the symposium session on Marine Life and Biodiversity we will obtain an overview of recent research and policy issues covering the food chain from the level of micro-organisms over fishes to fisheries and, ultimately, marine policy governing the human actions that affect marine ecosystems.

CO_2-SEQUESTRATION

Rising atmospheric CO_2 levels are one of the biggest environmental concerns, and to avert dangerous climate change, all carbon sequestration options need to be explored. This session will investigate the ocean's potential for absorbing significant amounts of CO_2 over the next decades to centuries. Recently proposed geo-engineering schemes to enhance the oceanic uptake of CO_2, such as ocean fertilization, will be discussed in terms of feasibility and accountability, with a special focus on associated ethical aspects.

In addition four workshops were organized, which were well attended. The workshops comprised the themes: „Novel Insight Into Redox and Nutrient Cycles in the Ocean (SFB 754)", „Marine and Costal Resources: Risks and Law", „Fisheries: Economy and Ecology"and „Marine Organisms Used to Understand Basic Mechanism Underlying Development and Disease". Under the title „The oceans and global climate change - a challenge to society and economy", the cluster of excellence organised a public panel discussion during the 2nd Bi-Annual Symposium „The Future Ocean". In the Kiel Art Gallery, Professor of meterology Mojib Latif (IFM-GEOMAR) and Professor for economy Till Requate (Kiel University) highlighted the consequences of oceanic and climate change from different perspectives. Altogether the symposium and workshops spanned the full spectrum of topics worked on in the Future Ocean. The next symposium is planned for September 2010.

Figure 2 | Rashid Sumaila talked about „Long-term management of fisheries".

Figure 3 | Sven Petersen gave an introduction into the origin of metal resources in the deep sea.

THE MALENTE SYMPOSIUM

Figure 1 | Various representatives from science, industry, politics and non-governmental organizations gathered during the 27th Malente Symposium in Lübeck.

The XVII Malente Symposium, entitled „More than Water – Oceans and Global Responsibility", took place in Lübeck from October 12 – 14, 2008. It was organized by the Dräger Foundation in cooperation with the ZEIT-Stiftung Ebelin und Gerd Bucerius in Hamburg, and the Cluster of Excellence „The Future Ocean" in Kiel. The conference aimed to examine in depth the 21st century challenges the world's oceans are facing through global warming and rising sea levels, overfishing, pollution, invasive species, and the exploitation of resources, and seeked to identify solutions to best manage these challenges. The symposium aimed to increase awareness and facilitate a dialog with the global business community, with politicians worldwide, and with society as a whole.

Since the publication by the Intergovernmental Panel on Climate Change (IPCC) of its most recent report in Paris at the beginning of 2007 and the results of the Stern Report toward the end of 2006, it has become obvious that the human induced climate change that our planet is experiencing could soon have drastic consequences for our quality of life, and especially for the earth's water balance. Thermal expansion of the oceans may bring about a rise in sea level of no less than 20 to 30 cm by the end of the century. Added to this would be a more uncertain increase of approximately 15 cm caused by the melting of the Greenland icesheet; on the other hand, increased snowfall in the Antarctic could cause global sea levels to drop by some 5 cm. Higher temperatures and precipitation would decrease the density of surface water in the North Atlantic, thereby potentially reducing ocean circulation and the transport of heat, and the ocean's uptake of CO_2.

Whereas attention hitherto has been primarily focused on the consequences of greenhouse gas emissions and the accompanying warming of the earth's atmosphere, public debate – and, by extension, political interest – will now revolve to a greater extent around the consequences of climate change for our oceans. After all, the oceans are at least as important as the earth's atmosphere when it comes to maintaining a balanced global climate. To date, however, this fact has only penetrated the public consciousness to a rudimentary degree.

At the same time, the world's oceans are increasingly becoming the scene of inter-governmental conflicts. The lines of conflict extend from fishing rights to the securing of fossil fuels. Yet the oceans present not only a danger and source of potential conflict, but are also a vital resource: the oceans are the biggest long-term sink of human-made CO_2, they store and generate energy, and they provide a habitat for fauna and flora. The oceans boast more than half the earth's biodiversity, with 1,600 new species being discovered every year. This gene pool of earthly life, which is largely still unknown, is essential for humankind – countless medical drugs, for example, are based on natural extracts from the marine fauna and flora. The biodiversity of the oceans, however, is increasingly at risk as a result of industrial waste dumping and overfishing. A lack of internationally valid legal codices means that it is virtually impossible to prevent this, or to pursue offenders. Expanding international law to take effective account of this area – i.e. in many cases drawing up such laws in the first place, incorporating them into national legal systems and implementing international mechanisms to enforce them – is a major undertaking which has yet to be attempted.

The XVII Malente Symposium brought together experts and stakeholders from around the world and from all fields of society to discuss these challenges in a comprehensive way and to identify practical solutions to facilitate future sustainable development.

THE APPENDIX

„All opinions are not equal. Some are a very great deal more robust, sophisticated and well supported in logic and argument than others.“

Douglas Adams

MEMBERS OF THE FUTURE OCEAN

NAME	INSTITUTION
Andersen, Nils	CAU
Behrmann, Jan	IFM-GEOMAR
Bensch, Wolfgang	CAU
Beyer, Martin	CAU
Bialas, Jörg	IFM-GEOMAR
Biastoch, Arne	IFM-GEOMAR
Bilger, Wolfgang	CAU
Bleich, Markus	CAU
Böning, Claus	IFM-GEOMAR
Börm, Steffen	CAU
Bosch , Thomas	CAU
Braack, Malte	CAU
Brandt, Peter	IFM-GEOMAR
Bröck, Ralf	CAU
Brückmann , Warner	IFM-GEOMAR
Clemmesen-Bokelmann, Catriona	IFM-GEOMAR
Colijn, Franciscus	FTZ
Croot, Peter	IFM-GEOMAR
Dahmke, Andreas	CAU
Dengg, Joachim	IFM-GEOMAR
Depmeier, Wulf	CAU
Devey, Colin	IFM-GEOMAR
Dombrowsky, Wolf R.	CAU
Dullo, Christian	IFM-GEOMAR
Duscher, Tom	MKHS
Eden, Carsten	IFM-GEOMAR
Eisenhauer, Anton	IFM-GEOMAR
Ernst, Rainer W.	MKHS
Feeser, Volker	CAU
Flögel, Sascha	IFM-GEOMAR
Flüh, Ernst R.	IFM-GEOMAR
Fouquet, Gerhard	CAU
Frank, Martin	IFM-GEOMAR
Friedrichs, Gernot	CAU
Froese, Rainer	IFM-GEOMAR
Garbe-Schönberg, Dieter	CAU
Garthe, Stefan	FTZ
Giegerich, Thomas	CAU
Götze, Hans-Jürgen	CAU
Greatbatch, Richard	IFM-GEOMAR
Grevemeyer, Ingo	IFM-GEOMAR
Grootes, Pieter M.	Leibniz Labor
Grotemeyer, Jürgen	CAU
Hackbusch, Wolfgang	CAU

NAME	INSTITUTION
Hanel, Reinhold	IFM-GEOMAR
Harms, Ute	IPN
Hartke, Bernd	CAU
Hasselbring, Wilhelm	CAU
Hauff, Folkmar	IFM-GEOMAR
Hensen, Christian	IFM-GEOMAR
Herzig, Peter	IFM-GEOMAR
Hoeher, Peter	CAU
Hoernle, Kaj	IFM-GEOMAR
Holzheid, Astrid	CAU
Horn, Rainer	CAU
Imhoff, Johannes F.	IFM-GEOMAR
Jegen-Kulczar, Marion	IFM-GEOMAR
Jenisch, Uwe	CAU
Jung, Christian	CAU
Karstensen, Johannes	IFM-GEOMAR
Kempken, Frank	CAU
Kläschen, Dirk	IFM-GEOMAR
Klepper, Gernot	IfW
Koch, Reinhard	CAU
Kopp, Heidrun	IFM-GEOMAR
Körtzinger, Arne	IFM-GEOMAR
Krastel, Sebastian	IFM-GEOMAR
Krawczak, Michael	CAU
Krüger, Kirstin	IFM-GEOMAR
Kuhnt, Wolfgang	CAU
Kunzendorf , Ulrich	CAU
Lackschewitz, Klas	IFM-GEOMAR
LaRoche, Julie	IFM-GEOMAR
Latif, Mojib	IFM-GEOMAR
Lehmann, Andreas	IFM-GEOMAR
Linke, Peter	IFM-GEOMAR
Luttenberger, Norbert	CAU
Macke, Andreas	IFM-GEOMAR
Maser, Edmund	CAU
Mayerle, Roberto	FTZ
Meier, Sebastian	CAU
Melzner, Frank	IFM-GEOMAR
Müller, Johannes	CAU
Müller, Wolf Ulrich	CAU
Nadeau, Marie-Josée	Leibniz Labor
Oschlies, Andreas	IFM-GEOMAR
Ott, Stephan	CAU
Petersen, Sven	IFM-GEOMAR

NAME	INSTITUTION
Peterson, Sonja	IfW
Pfannkuche, Olaf	IFM-GEOMAR
Piatkowski, Uwe	IFM-GEOMAR
Piepenburg, Dieter	CAU
Prenzel, Manfred	IPN
Proelß, Alexander	WSI
Quaas, Martin	CAU
Rabbel, Wolfgang	CAU
Rehdanz, Katrin	IfW
Requate , Till	CAU
Reusch, Thorsten	IFM-GEOMAR
Ricklefs, Klaus	FTZ
Riebesell, Ulf	IFM-GEOMAR
Rimbach , Gerald	CAU
Rosenstiel, Philip	CAU
Rüpke, Lars	IFM-GEOMAR
Sachs, Stefan	MKHS
Schäfer, Priska	CAU
Schenk, Volker	CAU
Schmidt, Nicole	IFM-GEOMAR
Schmidt, Mark	CAU
Schmidt, Ulrich	CAU
Schmidt, Ingmar	CAU
Schmitz-Streit, Ruth	CAU
Schneider, Ralph R.	CAU
Schneider, Birgit	CAU
Schönfeld, Joachim	IFM-GEOMAR
Schreiber, Stefan	CAU
Schröder, Jens-Michael	CAU
Schrottke , Kerstin	CAU
Schulz, Manfred	MKHS
Schulz, Rüdiger	CAU
Schwarzer, Klaus	CAU
Siebert, Ursula	FTZ
Slawig, Thomas	CAU
Snower, Dennis	IfW
Sommer, Ulrich	IFM-GEOMAR
Spindler, Michael	CAU
Srivastav, Anand	CAU
Stattegger, Karl	CAU
Sterr, Horst	CAU
Temps, Friedrich	CAU
Thalheim, Bernhard	CAU
Treude, Tina	IFM-GEOMAR
Vafeidis, Athanasios	CAU
Visbeck, Martin	IFM-GEOMAR
Wahl, Martin	IFM-GEOMAR
Wallace, Doug	IFM-GEOMAR
Wallmann, Klaus	IFM-GEOMAR
Weinberger, Florian	IFM-GEOMAR
Weinrebe, Wilhelm	IFM-GEOMAR
Wirtz, Kai	GKSS
Zimmer, Martin	CAU
Zimmermann, Andreas	CAU

INSTITUTIONS	
CAU	Christian-Albrechts-Universität zu Kiel
GKSS	GKSS-Forschungszentrum Geesthacht GmbH
IFM-GEOMAR	Leibniz-Institut für Meereswissenschaften (IFM-GEOMAR)
IfW	Institut für Weltwirtschaft
IPN	Leibniz-Institut für die Pädagogik der Naturwissenschaften (IPN)
Leibniz Labor	Leibniz-Labor für Altersbestimmung und Isotopenforschung
MKHS	Muthesius Kunsthochschule
FTZ	Forschungs- und Technologiezentrum Westküste (FTZ)

