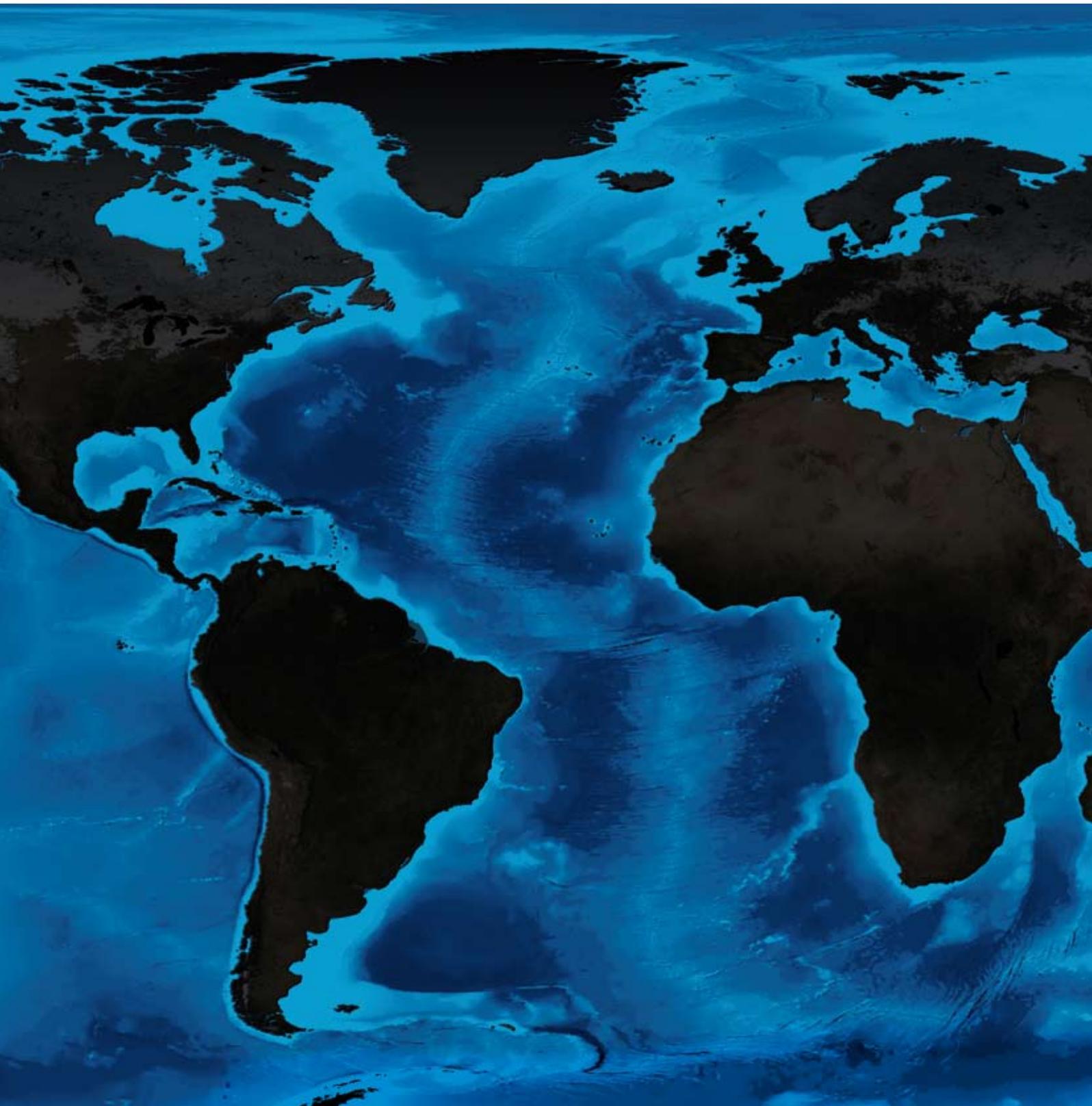




future ocean
KIEL MARINE SCIENCES

10 | Annual Report



Understanding
the ocean
sustaining our
future

Dear Friends of The Future Ocean,

We are excited to be able to share with you the fourth annual report of the Cluster of Excellence "The Future Ocean". 2010 has been an exciting and productive year for all of us – and we have compiled some highlights of our activities for you in this report.

The publication output in the Cluster is constantly growing, and – as hoped – it is producing exciting interdisciplinary marine science results. We have legal experts publishing in *Nature Geoscience* (see page 46), economists publishing in fishery journals (see page 34), and natural scientists publishing in economics periodicals. We are proud and satisfied that the Kiel Marine Science interdisciplinary approach is working and delivering on its promise. But success creates challenges. As expected, several of our junior research group leaders received job offers from other universities in 2010. While most of them could be convinced to stay in Kiel and continue to be part of our unique research infrastructure, Alexander

Proelß, the leader of the law of the sea group has decided to move on to a very prestigious position at another university in Germany. We wish him well for his new challenges and hope to remain in touch.

The cluster platform concept is gaining traction and in particular the Integrated School of Ocean Sciences has grown beyond expectations. More than 100 PhD students are taking advantage of the multidisciplinary educational framework. An impressive number of courses, seminars and career support activities were offered to all Marine Science doctoral students.

Other highlights of 2010 include Future Ocean exhibition activities – the major five month long exhibition at the Deutsches Museum in Munich and at the Paul Loebe Haus (house of parliament) in Berlin (see page 64). During late summer, the biannual Future Ocean Symposium attracted more than 350 researchers to Kiel (see page 86), and finally the publication, together with our partners, of the *World Ocean Review*,

the first comprehensive assessment of "ocean issues" written in layman's language (see page 84) sparked interest in both political and educational spheres.

We hope that these highlights and other information in this report inspire you and transfer the spirit of Kiel Marine Science to you and beyond.