PANEL MEMBERSHIPS

EXECUTIVE COMMITTEE

NAME	INSTITUTION*
Bleich, Markus	CAU
Bosch, Thomas	CAU
Eisenhauer, Anton	IFM-GEOMAR
Fouquet, Gerhard	CAU
Gimpel, Peter	Elac Nautic
Herzig, Peter	IFM-GEOMAR
Körtzinger, Arne	IFM-GEOMAR
Müller-Lupp, Wiebke	Maritimes Cluster
Oschlies, Andreas	IFM-GEOMAR
Requate , Till	CAU
Schmitz-Streit, Ruth	CAU
Schneider, Ralph R.	CAU
Schneider, Birgit	CAU
Sommer, Ulrich	IFM-GEOMAR
Srivastav, Anand	CAU
Temps, Friedrich	CAU
Treude, Tina	IFM-GEOMAR
Visbeck, Martin	IFM-GEOMAR

ADVISORY BOARD

NAME	INSTITUTION*
Prof. Dr. Jochem Marotzke	Max Planck Institute for Meteorology, Hamburg, Germany
Prof. Dr. Martin Hrabé de Angelis	GSF Forschungszentrum für Umwelt und Gesundheit, Neuherberg, Germany
Dr. Lindsay Parson	National Oceanography Centre, Southampton, UK
Prof. Dr. Heinz Welsch	Carl von Ossietzky Universität Oldenburg, Germany
Prof. Ralph Keeling	Scripps Institution of Oceanography, La Jolla, USA
Prof. Dr. Georg Teutsch	Helmholtz-Zentrums für Umweltfor-schung - UFZ, Leipzig, Germany
Prof. Dr. Wolfgang Dahmen	Institut für Geometrie und Praktische Mathematik, Aachen, Germany
Dr. Yoshiki Saito	Institute of Geology and Geoinformation (IGG), Tsukuba, Japan
Dr. Paul Nemitz	European Commission, Brüssel, Belgium
Nikolaus Gelpke	dreiviertel verlag, Hamburg, Germany
Prof. Dr. Antje Boetius	Max Planck Institute für Marine Mikrobio-logie, Bremen, Germany
Prof. Judy McKenzie	Eidgenössische Technische Hochschule Zürich, Zürich, Switzerland
Dr. Christian Bücker	RWE DEA AG, Hamburg, Germany

COUNCIL

NAME	INSTITUTION*
Behrmann, Jan	IFM-GEOMAR
Bleich, Markus	CAU
Böning, Claus	IFM-GEOMAR
Bosch , Thomas	CAU
Braack, Malte	CAU
Colijn, Franciscus	FTZ
Devey, Colin	IFM-GEOMAR
Eisenhauer, Anton	IFM-GEOMAR
Ernst, Rainer W.	MKHS
Flüh, Ernst R.	IFM-GEOMAR
Fouquet, Gerhard	CAU
Friedrichs, Gernot	CAU
Froese, Rainer	IFM-GEOMAR
Grootes, Pieter M.	CAU (AMS)
Grotemeyer, Jürgen	CAU
Hartke, Bernd	CAU
Herzig, Peter	IFM-GEOMAR
Hoernle, Kaj	IFM-GEOMAR
Klepper, Gernot	IfW
Körtzinger, Arne	IFM-GEOMAR
Krastel, Sebastian	IFM-GEOMAR
LaRoche, Julie	IFM-GEOMAR
Latif, Mojib	IFM-GEOMAR
Melzner, Frank	IFM-GEOMAR
Oschlies, Andreas	IFM-GEOMAR
Proelß, Alexander	CAU (WSI)
Quaas, Martin	CAU
Rabbel, Wolfgang	CAU
Rehdanz, Katrin	IfW
Requate, Till	CAU
Riebesell, Ulf	IFM-GEOMAR
Rosenstiel, Philip	CAU
Rüpke, Lars	IFM-GEOMAR
Schmitz-Streit, Ruth	CAU
Schneider, Ralph R.	CAU
Schneider, Birgit	CAU
Schreiber, Stefan	CAU
Schrottke , Kerstin	CAU
Slawig, Thomas	CAU
Snower, Dennis	IfW
Sommer, Ulrich	IFM-GEOMAR
Srivastav, Anand	CAU
Stattegger, Karl	CAU
Temps, Friedrich	CAU
Treude, Tina	IFM-GEOMAR
Vafeidis, Athanasios	CAU
Visbeck, Martin	IFM-GEOMAR
Wahl, Martin	IFM-GEOMAR
Wallace, Doug	IFM-GEOMAR
Wallmann, Klaus	IFM-GEOMAR

* Full name of the Institutions see previous page.

SELECTED PUBLICATIONS

A

Allen, A. E.; LaRoche, J.; Maheswari, U.; Lommer, M.; Schauer, N.; Lopez, P. J.; Finazzi, G.; Fernie, A. R. & Bowler, C. (2008), ‚Whole-cell response of the pennate diatom Phaeodactylum tricornutum to iron starvation', *Proceedings of the National Academy of Sciences of the United States of America* 105(30), 10438--10443.

Allgaier, M.; Riebesell, U.; Vogt, M.; Thyrhaug, R. & Grossart, H. P. (2008), ‚Coupling of heterotrophic bacteria to phytoplankton bloom development', *Biogeosciences* 5(4), 1007--1022.

Alvarez-Garcia, F.; Latif, M. & Biastoch, A. (2008), ‚On multidecadal and quasi-decadal North Atlantic variability', *Journal of Climate* 21(14), 3433--3452.

Amini, M.; Eisenhauer, A.; Bohm, F.; Fietzke, J.; Bach, W.; Garbe-Schonberg, D.; Rosner, M.; Bock, B.; Lackschewitz, K. S. & Hauff, F. (2008), ‚Calcium isotope (delta Ca-44/40) fractionation along hydrothermal pathways, Logatchev field (Mid-Atlantic Ridge, 14 degrees 45'N)', *Geochimica Et Cosmochimica Acta* 72(16), 4107--4122.

Amini, M.; Eisenhauer, A.; Holmden, C.; Boehm, F.; Hauff, F. & Jochum, K. P. (2008), ‚delta Ca-44/40 variability in igneous rocks', *Geochimica Et Cosmochimica Acta* 72(12), A19--A19.

Anderson, F. E.; Pilsits, A.; Clutts, S.; Laptikhovsky, V.; Bello, G.; Balguerias, E.; Lipinski, M.; Nigmatulin, C.; Pereira, J. M. F.; Piatkowski, U.; Robin, J. P.; Salman, A. & Tasende, M. G. (2008), ‚Systematics of Alloteuthis (Cephalopoda:Loliginidae) based on molecular and morphometric data', *Journal of Experimental Marine Biology and Ecology* 364(2), 99--109.

Anton-Erxleben, F.; Thomas, A.; Wittlieb, J.; Fraune, S. & Bosch, T. C. G. (2009), ‚Plasticity of epithelial cell shape in response to upstream signals: A whole-organism study using transgenic Hydra', *Zoology* 112(3), 185--194.

Arlt, A.; Rosenstiel, P.; Kruse, M. L.; Grohmann, F.; Minkenberg, J.; Perkins, N. D.; Folsch, U. R.; Schreiber, S. & Schafer, H. (2008), ‚IEX-1 directly interferes with RelA/p65 dependent transactivation and regulation of apoptosis', *Biochimica Et Biophysica Acta-molecular Cell Research* 1783(5), 941--952.

Arzhanov, M. M.; Eliseev, A. V.; Demchenko, P. F.; Mokhov, I. I. & Khon, V. C. (2008), ‚Simulation of thermal and hydrological regimes of Siberian river watersheds under permafrost conditions from reanalysis data', *Izvestiya Atmospheric and Oceanic Physics* 44(1), 83--89.

Augustin, N.; Lackschewitz, K. S.; Kuhn, T. & Devey, C. W. (2008), ‚Mineralogical and chemical mass changes in mafic and ultramafic rocks from the Logatchev hydrothermal field (MAR 15 degrees N)', *Marine Geology* 256(1-4), 18--29.

B

Balaj, O. P.; Berg, C. B.; Reitmeier, S. J.; Bondybey, V. E. & Beyer, M. K. (2009), ‚A novel design of a temperature-controlled FT-ICR cell for low-temperature black-body infrared radiative dissociation (BIRD) studies of hydrated ions', *International Journal of Mass Spectrometry* 279(1), 5--9.

Bartczak, B.; Jung, D. & Koch, R. (2008), ‚Real-time neighborhood based disparity estimation incorporating temporal evidence', *Pattern Recognition* 5096, 153--162.

Bartdorff, O.; Wallmann, K.; Latif, M. & Semenov, V. (2008), ‚Phanerozoic evolution of atmospheric methane', *Global Biogeochemical Cycles* 22(1).

Bartsch, I.; Wiencke, C.; Bischof, K.; Buchholz, C. M.; Buck, B. H.; Eggert, A.; Feuerpfeil, P.; Hanelt, D.; Jacobsen, S.; Karez, R.; Karsten, U.; Molis, M.; Roleda, M. Y.; Schubert, H.; Schumann, R.; Valentin, K.; Weinberger, F. & Wiese, J. (2008), ‚The genus Laminaria sensu lato: recent insights and developments', *European Journal of Phycology* 43(1), 1--86.

Baumann, H.; Voss, R.; Hinrichsen, H. H.; Mohrholz, V.; Schmidt, J. O. & Temming, A. (2008), ‚Investigating the selective survival of summer-over spring-born sprat, Sprattus sprattus, in the Baltic Sea', *Fisheries Research* 91(1), 1--14.

Baumgartner, S.; Becker, C.; Frank, K.; Muller, B. & Quaas, M. (2008), ‚Relating the philosophy and practice of ecological economics: The role of concepts, models, and case studies in inter- and transdisciplinary sustainability research', *Ecological Economics* 67(3), 384--393.

Beck, A. J.; Rapaglia, J. P.; Cochran, J. K.; Bokuniewicz, H. J. & Yang, S. (2008), ‚Submarine groundwater discharge to Great South Bay, NY, estimated using Ra isotopes', *Marine Chemistry* 109(3-4), 279--291.

Beder, C.; Schiller, I. & Koch, R. (2008), ‚Photoconsistent relative pose estimation between a PMD 2D3D-camera and multiple intensity cameras', *Pattern Recognition* 5096, 264--273.

Bellerby, R. G. J.; Schulz, K. G.; Riebesell, U.; Neill, C.; Nondal, G.; Heegaard, E.; Johannessen, T. & Brown, K. R. (2008), ‚Marine ecosystem community carbon and nutrient uptake stoichiometry under varying ocean acidification during the PeECE III experiment', *Biogeosciences* 5(6), 1517--1527.

Benthien, A.; Zondervan, I.; Engel, A.; Hefter, J.; Terbruggen, A. & Riebesell, U. (2007), ‚Carbon isotopic fractionation during a mesocosm bloom experiment dominated by Emiliania huxleyi: Effects of CO2 concentration and primary production', *Geochimica Et Cosmochimica Acta* 71(6), 1528--1541.

Bergstad, O. A.; Falkenhaug, T.; Astthorsson, O. S.; Byrkjedal, I.; Gebruk, A. V.; Piatkowski, U.; Priede, I. G.; Santos, R. S.; Vecchione, M.; Lorance, P. & Gordon, J. D. M. (2008), ‚Towards improved understanding of the diversity and abundance patterns of the mid-ocean ridge macro- and megafauna', *Deep-sea Research Part Ii-topical Studies In Oceanography* 55(1-2), 1--5.

Berrittella, M.; Rehdanz, K.; Roson, R. & Tol, R. S. J. (2008), ‚The economic impact of water taxes: a computable general equilibrium analysis with an international data set', *Water Policy* 10(3), 259--271.

Biastoch, A.; Boning, C. W. & Lutjeharms, J. R. E. (2008), ‚Agulhas leakage dynamics affects decadal variability in Atlantic overturning circulation', *Nature* 456(7221), 489--492.

Biastoch, A.; Boning, C. W.; Scheinert, M. & Lutjeharms, J. R. E. (2009), ‚The Agulhas System as a Key Region of the Global Oceanic Circulation', *High Performance Computing In Science and Engineering* ‚08, 459--469.

Biastoch, A.; Lutjeharms, J. R. E.; Boning, C. W. & Scheinert, M. (2008), ‚Mesoscale perturbations control inter-ocean exchange south of Africa', *Geophysical Research Letters* 35(20).