Sincerely,



Martin Visbeck

[Speaker of the Cluster of Excellence
"The Future Ocean"](#)



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UMD



The Project

*It is hard work,
but there is
happiness in it.*

Takayuki Ikkaku,
Arisa Hosaka
and Toshihiro Kawabata

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 as well as a source of major natural hazards. In short, the global ocean is vital for human welfare now and will be in the future. But mankind is altering the oceans in ways both direct and indirect 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 CO₂ and other pollutants.

The Future Ocean therefore manifests 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 it. They also imply a need to educate the next generation to be 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 Future Ocean was initially 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 have since deeply affected 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. This commitment prevails, manifested in the many activities that have been directed to implement the envisioned research framework.

To enhance the existing research environment the Future Ocean comprises several components intertwined with each other that form a structure allowing scientists to perform at their best. The Future Ocean is designed around funding instruments promoting research in marine and related science in Kiel. The core of this structure comprises 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 only distantly related subjects such as economics, medicine, law, molecular biology and computer science. Four research platforms were established to support all researchers with the technical infrastructure needed to deliver world class results. In addition the Future Ocean issues its own scientific proposal calls in order to be able to quickly respond to the latest scientific developments in the most flexible way. These proposals are externally reviewed to ensure the highest quality in science. Finally, the project 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 and granted quickly with little additional administrative work.

The junior research groups started operating as group leaders were hired between summer 2007 and spring 2008. During 2008 the groups successfully hired most of the required support personnel and began work on their related scientific questions. Since then the groups have settled in to working and 2009 and 2010 saw further slower growth and significant fluctuation within the groups. As a result the publication record is steadily increasing and the Future Ocean is now demonstrating its strength working at the forefront of scientific developments, preparing answers to some crucial questions of tomorrow. More than 57 projects from past proposal calls issued between late 2006 and 2009 have now been completed and have delivered their reports. These projects typically run for two years, many lead to new follow-up projects and external funding, many of them result in very interesting scientific findings. Most projects funded during the proposal round in 2009 are still continuing into 2011. The number of active projects shrank to about 20 at the end of 2010 (see the list of active projects in the appendix), but new project calls are already in the pipeline for 2011 to maintain a continuous research landscape.

The Future Ocean up to now has initiated a tremendous array of large and small initiatives of inter- and transdisciplinary nature, creating

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 supplementary training, a supervision framework, mentoring and mobility. Students prepare for life after PhD.
 - ▶ The public outreach project promotes marine sciences to the general public, but also fosters exchange of internal information within the Future Ocean.
-

a positive forward orientated spirit of curiosity in Kiel's research landscape. This is visible not only at Christian-Albrechts University, but also at the partner institutions IFM-GEOMAR, the Institute for the World Economy (IfW) and the Muthesius Academy of Fine Arts and Design. The Future Ocean is guided by the underlying principle of providing the most effective service and infrastructure to support marine science in developing a thorough understanding of the future of our oceans.

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 education in schools and offering events for children, to the active support of masters and graduate students. In 2010 the general public was addressed through various events and public exhibitions of marine research. The highlight of these activities was certainly the outstanding exhibition in the Deutsches Museum in Munich, where the Future Ocean displayed marine sciences for over five months between March and August (see pages 64-65). Immediately following this event, the federal parliament invited the Future Ocean to present the latest developments in marine science in the Paul Loebe Haus in Berlin, a building housing the offices of many members of parliament. Both exhibitions marked another milestone in the cooperation between Kiel University, IFM-GEOMAR and the Muthesius Academy. The result was an impressive example of what can be achieved by the integration of each partner's strengths in different areas, creating a unique synergy.

The Future Ocean successfully continued to address schools and teachers directly by providing marine science experiment boxes to schools in Schleswig-Holstein, enabling teachers to integrate marine sciences into their classes in a practical and demonstrative manner. This activity is complemented by the organization of the Children's University on marine science topics in Kiel (page 66-67), offering public lectures for children aged 8-12 and 12-16. Overall these activities have proven very successful. The public is increasingly identifying the state of Schleswig-Holstein with the topics of the Future Ocean, and local citizens are proud to hear that researchers in Kiel and Schleswig-Holstein are famous for research aiming to tackle many critical global environmental questions. Monitoring the press and public expressions we realize that Kiel is



Figure 1

Members and employees of the Cluster of Excellence Future Ocean.

becoming more and more recognized as the leading location for Future Ocean technical infrastructure platforms in marine science in Germany, a circumstance that is, of course, intended and which the Future Ocean strives to expand. 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 hope to achieve within the near future, and that we've started to work on with a new position for the coordination of international cooperation and partners (page 82).

Future Ocean Technical Infrastructure Platforms

To provide technical infrastructure and resources for all scientists within the Future Ocean, a platform concept has been established.

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. Platform P1 is predominantly used by the groups investigating Oceanic CO₂ 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. Research platform P2 is 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. Platform P3 is mainly used by the Ocean Acidification, Seafloor Warming and Marine Medicine groups.

P4 Ocean Observatories: This platform has the mandate to provide multi-faceted observational capabilities that meet the wide range of requirements for research to be carried out in the Kiel Future Ocean Network. The platform includes instruments deployed at the sea floor, traveling the water column, floating on the surface or observing from various distances. Platform P4 is mainly used by the research groups working on Sea level Rise and Coasts at Risk, Submarine Hazards, and Seafloor Resources.

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.