Blessing, S.; Greatbatch, R. J.; Fraedrich, K. & Lunkeit, F. (2008), ‚Interpreting the atmospheric circulation trend during the last half of the twentieth century: Application of an adjoint model', *Journal of Climate* 21(18), 4629--4646.

Bohm, F.; Rausch, S.; Eisenhauer, A.; Bach, W. & Klugel, A. (2008), ‚Low temperature alteration carbonates in the ocean crust and their importance for CO2 uptake and the global Ca cycle', *Geochimica Et Cosmochimica Acta* 72(12), A93--A93.

Boning, C. W.; Dispert, A.; Visbeck, M.; Rintoul, S. R. & Schwarzkopf, F. U. (2008), ‚The response of the Antarctic Circumpolar Current to recent climate change', *Nature Geoscience* 1(12), 864--869.

Bork, K.; Karstensen, J.; Visbeck, M. & Zimmermann, A. (2008), ‚The legal regulation of floats and gliders - In quest of a new regime?', *Ocean Development and International Law* 39(3), 298--328.

Bowler, C.; Allen, A. E.; Badger, J. H.; Grimwood, J.; Jabbari, K.; Kuo, A.; Maheswari, U.; Martens, C.; Maumus, F.; Otillar, R. P.; Rayko, E.; Salamov, A.; Vandepoele, K.; Beszteri, B.; Gruber, A.; Heijde, M.; Katinka, M.; Mock, T.; Valentin, K.; Verret, F.; Berges, J. A.; Brownlee, C.; Cadoret, J. P.; Chiovitti, A.; Choi, C. J. & Coesel, S. (2008), ‚The Phaeodactylum genome reveals the evolutionary history of diatom genomes', *Nature* 456(7219), 239--244.

Braack, M. (2008), ‚A Stabilized Finite Element Scheme For the Navier-stokes Equations On Quadrilateral Anisotropic Meshes', *Esaim-mathematical Modelling and Numerical Analysis-modelisation Mathematique Et Analyse Numerique* 42(6), 903--924.

Brandt, P.; Hormann, V.; Bourles, B.; Fischer, J.; Schott, F. A.; Stramma, L. & Dengler, M. (2008), ‚Oxygen tongues and zonal currents in the equatorial Atlantic', *Journal of Geophysical Research-oceans* 113(C4).

Braumann, I.; van den Berg, M. A. & Kempken, F. (2008), ‚Strain-specific retrotransposon-mediated recombination in commercially used Aspergillus niger strain', *Molecular Genetics and Genomics* 280(4), 319--325.

Braumann, I.; van den Berg, M. & Kempken, F. (2008), ‚Repeat induced point mutation in two asexual fungi, Aspergillus niger and Penicillium chrysogenum', *Current Genetics* 53(5), 287--297.

Breitbarth, E.; Wohlers, J.; Klas, J.; LaRoche, J. & Peeken, I. (2008), ‚Nitrogen fixation and growth rates of Trichodesmium IMS-101 as a function of light intensity', *Marine Ecology-progress Series* 359, 25--36.

Bromley, S. T.; Bandow, B. & Hartke, B. (2008), ‚Structural Correspondences between the Low-Energy Nanoclusters of Silica and Water', *Journal of Physical Chemistry* C 112(47), 18417--18425.

Busch, M. W.; Klimpel, S.; Sutton, T. & Piatkowski, U. (2008), ‚Parasites of the deep-sea smelt Bathylagus euryops (Argentiniformes : Microstomatidae) from the Charlie-Gibbs Fracture Zone (CGFZ)', *Marine Biology Research* 4(4), 313--317.

C

Cahyarini, S. Y.; Pfeiffer, M.; Timm, O.; Dullo, W. C. & Schonberg, D. G. (2008), ‚Reconstructing seawater delta O-18 from paired coral delta O-18 and Sr/Ca ratios: Methods, error analysis and problems, with examples from Tahiti (French Polynesia) and Timor (Indonesia)', *Geochimica Et Cosmochimica Acta* 72(12), 2841--2853.

Canning-Clode, J.; Kaufmann, M.; Molis, M.; Wahl, M. & Lenz, M. (2008), ‚Influence of disturbance and nutrient enrichment on early successional fouling communities in an oligotrophic marine system', *Marine Ecology-an Evolutionary Perspective* 29(1), 115--124.

Canning-Clode, J.; Valdivia, N.; Molis, M.; Thomason, J. C. & Wahl, M. (2008), ‚Estimation of regional richness in marine benthic communities: quantifying the error', *Limnology and Oceanography-methods* 6, 580--590.

Cao, Y.; Hockendorf, R. F. & Beyer, M. K. (2008), ‚Birch reduction of chlorobenzene in gas-phase hydrated electrons', *International Journal of Mass Spectrometry* 277(1-3), 206--209.

Contreras-Reyes, E.; Grevemeyer, I.; Flueh, E. R. & Reichert, C. (2008), ‚Upper lithospheric structure of the subduction zone offshore of southern Arauco peninsula, Chile, at similar to 38 degrees S', *Journal of Geophysical Research-solid Earth* 113(B7).

Contreras-Reyes, E.; Grevemeyer, I.; Flueh, E. R.; Scherwath, M. & Bialas, J. (2008), ‚Effect of trench-outer rise bending-related faulting on seismic Poisson's ratio and mantle anisotropy: a case study offshore of Southern Central Chile', *Geophysical Journal International* 173(1), 142--156.

Croot, P. L.; Bluhm, K.; Schlosser, C.; Streu, P.; Breitbarth, E.; Frew, R. & Van Ardelan, M. (2008), ‚Regeneration of Fe(II) during EIFeX and SOFeX', *Geophysical Research Letters* 35(19), L19606.

D

Das, K.; Siebert, U.; Gillet, A.; Dupont, A.; Dipoi, C.; Fonfara, S.; Mazzucchelli, G.; De Pauw, E. & De Pauw-Gillet, M. C. (2008), ‚Mercury immune toxicity in harbour seals: links to in vitro toxicity', *Environmental Health* 7.

Davey, M.; Tarran, G. A.; Mills, M. M.; Ridame, C.; Geider, R. J. & LaRoche, J. (2008), ‚Nutrient limitation of picophytoplankton photosynthesis and growth in the tropical North Atlantic', *Limnology and Oceanography* 53(5), 1722--1733.

Delacour, A.; Fruh-Green, G. L.; Frank, M.; Gutjahr, M. & Kelley, D. S. (2008), ‚Sr- and Nd-isotope geochemistry of the Atlantis Massif (30 degrees N, MAR): Implications for fluid fluxes and lithospheric heterogeneity', *Chemical Geology* 254(1-2), 19--35.

Devey, C. W. & Stroncik, N. (2008), ‚Plume-ridge interaction: Dying from the feet up', *Geochimica Et Cosmochimica Acta* 72(12), A215--A215.

Dobretsov, S. & Wahl, M. (2008), ‚Larval recruitment of the blue mussel Mytilus edulis: The effect of flow and algae', *Journal of Experimental Marine Biology and Ecology* 355(2), 137--144.

von Dollen, A. & Requate, T. (2008), ‚Environmental policy and uncertain arrival of future abatement technology', *B E Journal of Economic Analysis & Policy* 8(1).

Duce, R. A.; LaRoche, J.; Altieri, K.; Arrigo, K. R.; Baker, A. R.; Capone, D. G.; Cornell, S.; Dentener, F.; Galloway, J.; Ganeshram, R. S.; Geider, R. J.; Jickells, T.; Kuypers, M. M.; Langlois, R.; Liss, P. S.; Liu, S. M.; Middelburg, J. J.; Moore, C. M.; Nickovic, S.; Oschlies, A.; Pedersen, T.; Prospero, J.; Schlitzer, R.; Seitzinger, S.; Sorensen, L. L.; Uematsu, M.; Ulloa, O.; Voss, M.; Ward, B. & Zamora, L. (2008), ‚Impacts of atmospheric anthropogenic nitrogen on the open ocean', *Science* 320(5878), 893--897.

Durgadoo, J. V.; Lutjeharms, J. R. E.; Biastoch, A. & Ansorge, I. J. (2008), ‚The Conrad Rise as an obstruction to the Antarctic Circumpolar Current', *Geophysical Research Letters* 35(20).

Durkop, A.; Holbourn, A.; Kuhnt, W.; Zuraida, R.; Andersen, N. & Grootes, P. M. (2008), ‚Centennial-scale climate variability in the Timor Sea during Marine Isotope Stage 3', *Marine Micropaleontology* 66(3-4), 208--221.

E

Eden, C. & Dengler, M. (2008), ‚Stacked jets in the deep equatorial Atlantic Ocean', *Journal of Geophysical Research-oceans* 113(C4).

Eden, C. & Greatbatch, R. J. (2008), ‚Diapycnal mixing by meso-scale eddies', *Ocean Modelling* 23(3-4), 113--120.

Eden, C. & Greatbatch, R. J. (2008), ‚Towards a mesoscale eddy closure', *Ocean Modelling* 20(3), 223--239.

Ehlers, A.; Worm, B. & Reusch, T. B. H. (2008), ‚Importance of genetic diversity in eelgrass Zostera marina for its resilience to global warming', *Marine Ecology-progress Series* 355, 1--7.

Eisenhauer, A.; Boehm, F.; Fietzke, J.; Liebetrau, V.; Amini, M.; Kisakurek, B.; Heuser, A.; Tang, J. & Dietzel, M. (2008), ‚The application of natural divalent cation isotope (Ca, Sr, Mg) fractionation (DCIF) in earth system research', *Geochimica Et Cosmochimica Acta* 72(12), A241--A241.

El-Hawari, Y.; Pilka, E.; Martin, H. J.; Oppermann, U. & Maser, E. (2008), ‚Characterization of the human carbonyl reductase 3 (CBR3) by site-directed mutagenesis', *Naunyn-schmiedebergs Archives of Pharmacology* 377, 326.

Engelen, B.; Ziegelmueller, K.; Wolf, L.; Kopke, B.; Gittel, A.; Cypionka, H.; Treude, T.; Nakagawa, S.; Inagaki, F.; Lever, M. A. & Steinsbu, B. O. (2008), ‚Fluids from the oceanic crust support microbial activities within the deep biosphere', *Geomicrobiology Journal* 25(1), 56--66.

Eriksson, M.; Lindhorst, T. K. & Hartke, B. (2008), ‚Differential effects of oligosaccharides on the hydration of simple cations', *Journal of Chemical Physics* 128(10), 105105.

F

Feng, M.; Biastoch, A.; Boning, C.; Caputi, N. & Meyers, G. (2008), ‚Seasonal and interannual variations of upper ocean heat balance off the west coast of Australia', *Journal of Geophysical Research-oceans* 113(C12).

Ferber, S.; Reusch, T. B. H.; Stam, W. T. & Olsen, J. L. (2008), ‚Characterization of single nucleotide polymorphism markers for eelgrass (Zostera marina)', *Molecular Ecology Resources* 8(6), 1429--1435.

Ferrarin, C.; Rapaglia, J.; Zaggia, L.; Umgiesser, G. & Zuppi, G. M. (2008), ‚Coincident application of a mass balance of radium and a hydrodynamic model for the seasonal quantification of groundwater flux into the Venice Lagoon, Italy', *Marine Chemistry* 112(3-4), 179--188.

Fietzke, J.; Frische, M.; Hansteen, T. H. & Eisenhauer, A. (2008), ‚A simplified procedure for the determination of stable chlorine isotope ratios (delta Cl-37) using LA-MC-ICP-MS', *Journal of Analytical Atomic Spectrometry* 23(5), 769--772.

Fietzke, J.; Liebetrau, V.; Guenther, D.; Gurs, K.; Hametner, K.; Zumholz, K.; Hansteen, T. H. & Eisenhauer, A. (2008), ‚An alternative data acquisition and evaluation strategy for improved isotope ratio precision using LA-MC-ICP-MS applied to stable and radiogenic strontium isotopes in carbonates', *Journal of Analytical Atomic Spectrometry* 23(7), 955--961.

Fietzke, J.; Liebetrau, V.; Gunther, D.; Frische, A.; Zumholz, K.; Hansteen, T. H. & Eisenhauer, A. (2008), ‚Alternative data reduction for precise and accurate isotope ratio determination via LA-MC-ICP-MS', *Geochimica Et Cosmochimica Acta* 72(12), A267--A267.

Fischer, J.; Hormann, V.; Brandt, P.; Schott, F. A.; Rabe, B. & Funk, A. (2008), ‚South Equatorial Undercurrent in the western to central tropical Atlantic', *Geophysical Research Letters* 35(21).

Fonfara, S.; Kakuschke, A.; Rosenberger, T.; Siebert, U. & Prange, A. (2008), ‚Cytokine and acute phase protein expression in blood samples of harbour seal pups', *Marine Biology* 155(3), 337--345.

Frank, M.; Backman, J.; Jakobsson, M.; Moran, K.; O'Regan, M.; King, J.; Haley, B. A.; Kubik, P. W. & Garbe-Schonberg, D. (2008), ‚Beryllium isotopes in central Arctic Ocean sediments over the past 12.3 million years: Stratigraphic and paleoclimatic implications', *Paleoceanography* 23(1), PA1S02.

Friedrichs, G. (2008), ‚Sensitive absorption methods for quantitative gas phase kinetic measurements. Part 2: Cavity ringdown spectroscopy', *Zeitschrift Für Physikalische Chemie-international Journal of Research* 222(1), 31--61.

Friedrichs, G. (2008), ‚Sensitive absorption methods for quantitative gas phase kinetic measurements. Part 1: Frequency modulation spectroscopy', *Zeitschrift Für Physikalische Chemie-international Journal of Research* 222(1), 1--30.

Friedrichs, G.; Colberg, M.; Dammeier, J.; Bentz, T. & Olzmann, M. (2008), ‚HCO formation in the thermal unimolecular decomposition of glyoxal: rotational and weak collision effects', *Physical Chemistry Chemical Physics* 10(43), 6520--6533.

Friedrichs, G.; Fikri, M.; Guo, Y. & Temps, F. (2008), ‚Time-resolved cavity ringdown measurements and kinetic modeling of the pressure dependences of the recombination reactions of SiH2 with the alkenes C2H4, C3H6, and t-C4H8', *Journal of Physical Chemistry A* 112(25), 5636--5646.

Froese, R.; Stern-Pirlot, A.; Winker, H. & Gascuel, D. (2008), ‚Size matters: How single-species management can contribute to ecosystem-based fisheries management', *Fisheries Research* 92(2-3), 231--241.

G

Gangsto, R.; Gehlen, M.; Schneider, B.; Bopp, L.; Aumont, O. & Joos, F. (2008), ‚Modeling the marine aragonite cycle: changes under rising carbon dioxide and its role in shallow water CaCO3 dissolution', *Biogeosciences* 5(4), 1057--1072.

Garcia-Solsona, E.; Masque, P.; Garcia-Orellana, J.; Rapaglia, J.; Beck, A. J.; Cochran, J. K.; Bokuniewicz, H. J.; Zaggia, L. & Collavini, F. (2008), ‚Estimating submarine groundwater discharge around Isola La Cura, northern Venice Lagoon (Italy), by using the radium quartet', *Marine Chemistry* 109(3-4), 292--306.

Gebhardt, H.; Sarnthein, M.; Grootes, P. M.; Kiefer, T.; Kuehn, H.; Schmieder, F. & Rohl, U. (2008), ‚Paleonutrient and productivity records from the subarctic North Pacific for Pleistocene glacial terminations I to V', *Paleoceanography* 23(4), PA4212`.

Gilles, A.; Scheidat, M. & Siebert, U. (2009), ‚Seasonal distribution of harbour porpoises and possible interference of offshore wind farms in the German North Sea', *Marine Ecology-progress Series* 383, 295--307.

Glessmer, M. S.; Oschlies, A. & Yool, A. (2008), ‚Simulated impact of double-diffusive mixing on physical and biogeochemical upper ocean properties', *Journal of Geophysical Research-oceans* 113(C8).

Gloer, J.; Thummer, R.; Ullrich, H. & Schmitz, R. A. (2008), ‚Towards understanding the nitrogen signal transduction for nif gene expression in Klebsiella pneumoniae', *Febs Journal* 275(24), 6281--6294.

Gohler, A.; Xiong, G. M.; Paulsen, S.; Trentmann, G. & Maser, E. (2008), ‚Testosterone-inducible regulator is a kinase that drives steroid sensing and metabolism in Comamonas testosteroni', *Journal of Biological Chemistry* 283(25), 17380--17390.

Greaves, M.; Caillon, N.; Rebaubier, H.; Bartoli, G.; Bohaty, S.; Cacho, I.; Clarke, L.; Cooper, M.; Daunt, C.; Delaney, M.; deMenocal, P.; Dutton, A.; Eggins, S.; Elderfield, H.; Garbe-Schoenberg, D.; Goddard, E.; Green, D.; Groeneveld, J.; Hastings, D.; Hathorne, E.; Kimoto, K.; Klinkhammer, G.; Labeyrie, L.; Lea, D. W.; Marchitto, T.; Martinez-Boti, M. A.; Mortyn, P. G.; Ni, Y.; Nuernberg, D.; Paradis, G.; Pena, L.; Quinn, T.; Rosenthal, Y.; Russell, A.; Sagawa, T.; Sosdian, S.; Stott, L.; Tachikawa, K.; Tappa, E.; Thunell, R. & Wilson, P. A. (2008), ‚Interlaboratory comparison study of calibration standards for foraminiferal Mg/Ca thermometry', *Geochemistry Geophysics Geosystems* 9, Q08010.

Griesel, S.; Kakuschke, A.; Siebert, U. & Prange, A. (2008), ‚Trace element concentrations in blood of harbor seals (Phoca vitulina) from the Wadden Sea', *Science of the Total Environment* 392(2-3), 313--323.

Griffies, S. M.; Biastoch, A.; Boning, C.; Bryan, F.; Danabasoglu, G.; Chassignet, E. P.; England, M. H.; Gerdes, R.; Haak, H.; Hallberg, R. W.; Hazeleger, W.; Jungclaus, J.; Large, W. G.; Madec, G.; Pirani, A.; Samuels, B. L.; Scheinert, M.; Sen Gupta, A.; Severijns, C. A.; Simmons, H. L.; Treguier, A. M.; Winton, M.; Yeager, S. & Yin, J. J. (2009), ‚Coordinated Ocean-ice Reference Experiments (COREs)', *Ocean Modelling* 26(1-2), 1--46.

Griffith, E. M.; Paytan, A.; Kozdon, R.; Eisenhauer, A. & Ravelo, A. C. (2008), ‚Influences on the fractionation of calcium isotopes in planktonic foraminifera', *Earth and Planetary Science Letters* 268(1-2), 124--136.

Grootes, P. M.; Sarnthein, M.; Kennett, J. P.; Holbourn, A.; Nadeau, M. J. & Kuhn, H. (2008), ‚Changes in MOC revealed by chronostratigraphic correlation of ocean sediment cores via C-14 plateau tuning', *Geochimica Et Cosmochimica Acta* 72(12), A331--A331.

Gutowska, M. A.; Portner, H. O. & Melzner, F. (2008), ‚Growth and calcification in the cephalopod Sepia officinalis under elevated seawater pCO(2)', *Marine Ecology-progress Series* 373, 303--309.

H

Haley, B. A.; Frank, M.; Spielhagen, R. F. & Eisenhauer, A. (2008), ‚Influence of brine formation on Arctic Ocean circulation over the past 15 million years', *Nature Geoscience* 1(1), 68--72.

Han, X. Q.; Suess, E.; Huang, Y. Y.; Wu, N. Y.; Bohrrnann, G.; Su, X.; Eisenhauer, A.; Rehder, G. & Fang, Y. X. (2008), ‚Jiulong methane reef: Microbial mediation of seep carbonates in the South China Sea', *Marine Geology* 249(3-4), 243--256.

Hanke, F. D.; Kroger, R. H. H.; Siebert, U. & Dehnhardt, G. (2008), ‚Multifocal lenses in a monochromat: the harbour seal', *Journal of Experimental Biology* 211(20), 3315--3322.

Hartke, B. (2009), ‚Methane-water clusters under pressure: Are clathrate cages optimal clusters?', *Journal of Chemical Physics* 130(2), 024905.

Hartke, B. (2008), ‚Morphing Lennard-Jones clusters to TIP4P water clusters: Why do water clusters look like they do?', *Chemical Physics* 346(1-3), 286--294.

Hassan, A. A.; Vossen, A.; Lammler, C.; Siebert, U. & Fernandez-Garayzabal, J. F. (2008), ‚PCR amplification of species specific sequences of 16S rDNA and 16S-23S rDNA intergenic spacer region for identification of Streptococcus phocae', *Microbiological Research* 163(2), 132--135.

Heinemann, A.; Fietzke, J.; Eisenhauer, A. & Zumholz, K. (2008), ‚Modification of Ca isotope and trace metal composition of the major matrices involved in shell formation of Mytilus edulis', *Geochemistry Geophysics Geosystems* 9.

Hemmrich, G. & Bosch, T. C. G. (2008), ‚Compagen, a comparative genomics platform for early branching metazoan animals, reveals early origins of genes regulating stem-cell differentiation', *Bioessays* 30(10), 1010--1018.

Henrich, R.; Hanebuth, T. J. J.; Krastel, S.; Neubert, N. & Wynn, R. B. (2008), ‚Architecture and sediment dynamics of the Mauritania Slide Complex', *Marine and Petroleum Geology* 25(1), 17--33.

Hetzinger, S.; Pfeiffer, M.; Dullo, W. C.; Keenlyside, N.; Latif, M. & Zinke, J. (2008), ‚Caribbean coral tracks Atlantic Multidecadal Oscillation and past hurricane activity', *Geology* 36(1), 11--14.

Heuser, A. & Eisenhauer, A. (2008), ‚The calcium isotope composition (delta Ca-44/40) of NIST SRM 915b and NIST SRM 1486', *Geostandards and Geoanalytical Research* 32(3), 311--315.

Hiller, M.; Szafranski, K.; Sinha, R.; Huse, K.; Nikolajewa, S.; Rosenstiel, P.; Schreiber, S.; Backofen, R. & Platzer, M. (2008), ‚Assessing the fraction of short-distance tandem splice sites under purifying selection', *Rna-a Publication of the Rna Society* 14(4), 616--629.

Himmerkus, N.; Shan, Q. X.; Goerke, B.; Hou, J. H.; Goodenough, D. A. & Bleich, M. (2008), ‚Salt and acid-base metabolism in claudin-16 knockdown mice: impact for the pathophysiology of FHHNC patients', *American Journal of Physiology-renal Physiology* 295(6), F1641--F1647.

Hoppe, H. G.; Breithaupt, P.; Walther, K.; Koppe, R.; Bleck, S.; Sommer, U. & Jurgens, K. (2008), ‚Climate warming in winter affects the coupling between phytoplankton and bacteria during the spring bloom: a mesocosm study', *Aquatic Microbial Ecology* 51(2), 105--115.

Hoving, H. J. T.; Laptikhovsky, V.; Piatkowski, U. & Onsoy, B. (2008), ‚Reproduction in Heteroteuthis dispar (Ruppell, 1844) (Mollusca : Cephalopoda): a sepiolid reproductive adaptation to an oceanic lifestyle', *Marine Biology* 154(2), 219--230.

Hubler, M.; Klepper, G. & Peterson, S. (2008), ‚Costs of climate change The effects of rising temperatures on health and productivity in Germany', *Ecological Economics* 68(1-2), 381--393.

Hyatt, J.; Visbeck, M.; Beardsley, R. C. & Owens, W. B. (2008), ‚Estimating sea-ice coverage, draft, and velocity in Marguerite Bay (Antarctica) using a subsurface moored upward-looking acoustic Doppler current profiler (ADCP)', *Deep-sea Research Part Ii-topical Studies In Oceanography* 55(3-4), 351--364.

I

Isla, J. A.; Lengfellner, K. & Sommer, U. (2008), ‚Physiological response of the copepod Pseudocalanus sp in the Baltic Sea at different thermal scenarios', *Global Change Biology* 14(4), 895--906.