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 CO₂ 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 CO₂ 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 CO₂ 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 CO₂ 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

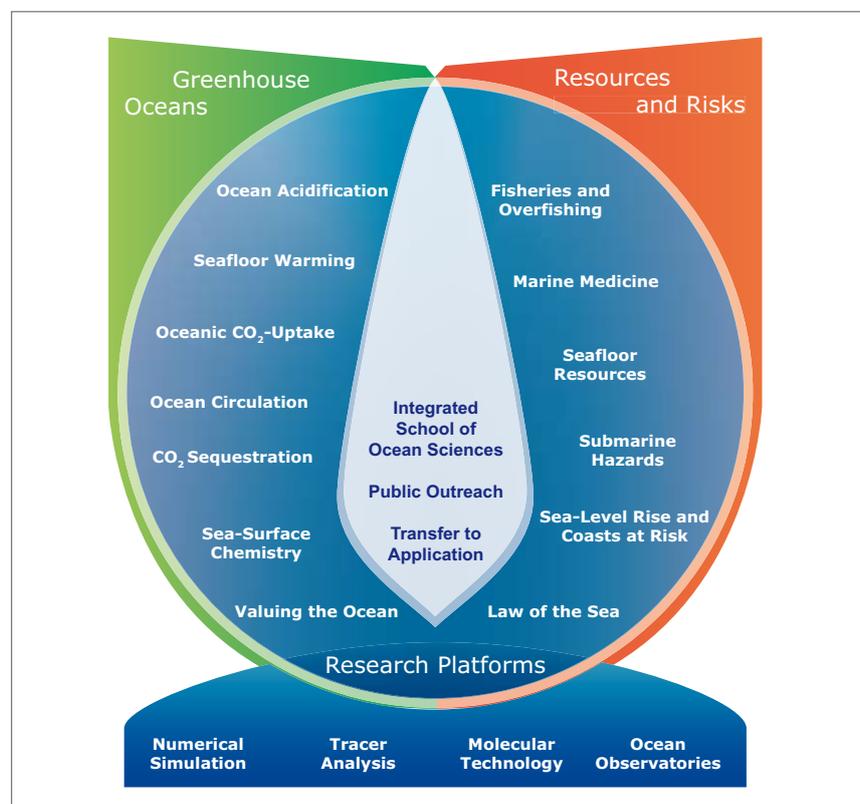


Figure 1

Structure of the Cluster of Excellence “The Future Ocean” consisting of the research themes Greenhouse Oceans (green) and Resources and Risks (red), central services (light blue) and the infrastructure platforms (dark blue).

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.

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?

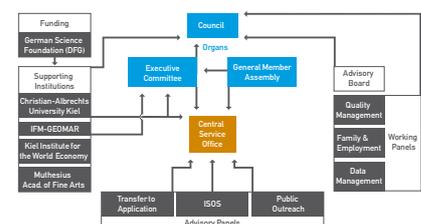
The "Fishery and Overfishing" project evaluates marine management with a special focus on multispecies interaction and the link between commercial species, non-commercial species, and the ecosystem. Marine life and fisheries are presently studied, but have not previously been linked to economic expertise. Building on this expertise, a research group was established to improve the management strategies of fish stocks and fisheries, incorpo-

rating 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 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 Muthe-sius Academy of Fine Arts and Design, 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 in 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).



2010 – The Year for The Future Ocean

Now in its fourth year, the Future Ocean has grown to be a major project, with many activities conducted smoothly on a regular basis. Several others are new challenges and exciting projects contributing to the overall output of the cluster. On the following pages we will give a brief overview of the most important happenings in 2010.

Publications

The most important and visible product of research projects are typically scientific publications. As an interdisciplinary project The Future Ocean is particularly proud of certain publication highlights involving the combined strength of several disciplines, which have come together through the Future Ocean project.

The interdisciplinary endeavor to develop strategies for sustainable fishery management has had a wide impact on fishery policy and has helped bring the issue to the attention of the general public. Failure analyzes of current fishery management and harvest control rules for European fisheries management have been examined. Furthermore, a common modeling framework has been designed, taking into consideration the age structure of fish stocks and multi-species interactions to develop new fishery management strategies. Results from new, ecologically and economically sustainable fishery management strategies have been published in biological and economic journals. The results were presented to the International Council for the Exploration of the Sea (ICES), which is a leading and active participant in the

fishery management field. Cluster proposals for new sustainable fishery management were discussed with representatives from fishery policymakers in an expert hearing at the European Parliament and the European Maritime Day 2010. Read more about fishery on page 34 and 37 in this report.

In another field, researchers from the cluster have provided a comprehensive assessment combining scientific, economic and legal issues of the potentials and risks of enhancing oceanic carbon uptake: ocean iron fertilization (OIF). From a scientific perspective, the potential of carbon sequestration through large-scale OIF is considerable, but there is also evidence for significant perturbations of marine biogeochemistry and ecology. These side effects are in part positive but they may also have potentially significant unintended consequences including enhanced production of nitrous oxide (N_2O) and methane (CH_4) (Oschlies *et al.* 2010). From an economic perspective, the potential of OIF is significant in relation to other abatement options. OIF could also generate more carbon credits, even taking into account the possibility that emissions will shift to other regions

or that the reductions are not permanent. As for the conformity of OIF with the requirements of public international law, the pertinent agreements dealing with the protection of the marine environment indicate that OIF is to be considered lawful to the extent to which it represents legitimate scientific research. According to Güssow *et al.* (2010), further scientific research must be permitted to explore the carbon sequestration potential of the ocean. Such research is necessary to make an informed decision on whether to reject ocean iron fertilization or to integrate it into the flexible mechanisms contained in the Kyoto Protocol.

A substantial assessment was produced by the cluster in cooperation with the publisher Mare and the International Ocean Institute (IOI) entitled the 'World Ocean Review: Living with the Oceans' (WOR, worldoceanreview.com). This, the first WOR, reports on the state of the oceans and will be followed by periodic updates in the future. Its aim is to reveal the consequences for the ocean realm of intense human intervention, including the impacts of climate change. Some of the effects are already understood, but many unanswered questions remain.



Figure 1
Cluster Presentation at the European Maritime Day in Gijon, Spain.