Ivandic, M.; Grevemeyer, I.; Berhorst, A.; Flueh, E. R. & McIntosh, K. (2008), ‚Impact of bending related faulting on the seismic properties of the incoming oceanic plate offshore of Nicaragua', *Journal of Geophysical Research-solid Earth* 113(B5).

K

Kakuschke, A.; Valentine-Thon, E.; Fonfara, S.; Griesel, S.; Rosenberger, T.; Siebert, U. & Prange, A. (2008), ‚Metal-induced impairment of the cellular immunity of newborn harbor seals (Phoca vitulina)', *Archives of Environmental Contamination and Toxicology* 55(1), 129--136.

Kakuschke, A.; Valentine-Thon, E.; Griesel, S.; Rosenberger, T.; Mundry, R.; Siebert, U. & Prange, A. (2008), ‚Blood metal levels and metal-influenced immune functions of harbour seals in captivity', *Marine Pollution Bulletin* 56(4), 764--769.

Karaca, D.; Hensen, C. & Wallmann, K. (2008), ‚Effects of Ca-enrichment on authigenic carbonate formation at cold vent sites off Costa Rica: a numerical model approach', *Mineralogical Magazine* 72(1), 325--327.

Karstensen, J.; Stramma, L. & Visbeck, M. (2008), ‚Oxygen minimum zones in the eastern tropical Atlantic and Pacific oceans', *Progress In Oceanography* 77(4), 331--350.

Kassner, N.; Huse, K.; Martin, H. J.; Godtel-Armbrust, U.; Metzger, A.; Meineke, I.; Brockmoller, J.; Klein, K.; Zanger, U. M.; Maser, E. & Wojnowski, L. (2008), ‚Carbonyl reductase 1 is a predominant doxorubicin reductase in the human liver', *Drug Metabolism and Disposition* 36(10), 2113--2120.

Keenlyside, N. S.; Latif, M.; Jungclaus, J.; Kornblueh, L. & Roeckner, E. (2008), ‚Advancing decadal-scale climate prediction in the North Atlantic sector', *Nature* 453(7191), 84--88.

Kempken, F. (2008), ‚The Tolypocladium inflatum CPA element encodes a RecQ helicase-like gene', *Journal of Basic Microbiology* 48(6), 496--499.

Khalturin, K.; Anton-Erxleben, F.; Sassmann, S.; Wittlieb, J.; Hemmrich, G. & Bosch, T. C. G. (2008), ‚A Novel Gene Family Controls Species-Specific Morphological Traits in Hydra', *Plos Biology* 6(11), 2436--2449.

Kisakurek, B.; Eisenhauer, A.; Bohm, F.; Garbe-Schonberg, D. & Erez, J. (2008), ‚Controls on shell Mg/Ca and Sr/Ca in cultured planktonic foraminiferan, Globigerinoides ruber (white)', *Earth and Planetary Science Letters* 273(3-4), 260--269.

Klemm, V.; Frank, M.; Levasseur, S.; Halliday, A. N. & Hein, J. R. (2008), ‚Seawater osmium isotope evidence for a middle Miocene flood basalt event in ferromanganese crust records', *Earth and Planetary Science Letters* 273(1-2), 175--183.

Kolb, A.; Barth, E. & Koch, R. (2008), ‚ToF-Sensors: New Dimensions for Realism and Interactivity', *2008 Ieee Computer Society Conference On Computer Vision and Pattern Recognition Workshops, Vols* 1-3, 1518--1523.

Konig, S.; Munker, C.; Schuth, S. & Garbe-Schonberg, D. (2008), ‚The geochemical behaviour of Sb, Mo and W in subduction zones', *Geochimica Et Cosmochimica Acta* 72(12), A488--A488.

Konig, S.; Munker, C.; Schuth, S. & Garbe-Schonberg, D. (2008), ‚Mobility of tungsten in subduction zones', *Earth and Planetary Science Letters* 274(1-2), 82--92.

Kopp, H.; Weinrebe, W.; Ladage, S.; Barckhausen, U.; Klaeschen, D.; Flueh, E. R.; Gaedicke, C.; Djajadihardja, Y.; Grevemeyer, I.; Krabbenhoeft, A.; Papenberg, C. & Zillmer, M. (2008), ‚Lower slope morphology of the Sumatra trench system', *Basin Research* 20(4), 519--529.

Kortzinger, A.; Send, U.; Lampitt, R. S.; Hartman, S.; Wallace, D. W. R.; Karstensen, J.; Villagarcia, M. G.; Llinas, O. & DeGrandpre, M. D. (2008), ‚The seasonal pCO(2) cycle at 49 degrees N/16.5 degrees W in the northeastern Atlantic Ocean and what it tells us about biological productivity', *Journal of Geophysical Research-oceans* 113(C4), C04020.

Kortzinger, A.; Send, U.; Wallace, D. W. R.; Karstensen, J. & DeGrandpre, M. (2008), ‚Seasonal cycle of O-2 and pCO(2) in the central Labrador Sea: Atmospheric, biological, and physical implications', *Global Biogeochemical Cycles* 22(1), GB1014.

Koschinsky, A.; Garbe-Schonberg, D.; Sander, S.; Schmidt, K.; Gennerich, H. H. & Strauss, H. (2008), ‚Hydrothermal venting at pressure-temperature conditions above the critical point of seawater, 5 degrees S on the Mid-Atlantic Ridge', *Geology* 36(8), 615--618.

Koser, K.; Beder, C. & Koch, R. (2008), ‚Conjugate rotation: Parameterization and estimation from an affine feature correspondence', *2008 Ieee Conference On Computer Vision and Pattern Recognition, Vols* 1-12, 3528--3535.

Koser, K. & Koch, R. (2008), ‚Differential Spatial Resection - Pose Estimation Using a Single Local Image Feature', *Computer Vision - Eccv 2008, Pt Iv, Proceedings* 5305, 312--325.

Krahmann, G.; Brandt, P.; Klaeschen, D. & Reston, T. (2008), ‚Mid-depth internal wave energy off the Iberian Peninsula estimated from seismic reflection data', *Journal of Geophysical Research-oceans* 113(C12).

Kriest, I. & Oschlies, A. (2008), ‚On the treatment of particulate organic matter sinking in large-scale models of marine biogeochemical cycles', *Biogeosciences* 5(1), 55--72.

Kukowski, N.; Harnpel, A.; Hoth, S. & Bialas, J. (2008), ‚Morphotectonic and morphometric analysis of the Nazca plate and the adjacent offshore Peruvian continental slope - Implications for submarine landscape evolution', *Marine Geology* 254(1-2), 107--120.

Kutterolf, S.; Liebetrau, V.; Morz, T.; Freundt, A.; Hammerich, T. & Garbe-Schonberg, D. (2008), ‚Lifetime and cyclicity of fluid venting at forearc mound structures determined by tephrostratigraphy and radiometric dating of authigenic carbonates', *Geology* 36(9), 707--710.

L

Landolfi, A.; Oschlies, A. & Sanders, R. (2008), ‚Organic nutrients and excess nitrogen in the North Atlantic subtropical gyre', *Biogeosciences* 5(5), 1199--1213.

Langer, G.; Gussone, N.; Nehrke, G.; Riebesell, U.; Eisenhauer, A. & Thoms, S. (2007), ‚Calcium isotope fractionation during coccolith formation in Emiliania huxleyi: Independence of growth and calcification rate', *Geochemistry Geophysics Geosystems* 8, Q05007.

Langlois, R. J.; Hummer, D. & LaRoche, J. (2008), ‚Abundances and distributions of the dominant nifH phylotypes in the Northern Atlantic Ocean', *Applied and Environmental Microbiology* 74(6), 1922--1931.

Liebetrau, V.; Eisenhauer, A.; Fietzke, J.; Kutterolf, S.; Hammerich, T.; Gunther, D. & Linke, P. (2008), ‚Cold-seep carbonates as marine isotope geochemical archives: New insights comparing chronology and emplacement controlling processes of circuni-Pacific settings', *Geochimica Et Cosmochimica Acta* 72(12), A551--A551.

Linden, A.; Gulden, M.; Martin, H. J.; Maser, E. & Seibert, H. (2008), ‚Peroxide-induced cell death and lipid peroxidation in C6 glioma cells', *Toxicology In Vitro* 22(5), 1371--1376.

Lonsdale, K. G.; Downing, T. E.; Nicholls, R. J.; Parker, D.; Vafeidis, A. T.; Dawson, R. & Hall, J. (2008), ‚Plausible responses to the threat of rapid sea-level rise in the Thames Estuary', *Climatic Change* 91(1-2), 145--169.

Loptien, U.; Zolina, O.; Gulev, S.; Latif, M. & Soloviov, V. (2008), ‚Cyclone life cycle characteristics over the Northern Hemisphere in coupled GCMs', *Climate Dynamics* 31(5), 507--532.

Lu, Z. L.; Hensen, C.; Fehn, U. & Wallmann, K. (2008), ‚Halogen and I-129 systematics in gas hydrate fields at the northern Cascadia margin (IODP Expedition 311): Insights from numerical modeling', *Geochemistry Geophysics Geosystems* 9.

M

Mark, F.; Melzner, F.; Bock, C.; Poermer, H.; Ellington, C. & Claireaux, G. (2008), ‚Thermal effects on cephalopod energy metabolism - A case study for Sepia officinalis', *Comparative Biochemistry and Physiology A-molecular & Integrative Physiology* 150(3), S171--S171.

Maser, E.; Guhl, J.; Broszat, S. & Xiong, G. (2008), ‚Isolation and activity identification of the LysR gene', *Naunyn-schmiedebergs Archives of Pharmacology* 377, 337.

Masson, D. G. (2008), ‚Flank collapse and large-scale landsliding in the Cape Verde Islands, off West Africa', *Geochemistry Geophysics Geosystems* 9, Q07015.

Matei, D.; Keenlyside, N.; Latif, M. & Jungclaus, J. (2008), ‚Subtropical forcing of tropical Pacific climate and decadal ENSO modulation', *Journal of Climate* 21(18), 4691--4709.

Mather, R. L.; Reynolds, S. E.; Wolff, G. A.; Williams, R. G.; Torres-Valdes, S.; Woodward, E. M. S.; Landolfi, A.; Pan, X.; Sanders, R. & Achterberg, E. P. (2008), ‚Phosphorus cycling in the North and South Atlantic Ocean subtropical gyres', *Nature Geoscience* 1(7), 439--443.

Melchert, B.; Devey, C. W.; German, C. R.; Lackschewitz, K. S.; Seifert, R.; Walter, M.; Mertens, C.; Yoerger, D. R.; Baker, E. T.; Paulick, H. & Nakamura, K. (2008), ‚First evidence for high-temperature off-axis venting of deep crustal/mantle heat: The Nibelungen hydrothermal field, southern Mid-Atlantic Ridge', *Earth and Planetary Science Letters* 275(1-2), 61--69.

Mills, M. M.; Moore, C. M.; Langlois, R.; Milne, A.; Achterberg, E.; Nachtigall, K.; Lochte, K. & Geider, R. J. (2008), ‚Nitrogen and phosphorus co-limitation of bacterial productivity and growth in the oligotrophic subtropical North Atlantic', *Limnology and Oceanography* 53(2), 824--834.

Moore, C. M.; Mills, M. M.; Langlois, R.; Milne, A. & Achterberg, E. P. (2008), ‚Relative influence of nitrogen and phosphorus availability on phytoplankton physiology and productivity in the oligotrophic sub-tropical North Atlantic Ocean', *Limnology and Oceanography* 53(1), 291--305.

Moorthi, S. I.; Hillebrand, H.; Wahl, M. & Berninger, U. G. (2008), ‚Consumer diversity enhances secondary production by complementarily effects in experimental ciliate assemblages', *Estuaries and Coasts* 31(1), 152--162.

Muller, G.; Kaim, U.; Haas, L.; Greiser-Wilke, I.; Wohlsein, P.; Siebert, U. & Baumgartner, W. (2008), ‚Phocine distemper virus: characterization of the morbillivirus causing the seal epizootic in northwestern Europe in 2002', *Archives of Virology* 153(5), 951--956.

Muller, M. N.; Antia, A. N. & LaRoche, J. (2008), ‚Influence of cell cycle phase on calcification in the coccolithophore Emiliania huxleyi', *Limnology and Oceanography* 53(2), 506--512.

N

Nicholls, R. J.; Tol, R. S. J. & Vafeidis, A. T. (2008), ‚Global estimates of the impact of a collapse of the West Antarctic ice sheet: an application of FUND', *Climatic Change* 91(1-2), 171--191.

Novotna, R.; Wsol, V.; Xiong, G. & Maser, E. (2008), ‚Inactivation of the anticancer drugs doxorubicin and oracin by aldo-keto reductase (AKR) 1C3', *Toxicology Letters* 181(1), 1--6.

O

Oschlies, A.; Schulz, K. G.; Riebesell, U. & Schmittner, A. (2008), ‚Simulated 21st century's increase in oceanic suboxia by CO2-enhanced biotic carbon export', *Global Biogeochemical Cycles* 22(4), GB4008.

P

Park, W. & Latif, M. (2008), ‚Multidecadal and multicentennial variability of the meridional overturning circulation', *Geophysical Research Letters* 35(22).

Pavlova, G. Y.; Tishchenko, P. Y.; Volkova, T. I.; Dickson, A. & Wallmann, K. (2008), ‚Intercalibration of Bruevich's method to determine the total alkalinity in seawater', *Oceanology* 48(3), 438--443.

Peytcheva, I.; von Quadt, A.; Georgiev, N.; Ivanov, Z.; Heinrich, C. A. & Frank, M. (2008), ‚Combining trace-element compositions, U-Pb geochronology and Hf isotopes in zircons to unravel complex calcalkaline magma chambers in the Upper Cretaceous Srednogorie zone (Bulgaria)', *Lithos* 104(1-4), 405--427.

Pierce, G. J.; Valavanis, V. D.; Guerra, A.; Jereb, P.; Orsi-Relini, L.; Bellido, J. M.; Katara, I.; Piatkowski, U.; Pereira, J.; Balguerias, E.; Sobrino, I.; Lefkaditou, E.; Wang, J.; Santurtun, M.; Boyle, P. R.; Hastie, L. C.; MacLeod, C. D.; Smith, J. M.; Viana, M.; Gonzalez, A. F. & Zuur, A. F. (2008), ‚A review of cephalopod-environment interactions in European Seas', *Hydrobiologia* 612, 49--70.

Piontek, J.; Handel, N.; Langer, G.; Wohlers, J.; Riebesell, U. & Engel, A. (2009), ‚Effects of rising temperature on the formation and microbial degradation of marine diatom aggregates', *Aquatic Microbial Ecology* 54(3), 305--318.

Portnyagin, M.; Savelyev, D.; Hoernle, K.; Hauff, F. & Garbe-Schonberg, D. (2008), ‚Mid-Cretaceous Hawaiian tholeiites preserved in Kamchatka', *Geology* 36(11), 903--906.

Poumadere, M.; Mays, C.; Pfeifle, G. & Vafeidis, A. T. (2008), ‚Worst case scenario as stakeholder decision support: a 5-to 6-m sea level rise in the Rhone delta, France', *Climatic Change* 91(1-2), 123--143.

Prenger-Berninghoff, E.; Siebert, U.; Stede, M.; Koenig, A.; Weiss, R. & Baljer, G. (2008), ‚Incidence of Brucella species in marine mammals of the German north sea', *Diseases of Aquatic Organisms* 81(1), 65--71.

Q

Quaas, M. F. & Baumgartner, S. (2008), ‚Natural vs. financial insurance in the management of public-good ecosystems', *Ecological Economics* 65(2), 397--406.

R

Ranero, C. R.; Grevemeyer, I.; Sahling, H.; Barckhausen, U.; Hensen, C.; Wallmann, K.; Weinrebe, W.; Vannucchi, P.; von Huene, R. & McIntosh, K. (2008), ‚Hydrogeological system of erosional convergent margins and its influence on tectonics and interplate seismogenesis', *Geochemistry Geophysics Geosystems* 9.

Rauch, G.; Kalbe, M. & Reusch, T. B. H. (2008), ‚Partitioning average competition and extreme-genotype effects in genetically diverse infections', *Oikos* 117(3), 399--405.

Rehdanz, K. & Maddison, D. (2008), ‚Local environmental quality and life-satisfaction in Germany', *Ecological Economics* 64(4), 787--797.

Rehdanz, K. & Stowhase, S. (2008), ‚Cost Liability and Residential Space Heating Expenditures of Welfare Recipients in Germany', *Fiscal Studies* 29(3), 329--345.

Reusch, T. B. H.; Veron, A. S.; Preuss, C.; Weiner, J.; Wissler, L.; Beck, A.; Klages, S.; Kube, M.; Reinhardt, R. & Bornberg-Bauer, E. (2008), ‚Comparative analysis of expressed sequence tag (EST) libraries in the seagrass Zostera marina subjected to temperature stress', *Marine Biotechnology* 10(3), 297--309.

Reuter, S.; Velic, A.; Edemir, B.; Schroter, R.; Pavenstadt, H.; Gabriels, G.; Bleich, M. & Schlatter, E. (2008), ‚Protective role of NHE-3 inhibition in rat renal transplantation undergoing acute rejection', *Pflugers Archiv-european Journal of Physiology* 456(6), 1075--1084.

Reynolds, B. C.; Frank, M. & Halliday, A. N. (2008), ‚Evidence for a major change in silicon cycling in the subarctic North Pacific at 2.73 Ma', *Paleoceanography* 23(4).

Riebesell, U.; Bellerby, R. G. J.; Engel, A.; Fabry, V. J.; Hutchins, D. A.; Reusch, T. B. H.; Schulz, K. G. & Morel, F. M. M. (2008), ‚Comment on „Phytoplankton Calcification in a High-CO2 World"', *Science* 322(5907).

Riebesell, U.; Bellerby, R. G. J.; Grossart, H. P. & Thingstad, F. (2008), ‚Mesocosm CO2 perturbation studies: from organism to community level', *Biogeosciences* 5(4), 1157--1164.

Rohde, S.; Hiebenthal, C.; Wahl, M.; Karez, R. & Bischof, K. (2008), ‚Decreased depth distribution of Fucus vesiculosus (Phaeophyceae) in the Western Baltic: effects of light deficiency and epibionts on growth and photosynthesis', *European Journal of Phycology* 43(2), 143--150.

Rohde, S. & Wahl, M. (2008), ‚Temporal dynamics of induced resistance in a marine macroalga: Time lag of induction and reduction in Fucus vesiculosus', *Journal of Experimental Marine Biology and Ecology* 367(2), 227--229.

Rohde, S. & Wahl, M. (2008), ‚Antifeeding defense in baltic macroalgae: Induction by direct grazing versus waterborne cues', *Journal of Phycology* 44(1), 85--90.

Rohl, C.; Armbrust, E.; Kolbe, K.; Lucius, R.; Maser, E.; Venz, S. & Gulden, M. (2008), ‚Activated microglia modulate astroglial enzymes involved in oxidative and inflammatory stress and increase the resistance of astrocytes to oxidative stress in vitro', *Glia* 56(10), 1114--1126.

Rosenstiel, P.; Derer, S.; Till, A.; Hasler, R.; Eberstein, H.; Bewig, B.; Nikolaus, S.; Nebel, A. & Schreiber, S. (2008), ‚Systematic expression profiling of innate immune genes defines a complex pattern of immunosenescence in peripheral and intestinal leukocytes', *Genes and Immunity* 9(2), 103--114.

Rosenstiel, P.; Philipp, E. E. R.; Schreiber, S. & Bosch, T. C. G. (2009), ‚Evolution and Function of Innate Immune Receptors - Insights from Marine Invertebrates', *Journal of Innate Immunity* 1(4), 291--300.

Ruggeberg, A.; Fietzke, J.; Liebetrau, V.; Eisenhauer, A.; Dullo, W. C. & Freiwald, A. (2008), ‚Stable strontium isotopes (delta Sr-88/86) in cold-water corals - A new proxy for reconstruction of intermediate ocean water temperatures', *Earth and Planetary Science Letters* 269(3-4), 569--574.

Rupke, L. H.; Schmalholz, S. M.; Schmid, D. W. & Podiadchikov, Y. Y. (2008), ‚Automated thermotectonostratigraphic basin reconstruction: Viking Graben case study', *Aapg Bulletin* 92(3), 309--326.

Ruweler, M.; Anker, A.; Gulden, M.; Maser, E. & Seibert, H. (2008), ‚Inhibition of peroxide-induced radical generation by plant polyphenols', *Toxicology In Vitro* 22(5), 1377--1381.

S

Sahling, H.; Bohrmann, G.; Spiess, V.; Bialas, J.; Breitzke, M.; Ivanov, M.; Kasten, S.; Krastel, S. & Schneider, R. (2008), ‚Pockmarks in the Northern Congo Fan area, SW Africa: Complex seafloor features shaped by fluid flow', *Marine Geology* 249(3-4), 206--225.

Sallhoglu, B.; Garcon, V.; Oschlies, A. & Lomas, M. W. (2008), ‚Influence of nutrient utilization and remineralization stoichiometry on phytoplankton species and carbon export: A modeling study at BATS', *Deep-sea Research Part I-oceanographic Research Papers* 55(1), 73--107.

Schedel, M.; Pinto, L. A.; Schaub, B.; Rosenstiel, P.; Cherkasov, D.; Cameron, L.; Klopp, N.; Illig, T.; Vogelberg, C.; Weiland, S. K.; von Mutius, E.; Lohoff, M. & Kabesch, M. (2008), ‚IRF-1 gene variations influence IgE regulation and atopy', *American Journal of Respiratory and Critical Care Medicine* 177(6), 613--621.

Schlosser, C. & Croot, P. L. (2008), ‚Application of cross-flow filtration for determining the solubility of iron species in open ocean seawater', *Limnology and Oceanography-methods* 6, 630--642.

Schmittner, A.; Oschlies, A.; Matthews, H. D. & Galbraith, E. D. (2008), ‚Future changes in climate, ocean circulation, ecosystems, and biogeochemical cycling simulated for a business-as-usual CO2 emission scenario until year 4000 AD', *Global Biogeochemical Cycles* 22(1).

Schneider, B.; Bopp, L. & Gehlen, M. (2008), ‚Assessing the sensitivity of modeled air-sea CO2 exchange to the remineralization depth of particulate organic and inorganic carbon', *Global Biogeochemical Cycles* 22(3), GB3021.

Schneider, B.; Bopp, L.; Gehlen, M.; Segschneider, J.; Frolicher, T. L.; Cadule, P.; Friedlingstein, P.; Doney, S. C.; Behrenfeld, M. J. & Joos, F. (2008), ‚Climate-induced interannual variability of marine primary and export production in three global coupled climate carbon cycle models', *Biogeosciences* 5(2), 597--614.

Schnitzler, J. G.; Koutrakis, E.; Siebert, U.; Thome, J. P. & Das, K. (2008), ‚Effects of persistent organic pollutants on the thyroid function of the European sea bass (Dicentrarchus labrax) from the Aegean sea, is it an endocrine disruption?', *Marine Pollution Bulletin* 56(10), 1755--1764.

Scholten, J. C.; Fietzke, J.; Mangini, A.; Garbe-Schbnberg, C. D.; Eisenhauer, A.; Schneider, R. & Stoffers, P. (2008), ‚Advection and scavenging: Effects on Th-230 and Pa-231 distribution off Southwest Africa', *Earth and Planetary Science Letters* 271(1-4), 159--169.

von Schuckmann, K.; Brandt, P. & Eden, C. (2008), ‚Generation of tropical instability waves in the Atlantic Ocean', *Journal of Geophysical Research-oceans* 113(C8).

Schwarz, R. S.; Bosch, T. C. G. & Cadavid, L. F. (2008), ‚Evolution of polydom-like molecules: Identification and characterization of cnidarian polydom (Cnpolydom) in the basal metazoan Hydractinia', *Developmental and Comparative Immunology* 32(10), 1192--1210.

van Sebille, E.; Biastoch, A.; van Leeuwen, P. J. & de Ruijter, W. P. M. (2009), ‚A weaker Agulhas Current leads to more Agulhas leakage', *Geophysical Research Letters* 36.