Figure 2
View of the cluster exhibition at the Paul-Löbe Haus in Berlin.



Figure 3
Audience at the Retreat 2010 in Kiel.

The WOR summarizes key findings on 10 hot topics in marine research in a format that is scientifically correct but in a language readable by the educated public. The production process from the initial idea to printing in October 2010 took more than two years. About 50 researchers contributed material to the 200 page volume. The WOR was published in German and English and roughly 50,000 copies each have been printed and distributed globally by the IOI free of charge (read more on the World Ocean review on page 84).

In the wake of the March 2010 oil spill in the Gulf of Mexico, the Cluster compiled a position paper in early July 2010 in which experts wrote brief assessments related to sub-seafloor drilling technology, gas hydrate formation, decomposition of the oil in the ocean, dispersal of the oil by ocean currents, and the economic and legal impact of the incident. The 500 printed copies and online version quickly spread throughout ministries, NGOs, news and other organizations. It was one of the very few sound scientific statements in German and highly cited in public discourse.

Exhibitions

The Cluster developed an innovative marine science exhibition during its first phase. The exhibition was designed in close cooperation with the Muthesius Academy of Fine Arts and Design. This is a striking example of how fruitful such cooperation can be, once disciplinary boundaries are overcome. Several unique technical installations were developed to introduce marine research topics to the interested public. In 2010 the exhibition was displayed at several venues throughout Germany, e.g. the world famous Deutsches Museum in Munich and the Paul Loebe Haus (House of the German Parliament) Berlin. See more on the exhibitions on page 64.

Events

The third biannual symposium organized by the Future Ocean in September 2010 attracted 250 participants from 18 countries for a four day conference and workshops. The program was organized in seven thematic sessions ranging from Recent Breakthroughs in Coral Research to Climate Engineering, from Chemistry at Marine Interfaces to the Oceanic CO₂ Sink. Aside from German and other European scientists, numerous experts from the USA, Australia, New Zealand and Japan took part in the symposium and led panels and workshops.

On a national level Future Ocean scientists regularly collaborate with the two other marine science clusters in Germany: 'The Ocean in the Earth System' (MARUM) in Bremen and 'Integrated Climate System Analysis and Prediction' (CliSAP) with its KlimaCampus in Hamburg. All three clusters complement German marine science expertise and are unique in their mission and approaches. In 2010 the first Young Scientist Excellence Cluster Conference on Marine and Climate Research took place in Hamburg jointly organized by all three clusters. For three days young and senior researchers used the conference workshops to discuss topics from the three clusters. These workshops provided an important measure for promoting young scientists as well as an important vehicle for exchanging knowledge among the different projects. The Young Scientists Excellence Cluster Conference is a continuation of the so called Nordcluster meetings, which were organized in 2009 in Bremen and Kiel. The next conference will take place in Bremen in October 2011.

Since the members and employees of the Future Ocean are scattered all over Kiel the annual retreat offers an important opportunity, to meet each other, present current research activities and discuss future projects. In 2010 the annual retreat of the Future Ocean took place in Schleswig. In anticipation of the proposal for the second phase

of the Future Ocean, members were invited to submit very short ideas for future research topics. More than 50 suggestions were submitted, and the ideas were presented in very short talks to the audience. More than 170 members and employees participated in the meeting and heard lively discussions on present and future topics of the Future Ocean over two days. The event was complemented with a poster session showing current research being done in the cluster.

Tenure Track Process

The cluster installed 13 Junior Research groups (JRGs), hiring 13 Professors as JRG leaders on a tenure track basis. During the setup of the cluster, the university and IFM-GEOMAR committed to granting tenure to nine of these thirteen professors. In 2010, three JRG leaders received external offers for permanent positions, creating the need to formalize and conduct an independent *ad hoc* review process for these candidates, taking into account a comparative evaluation with the other JRG leaders. As the evaluation and hiring process took place in 2011 we will report on this in detail in the next annual report. As an outcome of the *ad hoc* process all three candidates Alexander Proelß (law of the sea), Lars Ruepke (sea floor resources) and Martin Quaas (fishery economics) were offered permanent positions by the University. Subsequently Lars Ruepke and Martin Quaas accepted these offers, while Alexander Proelß, despite a very competitive offer from the university, chose to accept the prestigious position of the director of the Institute of Environmental and Technology Law at the University Trier. He remains connected to the Future Ocean through numerous links and projects and the position he held in Kiel will be refilled.

All in all, this summary gives a brief glimpse into what was happening in the cluster in 2010. For more details please refer to the other sections of the report mentioned here.

Selected Publications

- 1 | Güssow, K., Proelß, A., Oschlies, A., Rehdanz, K., Rickels, W. [2010] Ocean Iron Fertilization: Why Further Research is Needed. *Mar. Policy* 34, 911–918.
- 2 | Oschlies, A., Koeve, W., Rickels, W., Rehdanz, K. [2010] Side effects and accounting aspects of hypothetical largescale Southern Ocean iron fertilization. *Biogeosciences* 7, 4017–4035.
- 3 | Rainer Froese, Trevor A. Branch, Alexander Proelß, Martin Quaas, Keith Sainsbury, Christopher Zimmermann: Generic Harvest Control Rules for European Fisheries. *Fish and Fisheries*. DOI: 10.1111/j.1467-2979.2010.00387.x

Project Statistics

To monitor the project, the Future Ocean collects project data on a regular basis. These are financial, personnel, and funding data, as well as information on publications, attendance at meetings and the exchange of scientific personnel. The data collected on the project shows the initial setup, networks and growth of the research groups. In 2010 the research groups of the Future Ocean continued developing their infrastructure. Consequently the number of visitors grew, so did the number of publications.