Semenov, V. A.; Latif, M.; Jungclaus, J. H. & Park, W. (2008), ‚Is the observed NAO variability during the instrumental record unusual?', *Geophysical Research Letters* 35(11).

Siebert, S.; Anton-Erxleben, F. & Bosch, T. C. G. (2008), ‚Cell type complexity in the basal metazoan Hydra is maintained by both fly stem cell based mechanisms and transdifferentiation', *Developmental Biology* 313(1), 13--24.

Sinha, V.; Williams, J.; Meyerhofer, M.; Riebesell, U.; Paulino, A. I. & Larsen, A. (2007), ‚Air-sea fluxes of methanol, acetone, acetaldehyde, isoprene and DMS from a Norwegian fjord following a phytoplankton bloom in a mesocosm experiment', *Atmospheric Chemistry and Physics* 7, 739--755.

Sommer, U.; Aberle, N.; Engel, A.; Hansen, T.; Lengfellner, K.; Sandow, M.; Wohlers, J.; Zollner, E. & Riebesell, U. (2007), ‚An indoor mesocosm system to study the effect of climate change on the late winter and spring succession of Baltic Sea phyto- and zooplankton', *Oecologia* 150(4), 655--667.

Sommer, U. & Lengfellner, K. (2008), ‚Climate change and the timing, magnitude, and composition of the phytoplankton spring bloom', *Global Change Biology* 14(6), 1199--1208.

Steigenberger, S. & Croot, P. L. (2008), ‚Identifying the processes controlling the distribution of H2O2 in surface waters along a meridional transect in the eastern Atlantic', *Geophysical Research Letters* 35(3), L03616.

Steinke, S.; Hanebuth, T. J. J.; Vogt, C. & Stattegger, K. (2008), ‚Sea level induced variations in clay mineral composition in the southwestern South China Sea over the past 17,000 yr', *Marine Geology* 250(3-4), 199--210.

Stieglitz, T.; Rapaglia, J. & Bokuniewicz, H. (2008), ‚Estimation of submarine groundwater discharge from bulk ground electrical conductivity measurements', *Journal of Geophysical Research-oceans* 113(C8).

Stramma, L.; Brandt, P.; Schafstall, J.; Schott, F.; Fischer, J. & Kortzinger, A. (2008), ‚Oxygen minimum zone in the North Atlantic south and east of the Cape Verde Islands', *Journal of Geophysical Research-oceans* 113(C4), C04014.

Suffrian, K.; Simonelli, P.; Nejstgaard, J. C.; Putzeys, S.; Carotenuto, Y. & Antia, A. N. (2008), ‚Microzooplankton grazing and phytoplankton growth in marine mesocosms with increased CO2 levels', *Biogeosciences* 5(4), 1145--1156.

Sugden, H.; Lenz, M.; Molis, M.; Wahl, M. & Thomason, J. C. (2008), ‚The interaction between nutrient availability and disturbance frequency on the diversity of benthic marine communities on the north-east coast of England', *Journal of Animal Ecology* 77(1), 24--31.

Suttner, K.; Rosenstiel, P.; Depner, M.; Ruoss, I.; Peters, W.; Klopp, N.; Illig, T.; Vogelberg, C.; Weiland, S. K.; von Mutius, E. & Kabesch, M. (2008), ‚Characterisation of gene variations in the transcription T-bet and HLX1 and their functional role in the development of asthma', *Journal of Allergy and Clinical Immunology* 121(2), 246.

T

Talukder, A. R.; Bialas, J.; Klaeschen, D.; Brueckmann, W.; Reston, T. & Petersen, J. (2008), ‚Tectonic framework of the mud mounds, associated BSRs and submarine landslides, offshore Nicaragua Pacific margin', *Journal of the Geological Society* 165, 167--176.

Tanaka, T.; Thingstad, T. F.; Lovdal, T.; Grossart, H. P.; Larsen, A.; Allgaier, M.; Meyerhofer, M.; Schulz, K. G.; Wohlers, J.; Zollner, E. & Riebesell, U. (2008), ‚Availability of phosphate for phytoplankton and bacteria and of glucose for bacteria at different pCO(2) levels in a mesocosm study', *Biogeosciences* 5(3), 669--678.

Tang, J. W.; Dietzel, M.; Bohm, F.; Kohler, S. J. & Eisenhauer, A. (2008), ‚Sr2+/Ca2+ and Ca-44/Ca-40 fractionation during inorganic calcite formation: II. Ca isotopes', *Geochimica Et Cosmochimica Acta* 72(15), 3733--3745.

Tasarova, Z. A.; Bielik, M. & Gotze, H. J. (2008), ‚Stripped image of the gravity field of the Carpathian-Pannonian region based on the combined interpretation of the CELEBRATION 2000 data', *Geologica Carpathica* 59(3), 199--209.

Thomas, H.; Prowe, A. E. F.; Lima, I. D.; Doney, S. C.; Wanninkhof, R.; Greatbatch, R. J.; Schuster, U. & Corbiere, A. (2008), ‚Changes in the North Atlantic Oscillation influence CO2 uptake in the North Atlantic over the past 2 decades', *Global Biogeochemical Cycles* 22(4).

Till, A.; Rosenstiel, P.; Braeutigam, K.; Sina, C.; Jacobs, G.; Oberg, H. H.; Seegert, D.; Chakraborty, T. & Schreiber, S. (2008), ‚A role for membrane-bound CD147 in NOD2-mediated recognition of bacterial cytoinvasion', *Journal of Cell Science* 121(4), 487--495.

Tilmann, F. J.; Greverneyer, I.; Flueh, E. R.; Dahm, T. & Gossler, J. (2008), ‚Seismicity in the outer rise offshore southern Chile: Indication of fluid effects in crust and mantle', *Earth and Planetary Science Letters* 269(1-2), 41--55.

Tol, R. S. J. & Rehdanz, K. (2008), ‚A no cap but trade proposal for emission targets', *Climate Policy* 8(3), 293--304.

Tolentino-Pablico, G.; Bailly, N.; Froese, R. & Elloran, C. (2008), ‚Seaweeds preferred by herbivorous fishes', *Journal of Applied Phycology* 20(5), 933--938.

U

Ubbecke, J. F. L.; Boning, C. W. & Biastoch, A. (2008), ‚Variability in the subtropical-tropical cells and its effect on near-surface temperature of the equatorial Pacific: a model study', *Ocean Science* 4(1), 73--88.

V

Vafeidis, A. T.; Nicholls, R. J.; McFadden, L.; Tol, R. S. J.; Hinkel, J.; Spencer, T.; Grashoff, P. S.; Boot, G. & Klein, R. J. T. (2008), ‚A new global coastal database for impact and vulnerability analysis to sea-level rise', *Journal of Coastal Research* 24(4), 917--924.

Valdivia, N.; Stehbens, J. D.; Hermelink, B.; Connell, S. D.; Molis, M. & Wahl, M. (2008), ‚Disturbance mediates the effects of nutrients on developing assemblages of epibiota', *Austral Ecology* 33(8), 951--962.

Verma, M.; Martin, H. J.; Haq, W.; O'Connor, T. R.; Maser, E. & Balendiran, G. K. (2008), ‚Inhibiting wild-type and C299S mutant AKR1B10: a homologue of aldose reductase upregulated in cancers', *European Journal of Pharmacology* 584(2-3), 213--221.

Visbeck, M. (2008), ‚From climate assessment to climate services', *Nature Geoscience* 1(1), 2--3.

Vital, H.; Stattegger, K.; Amaro, V. E.; Schwarzer, K.; Frazao, E. P.; Tabosa, W. F. & Silveira, I. M. (2008), ‚A Modern High-energy Siliciclastic-carbonate Platform: Continental Shelf Adjacent To Northern Rio Grande Do Norte State, Northeastern Brazil', *Recent Advances In Models of Siliciclastic Shallow-marine Stratigraphy* 90, 177--190.

Voss, R.; Dickmann, M.; Hinrichsen, H. H. & Floeter, J. (2008), ‚Environmental factors influencing larval sprat Sprattus sprattus feeding during spawning time in the Baltic Sea', *Fisheries Oceanography* 17(3), 219--230.

W

Wagner-Friedrichs, M.; Krastel, S.; Spiess, V.; Ivanov, M.; Bohrmann, G. & Meisner, L. (2008), ‚Three-dimensional seismic investigations of the Sevastopol mud volcano in correlation to gas/fluid migration pathways and indications for gas hydrate occurrences in the Sorokin Trough (Black Sea)', *Geochemistry Geophysics Geosystems* 9.

Wahl, M. (2008), ‚Ecological lever and interface ecology: epibiosis modulates the interactions between host and environment', *Biofouling* 24(6), 427--438.

Wahl, M. (2008), ‚Ecological modulation of environmental stress: interactions between ultraviolet radiation, epibiotic snail embryos, plants and herbivores', *Journal of Animal Ecology* 77(3), 549--557.

Wallmann, K. (2008), ‚Mesozoic climate - Liverworts and all', *Nature Geoscience* 1(1), 14--15.

Wallmann, K.; Aloisi, G.; Haeckel, M.; Tishchenko, P.; Pavlova, G.; Greinert, J.; Kutterolf, S. & Eisenhauer, A. (2008), ‚Silicate weathering in anoxic marine sediments', *Geochimica Et Cosmochimica Acta* 72(12), 2895--2918.

Wallmann, K.; Aloisi, G.; Haeckel, M.; Tishchenko, P.; Pavlova, G.; Greinert, J.; Kutterolf, S. & Eisenhauer, A. (2008), ‚Silicate weathering in anoxic marine sediments', *Mineralogical Magazine* 72(1), 363--366.

Wang, L.; Winter, C.; Schrottke, K.; Hebbeln, D. & Bartholoma, A. (2008), ‚Modelling of Estuarine Fluid Mud Evolution In Troughs of Large Subaqueous Dune', *Proceedings of the Chinese-german Joint Symposium On Hydraulic and Ocean Engineering*, 369--376.

Wegner, K. M.; Kalbe, M.; Milinski, M. & Reusch, T. B. H. (2008), ‚Mortality selection during the 2003 European heat wave in three-spined sticklebacks: effects of parasites and MHC genotype', *Bmc Evolutionary Biology* 8.

Weidenbach, K.; Ehlers, C.; Kock, J.; Ehrenreich, A. & Schmitz, R. A. (2008), ‚Insights into the NrpR regulon in Methanosarcina mazei Go1', *Archives of Microbiology* 190(3), 319--332.

Weidenbach, K.; Gloer, J.; Ehlers, C.; Sandman, K.; Reeve, J. N. & Schmitz, R. A. (2008), ‚Deletion of the archaeal histone in Methanosarcina mazei Go1 results in reduced growth and genomic transcription', *Molecular Microbiology* 67(3), 662--671.

Weinberger, F.; Buchholz, B.; Karez, R. & Wahl, M. (2008), ‚The invasive red alga Gracilaria vermiculophylla in the Baltic Sea: adaptation to brackish water may compensate for light limitation', *Aquatic Biology* 3(3), 251--264.

Werban, U.; al Hagrey, S. A. & Rabbel, W. (2008), ‚Monitoring of root-zone water content in the laboratory by 2D geoelectrical tomography', *Journal of Plant Nutrition and Soil Science-zeitschrift Für Pflanzenernahrung Und Bodenkunde* 171(6), 927--935.

Wingenter, O. W.; Haase, K. B.; Zeigler, M.; Blake, D. R.; Rowland, F. S.; Sive, B. C.; Paulino, A.; Thyrhaug, R.; Larsen, A.; Schulz, K. G.; Meyerhofer, M. & Riebesell, U. (2007), ‚Unexpected consequences of increasing CO2 and ocean acidity on marine production of DMS and CH2Cll: Potential climate impacts', *Geophysical Research Letters* 34(5), L05710.

Wohlers, J.; Engel, A.; Zollner, E.; Breithaupt, P.; Jurgens, K.; Hoppe, H. G.; Sommer, U. & Riebesell, U. (2009), ‚Changes in biogenic carbon flow in response to sea surface warming', *Proceedings of the National Academy of Sciences of the United States of America* 106(17), 7067--7072.