Monitoring

Each year the Future Ocean conducts an online survey among its members and employees, to compile data on publications, participation in workshops and meetings, visits to external institutions, and incoming visitors from external institutions. The survey also collects data on the use of the platforms, ISOS course offerings, family and employment measures, networking within the cluster and with other institutions, within Germany and abroad. The surveys are conducted using an online survey tool, which allows setting up questionnaires as custom made forms. Subsequently the data is compiled and plotted by the central service office and is discussed and analyzed by the Future Ocean quality management panel. The quality management panel reports findings and recommendations to the cluster council and to the executive board to allow adjustments to the overall Future Ocean strategy and plan for a successful future.

The financial data of the cluster are compiled from the financial reports of the four project partners and evaluated in the controlling section of the Future Ocean central service office. The data is organized in a way that allows viewing data and drawing conclusions according to the overall employee structure and gender balance, but also relative to the major funding schemes of the Future Ocean.

Budget and Funding

The total annual budget in 2010 was about 5M €. In addition 0.6M € were carried over from 2011 resulting in a total budget of 5.6M €, slightly less than in 2009. See figure 1 for a summary of the expenses in 2010. Overall the amount spent for personnel grew slightly from 4.3M € (73%) to about 4.4M € (78%). About 0.95M € were spent on investments and consumables, which is about 20% less than in 2009 (1.15M €). About 300,000 € (6%) were spent on other items like workshops, and retreats, meetings and outreach activities, travel grants for outgoing and incoming visitors, equal opportunity measures and others. In addition some activities, like the symposium, but also the major exhibitions in Munich and Berlin were significantly supported by the Christian Albrechts University and IFM-GEOMAR.

The Future Ocean spends funds mainly for its JRG research groups and internal research projects. The total budget of the JRGs increased again in 2010. It went from about 3M € to about 3.4M € (12%). Consequently the amount spent on other research in cluster projects declined by about 25% to 1.45M € (26% of the total budget). This is a straightforward and expected development, as the projects funded in 2007 were concluded during late 2009 to the middle of 2010 (see fig. 2). Only projects from two funding rounds in 2008 and 2009 were still active at the

end of 2010. Money spent on the central service projects, public outreach, graduate education and others stayed about the same at 780,000€ in 2010, vs. 900,000€ in 2009. No major investments in research infrastructure platforms were made in 2010.

What was the money spent for? The JRGs continued to further shift funds towards personnel (Fig 1). Merely 15% was spent for consumables mainly to sustain the personnel. Overall the personnel costs again increased, and account for about 78% of the total budget in 2010. Personnel costs are a constant and allow reliable long-term planning for the project. It is, however, difficult to adjust the direction of the project as most money at the moment is bound long-term. The Future Ocean research projects, on the other hand, start and end in waves, and therefore regularly free up a certain amount of funding. Relatively few investments were made in 2010.

Other expenses included costs for administrative infrastructure, public outreach activities, graduate education and support for numerous workshops, retreats and the symposium. Significant money was spent for science mobility activities such as inviting guests to Kiel for research, but also travel support for researchers to attend conferences.

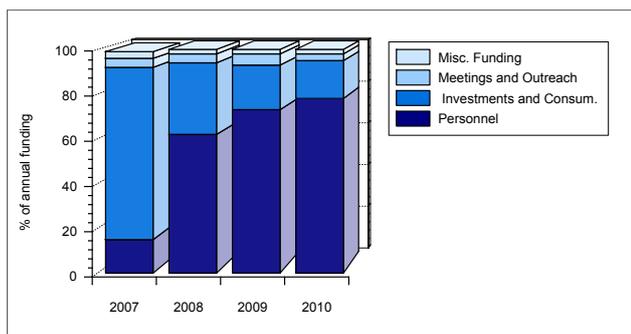


Figure 1
Percentage of annual funding according to funding categories.

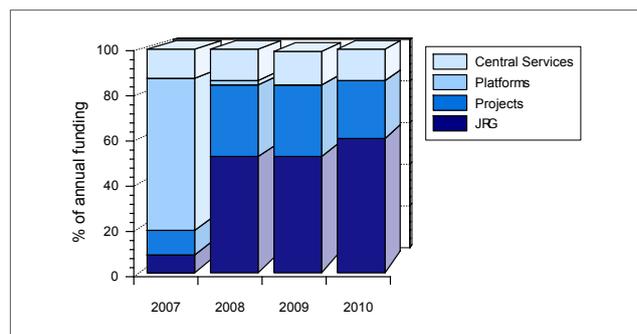


Figure 2
Percentage of annual funding according to funding schemes.

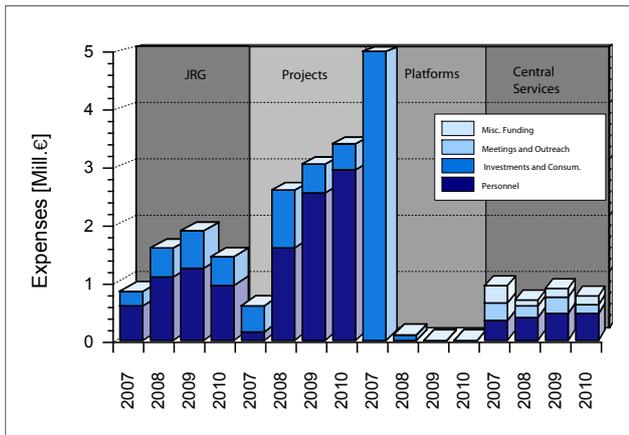


Figure 3
Development of expenses 2007-2010 in the categories Research Projects, JRGs, Platforms and Central Service Projects.

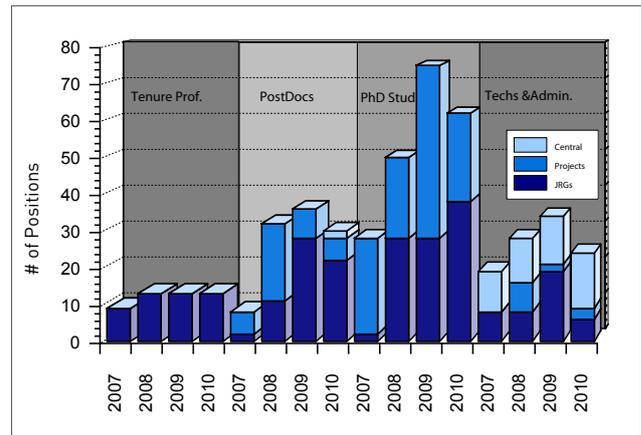


Figure 4
Development of the distribution of positions within the different funding schemes, junior research groups, cluster projects and central services.

Personnel

Despite the slightly increased amount spent on personnel, the number of Future Ocean employees decreased from 157 to 129 in 2010. Of these 71 are women, 58 men. For details on gender distribution see the respective chapter in this report (page 18-19). Employees can be grouped in four categories: junior professors on tenure track, postdoctoral researchers, PhD students and technical and administrative staff. The structure is illustrated in figure 4. It can be noted that the number of the largest group by far, the PhD students, declined due to cluster projects ending. On the other hand, the JRG groups hired more PhD students, effectively shifting several of them from projects to their research groups. Still the net number is negative. This diagram does not reflect the fact, that one of the JRG leaders, Alexander Proelß, accepted an offer from the University Trier in summer 2010 and left Kiel in the second half of the year. It is expected that his position will

be refilled in 2011. His research group will be disbanded and a new group will have to be set up by Prof. Proelß' successor.

National and International Institutional Networking

An important measure of exchange for any research location is the rate of interaction of scientists with external colleagues and institutions. During our survey the members of the Future Ocean were asked to list the national and international institutions they regularly cooperate with. It turned out that the most important national partners of the Future Ocean in 2010 were the Alfred Wegener Institute in Bremerhaven, the Clusters of Excellence Marum in Bremen and Clisap in Hamburg, including their respective universities, the Institute for Climate Impact Research (PIK) in Potsdam and related institutions and the Institute for Baltic Sea Research Warnemünde (IOW). The most often mentioned international institutions, as in

2009, were the National Oceanography Centre (NOC), Southampton, UK, the Royal Netherlands Institute for Sea Research (NIOZ), the University of Bergen, Norway, and the SCRIPPS Institute for Oceanography, California, USA. In total in the survey, the members of the Future Ocean mentioned over 180 different international institutions outside Germany with whom they cooperate.

International Exchange

Incoming visitors and visits to foreign institutions by Future Ocean scientists are an important benchmark for international cooperation. In 2010 Future Ocean scientists had 86 visitors in total. 41 of them were on the professor level, 24 postdoctoral researchers and 17 PhD students. The most important countries in terms of the number of visitors were China, the USA, Brazil, Japan and Indonesia. The second most visitors came from the UK, however, their stay was usually very short, so the don't appear

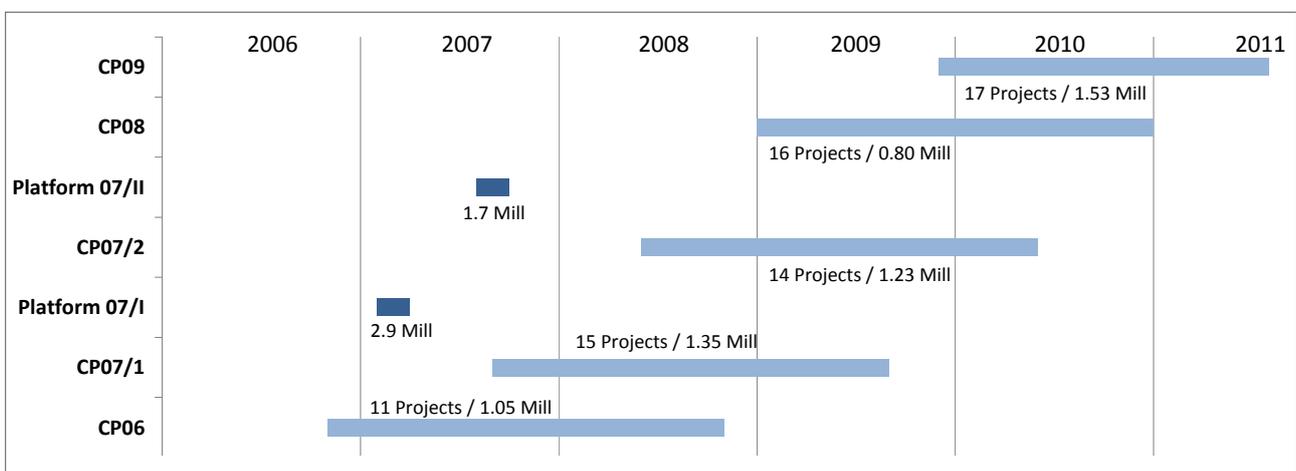


Figure 5
Timeline of cluster projects as funded between 2006 and 2011. Light blue bars represent research projects, darker bars represent funding for platform investments.

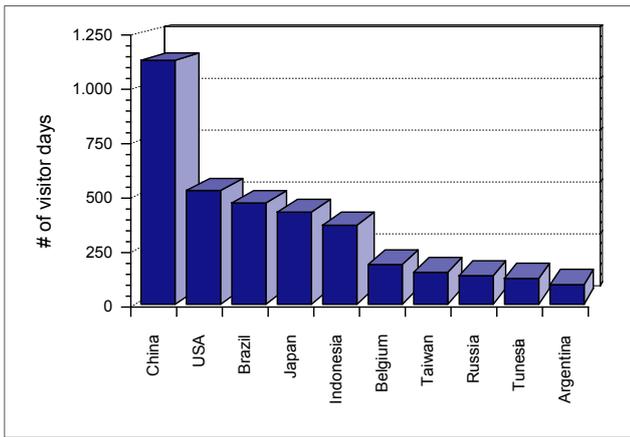


Figure 6
Number of visitor days in 2010 per country.