Wollgast, S.; Lenz, M.; Wahl, M. & Molis, M. (2008), ‚Effects of regular and irregular temporal patterns of disturbance on biomass accrual and species composition of a subtidal hard-bottom assemblage', *Helgoland Marine Research* 62(4), 309--319.

X

Xiong, G.; Draus, E. & Maser, E. (2008), ‚Isolation and characterization of a steroid degrading bacterial strain', *Naunyn-schmiedebergs Archives of Pharmacology* 377, 336.

Y

You, Y. Z.; Ribbe, J.; Karstensen, J. & Church, J. (2008), ‚Matthias Tomczak: A distinguished regional oceanographer and water-mass expert', *Progress In Oceanography* 77(4), 269--272.

Z

Zeller, M.; Reusch, T. B. H. & Lampert, W. (2008), ‚Small effective population sizes in two planktonic freshwater copepod species (Eudiaptomus) with apparently large census sizes', *Journal of Evolutionary Biology* 21(6), 1755--1762.

Zhai, L.; Sheng, J. Y. & Greatbatch, R. J. (2008), ‚Baroclinic dynamics of wind-driven circulation in a stratified bay: A numerical study using models of varying complexity', *Continental Shelf Research* 28(17), 2357--2370.

Zhai, L.; Sheng, J. Y. & Greatbatch, R. J. (2008), ‚Application of a nested-grid ocean circulation model to Lunenburg Bay of Nova Scotia: Verification against observations', *Journal of Geophysical Research-oceans* 113(C2).

Zhai, X. M.; Greatbatch, R. J. & Kohlmann, J. D. (2008), ‚On the seasonal variability of eddy kinetic energy in the Gulf Stream region', *Geophysical Research Letters* 35(24).

Zitter, T. A. C.; Henry, P.; Aloisi, G.; Delaygue, G.; Cagatay, M. N.; de Lepinay, B. M.; Al-Samir, M.; Fornacciari, F.; Tesmer, M.; Pekdeger, A.; Wallmann, K. & Lericolais, G. (2008), ‚Cold seeps along the main Marmara Fault in the Sea of Marmara (Turkey)', *Deep-sea Research Part I-oceanographic Research Papers* 55(4), 552--570.

Zuhayra, M.; Lutzen, U.; Lutzen, A.; Papp, L.; Henze, E.; Friedrichs, G. & Oberdorfer, F. (2008), ‚C-H Bond Activation of Coordinated Pyridine: Ortho-Pyridyl-Ditechnetiumhydridocarbonyl Metal Cyclus. Crystal Structure and Dynamic Behavior in Solution', *Inorganic Chemistry* 47(21), 10177--10182.

FUNDED CLUSTER PROJECTS

ID	AUTHOR	TITEL	DURATION
CP0602	Bleich	CO2-induced Ocean Acidification: Biological Responses and Adaptions	24 months
CP0603	Eisenhauer et al.	Boron Isotopes as a Proxy for pH decresse an pCo2 increase	0 (Investment)
CP0605	Froese et al.	Managing Cod and Sprat in the Central Baltic Sea - A bio-economic multi-species approach with Stochastic regeneration functions	24 months
CP0608	Luttenberger et al.	dearX - XML Technology for marine Data Exchange, Archiving and Retrieval	12 months
CP0609	Macke et al.	The role of light fluctuations on ocean heting and photosynthesis	24 months
CP0610	Piepenburg et al.	Synergetic effects of temperature, pH and salinity on the metabolism of benthic organism	12 months
CP0611	Schmitz-Streit et al.	Complex Barriers and Microbiota in the Ocean: implications for human barrier disorders	24 months
CP0612	R Schneider et al.	Radiocarbon dating of fossil biogenic as an indicator of age differences in surface and subsurface water masses in the past ocean	12 months
CP0614	Srivastav et al.	Mathematical and Algorithmic in Modelling Marine Biogeochemical Cycles	24 months
CP0618	Zimmermann et al.	Beyond Mineral Resources - The International Legal Regime and Regulation of New Uses of the Deep Sea Bed	24 months
CP0619	Latif et al.	Development of a Coupled Climate/Ocean Biogeochemistry Model	24 months
CP0063	Körtzinger	Data Mining	6 months
CP0702	Bosch et al.	Transgenic Aurelia allow functional analysis of genes involved in control of tissue homeostasis and biological barriers	24 months
CP0704	Schulz-Friedrich et al.	Carbon acquisition in coccolithophores: molecular basis and adaptive potential	12 months
CP0706	Wahl & Schmitz-Streit	Complex barriers: The biotic control of marine biofilms on algal surfaces	24 months
CP0709	Maser et al.	Marine Steroid Pharmaceuticals to Control Human Diseases	24 months
CP0710	Eisenhauer et al.	VARAN -Variations of Trace Element Fluxes induced by Ocean Acidification at Ca2+-Channels/ Ca2+-ATPases	24 months
CP0713	Oschlies et al.	A new computational framework to efficiently integrate biogeochemical models from seasonal to multi-millennial time scales	24 months
CP0717	Thomsen et al.	Complex barriers and microbiota in the Ocean	24 months
CP0718	Klepper et al.	Economic valuation of the ocean's role in the carbon cycle and consequences for abatement and mitigation strategies	24 months
CP0721	Braack et al.	Parameterization of near surface vertical mixing processes by multiscale methods	24 months
CP0722	Sommer et al.	Building up the capacity for δ34S measurements from organic samples by continuous flow isotope mass spectrometry	24 months
CP0724	Braack & Schneider	3-D Simulation of Thermohaline Convection in the Ocean's Crust with Adaptive Finite Elements	24 months
CP0725	Schönfeld et al.	Changing habitats of calcareous plankton in the Greenhouse World	24 months
CP0726	Wallace et al.	Improved Methods for Nitrogen Isotope Studies with Specific Application at the Tropical Eastern North Atlantic Time-Series Observatory, Cape Verde	24 months
CP0727	Rosenstiel et al.	Deciphering transcriptomal responses to environmental stimuli in simple aquatic model organisms by massive parallel sequencing technology	24 months
CP0730	Oschlies et al.	Modelling chemosensor-aided foraging in zooplankton	24 months

ID	AUTHOR	TITEL	DURATION
CP07A32	Koch et al.	3-D Modeling of Seafloor Struktures	8 months
CP07A34	Oschlies et al.	Carbon and Nitrogen Cycle Dynamics	18 months
CP07A37	Luttenberger et al.	An XML-based workbench for marine and biological data (XDataCollection)	6 months
CP07A39	Oschlies et al.	Neuronal-network based coupling of benthic and pelagic..	12 months
CP07A43	LaRoche et al.	Bioprospecting of Deep-Sea genetic resources	24 months
CP07A45	Dullo et al.	Biogeochemical Studies on the effects of ocean accidification	6 months
CP07A46	Weinberger et al.	A transcript profiling tool to investigate synergistic effects of non-biotoc and biotic changes	15 months
CP07A47	Karstensen et al.	Glider swarm Project	18 months
CP07A51	Requate et al.	Alternative Scenarios for European Fisheries Management	12 months
CP07A52	Wahl et al.	The neglected bottleneck: Early life stage ecology in times of global change	24 months
CP07A53	Weinrebe	Iceflow activity revealed from submarine morphology - mapping …	12 months
CP07A54	Piepenburg et al.	Ecophysiological consequences of ocean warming and acidification	12 months
CP07A58	Friedrichs et al.	The Potential of Field Measurement of Surface Water pCo_2	24 months
CP07A65	Melzner et al.	Gene expression patterns in sea urchin embryos: Establishing a model system for	12 months
CP0801	Schönfeld & Spindler	Foraminiferal shell loss in the Flensburg Fjord (SW Baltic Sea). Living benthic communities under the risk due to acidification?	10 months
CP0802	Zimmer	Bacterial symbionts of an invasive species in a warming sea: Mnemiopsis leidyi	12 months
CP0805	Bosch et al.	Developing a novel framework for understanding evolutionary adaption to changing environments: comparative transcriptomics of disparate members of marine Cnidaria	6 months
CP0809	Reusch & Waller	Pipefish-parasite interactions under global warming	12 months
CP0810	Bialas et al.	OBS-Thermo: co-registration of geophysical data at hydrothermal vents - a first step to a new ocean bottom observatory	14 months
CP0811	Meier & Kinkel	Planktonic calcifiers in the Baltic Sea: adaption to carbonate undersaturation in calcifying dinoflagellates?	15 months
CP0812	Quaas et al.	Tradable Fishing Grounds	8 months
CP0813	Oschlies et al.	Can different feeding strategies help to resolve the paradox of the plankton?	6 months
CP0815	Mayerle	The effects of sea-level rise and climate change on long-term morphodynamics in the german wadden sea	24 months
CP0816	Melzner & Körtzinger	Seasonal carbonate system variability in Kiel Bay and correlated physiological performance of local blue mussels	12 months
CP0818	Weinberger & Treude	Consequences of seafloor warming and salinity decrease for macroalga-microbe interactions	12 months
CP0819	Lehmann & Bumke	Detailed assessement of climate variability of the Baltic Sea area for the period 1970-2008	24 months
CP0820	Vafeidis et al.	Shipping induced sediment resuspension in the port of Venice: a case study of the effects of forced Shallow water waves	12 months
CP0822	Wallmann et al.	Assessing the risk of leakage from submarine CCS	15 months
CP0823	Rosenstiel & Schreiber	Establishment of marine invertebrate cell cultures as a tool for immune system and invironmental stress research	25 months
CP0824	Wallace et al.	Air-sea flux measurements of trace gases with atmospheric pressure chemical ionization time of flight mass spectometry (APCI-TOF-MS)	12 months

PICTURE CREDITS

All figures and photographs courtesy of the Cluster of Excellence „The Future Ocean" or its partners Christian-Albrechts-Universität zu Kiel, Leibniz-Institut für Meereswissenschaften (IFM-GEOMAR), Institut für Weltwirtschaft, Muthesius Kunsthochschule, except the following:

PAGE	REFERENCE
Title, Backcover, 50 (top centre)	http://visibleearth.nasa.gov, NASA Terms of Use, For all non-private uses, Collage by Tom Duscher Copyright Cluster of Excellence "The Future Ocean".
44 (bottom right)	Tim Kalvelage, Max-Planck-Institute for Microbiology, Bremen.
52 (top left)	Ilja C. Hendel for Wissenschaft im Dialog.
52 (bottom right)	Michael Zapf, Internationales Maritimes Museum, Hamburg.
54 (bottom right)	Tim Kalvelage, Max-Planck-Institute for Microbiology, Bremen.

IMPRINT

Editing
Emanuel Söding, Friederike Balzereit, Kirsten Schäfer, Irena Kerca

Layout, Production
Sonja Dierk, Mette Lüning

Printing
Universitätsdruckerei (Zentrale Vervielfältigungsstelle)
Christian - Albrechts - Universität zu Kiel
Wilhelm-Seelig-Platz 3-5
24118 Kiel

Future Ocean Office
The Cluster of Excellence „The Future Ocean"
Christian - Albrechts - Universität zu Kiel
Christian - Albrechts - Platz 4
24118 Kiel, Germany
Tel. ++49 - (0) 431 - 880 16 04
Fax. ++49 - (0) 431 - 880 25 39
info@ozean-der-zukunft.de
www.ozean-der-zukunft.de

The Cluster of Excellence 80 „The Future Ocean" is funded within the framework of the Excellence Initiative by the German Research Foundation (DFG) on behalf of the German federal and state governments. Member institutions of the cluster of excellence are the Christian-Albrechts-Universität zu Kiel, the Leibniz Institute of Marine Sciences, the IFM GEOMAR, the Institute for the World Economy at the Universität Kiel and the Muthesius School of Fine Arts and Design.

Published 29.09.2009

future ocean
KIEL MARINE SCIENCES

Exzellenzcluster „Ozean der Zukunft”
Christian-Albrechts-Universität zu Kiel
Christian-Albrechts-Platz 4
24118 Kiel, Germany
info@ozean-der-zukunft.de
www.ozean-der-zukunft.de

C|A|U Christian-Albrechts-Universität zu Kiel

ifw

muthesius kunsthochschule

IFM-GEOMAR