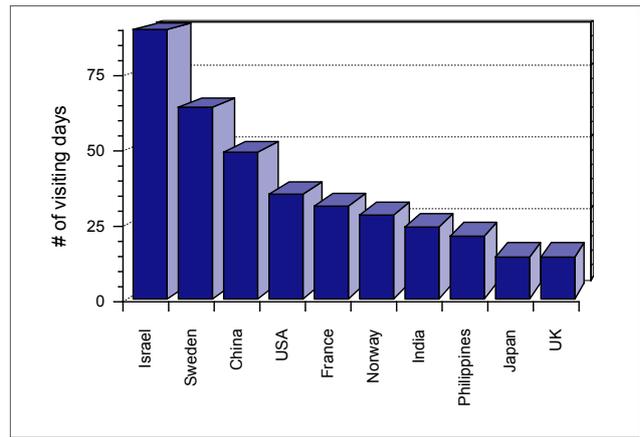


Figure 7
Number of days Future Ocean scientists stayed abroad for the 10 most visited countries.

on the visitors by day graph. According to the number of visiting days, several colleagues from China had the longest stays with the leader from 2009, the USA, following.

Looking at the number of visits Future Ocean members and employees made abroad, China, the USA, France and Sweden are the most visited partner countries. In terms of total time spent abroad, however, extended stays to Israel, Norway and India also took place (Fig. 8). Again it is surprising, that the UK does not play a greater role in this statistic, even though the most often mentioned international coope-

ration takes place with the National Oceanography Centre (NOC), Southampton, UK. It can only be assumed that due to the close distance, visits are only very short or very frequent and were hence not mentioned in this survey.

These numbers illustrate, how well integrated the Future Ocean and its members are within the international science community. The project cultivates an extensive exchange of research, knowledge, and personnel with foreign colleagues on all levels, actively contributing to the forefront of marine science.

Meetings

As with the publication venues, the most important meetings and conferences are biased by the earth and ocean science communities. The European Geosciences Union (EGU) annual assembly was the most frequented meeting in 2010, with the Ocean Sciences Meeting in February in Portland, Oregon following. The EPOCA/BIOACID workshop in Bremerhaven was the most visited workshop mentioned. The Fourth World Congress of Environmental and Resource Economists (EAERE) attracted a number of participants as well. The most important national meeting was of course the 3rd Biannual Future Ocean Symposium.

Publications

The most important benchmark factor for evaluating people, projects or institutions is related to publication statistics. In 2009 Future Ocean researchers published about 535 articles in about over 250 different Journals. In 2010 the most important journals were Biogeosciences, Marine Geology and the Journal of Geophysical Research with over 15 articles each, followed by the Marine Ecology Progress Series with 12 articles. The fourteen journals in which cluster members most frequently published are summarized in Figure 9. Although the spectrum of these journals is still strongly biased by the earth science community, which has the strongest representation in the Future Ocean, the publications span the whole spectrum of research conducted in the project, from oceanography to law, from geoscience to economics, from medicine to mathematics.

For the broad range of publications in 2010 see the "Selected publications" section in the Appendix (Page 92)

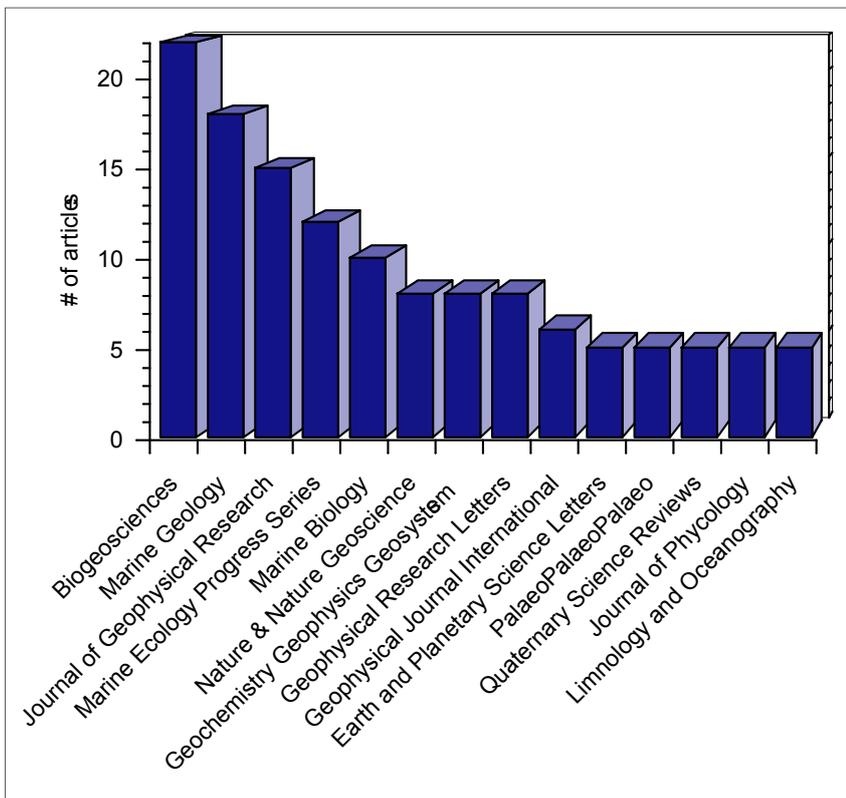


Figure 8
The fourteen most important publication venues for the Future Ocean.

The Founding Institutions

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 between 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. Throughout its nearly 350 year history, the Christian-Albrechts-Universität zu Kiel has been 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, economics and society, and keeps the interested public informed on important matters of economic policy. As a portal to world economic research, it manages a broad 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 places particular emphasis on 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 program 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.



Figure 1
Christian-Albrechts-Universität zu Kiel.



Figure 2
Leibniz Institute of Marine Sciences.



Figure 3
Kiel Institute for the World Economy.



Figure 4
Muthesius Academy of Fine Arts and Design.

Equal Opportunity?

Providing measures to ensure gender equality is an important prerequisite for top level research, as men and women have different goals and demands in planning careers. The cluster divides its efforts in providing gender equal working conditions into two major categories: a) measures to support family and employment and b) measures to promote equal participation of women in science. All measures are organized in close cooperation with the university's relevant existing institutions, namely the equal opportunity officer and the family office.

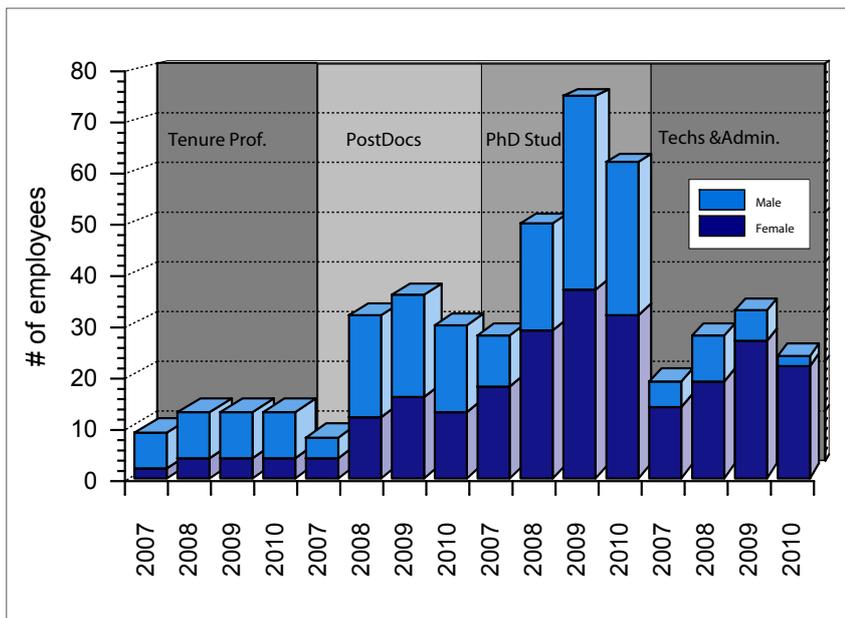


Figure 1

Distribution of male/female employees in different status groups throughout the course of the Future Ocean.



Figure 2

The cluster's day care facilities allows an early return to the job for young parents.

Family and Employment

The central management is assigned the task of implementing family friendly and gender equal working conditions at the CAU and its partner institutions. The Christian-Albrechts Universität itself is a certified family friendly employer; however, the cluster provides additional services for its own members and employees.

To enable young parents to return to their jobs as quickly as possible the Future Ocean fills the existing gap in childcare for children between one and three years of age. For this reason the cluster provides day care facilities for cluster members with children in this age group in collaboration with the university's family office. Cluster members and employees have prioritized access to these facilities and consequently an early return to their jobs after the birth of their children.

While the cluster has considered scheduling meetings exclusively at family-friendly times, this could not yet be accomplished as demands vary too much. Consequently, standard childcare is offered nearby the meeting place whenever possible during major meetings, conferences, workshops and symposia. In addition the Future Ocean plans to establish emergency child care service in the future. This is meant to support parents who have an immediate need for day care on short notice.

While it is difficult for medium sized universities to guarantee a dual career option for accompanying partners, the cluster offers support with a dual career option for hires at the professorial level. Support in this case means, that the administration, together with its counterparts at the university and IFM-GEOMAR will make an effort to create suitable project positions for partners working within Future Ocean disciplines or identify suitable positions within the university wherever possible. Due to the size of the university these efforts cannot always be successful, however, they raise the

likelihood that potential employees will feel welcomed in Kiel.

In addition, the cluster provides standard DFG family support measures such as student and contractual support for pregnant women when they, for health reasons, cannot work in their usual working environment during pregnancy, and time off for parental leave. As a result our member surveys tell us, that overall the Future Ocean is recognized as a very family friendly employer, appreciated by its employees and project partners.

Promoting Women in Science

In order to push for a fair and equal treatment of men and women in marine research the cluster is committed to supporting DFG gender equality standards promoting a) continuity, b) transparency, c) competitiveness and d) future orientation, as well as e) competency in its gender measures. For this purpose the Future Ocean regularly publishes its personnel structure by male/female ratio as illustrated in figures 1 and 2. Figure 1 shows the personnel structure since 2007 for the four groups: tenure track professors, postdocs, PhD students and technical and administrative staff. While the overall number of personnel has decreased slightly by 18% from 157 (84 female) in 2009 to 129 (71 female) in 2010, the proportion of male to female workers has remained approximately the same (55% in 2010 vs. 54% in 2009). Consequently the overall picture is about the same as in 2009, with the percentage of male/female employees broken down by groups approximately the same as in the previous year (Fig. 3). The overall picture still illustrates the underrepresentation of women in high level research positions in the cluster (30%), compared to a federal average of 16% for female professors. On the other hand women are overrepresented in administrative and technical positions, making up 90% of cluster employees in this category.

To learn more about improvements and shortcomings, the Future Ocean participates in workshops and conferences organized by external research groups, such as the project "Frauen in der Spitzenforschung" (Women in cutting-edge research) in Hamburg. The cluster also actively participates in studies undertaken by this project, accompanying the Excellence initiative, researching reasons and consequences of gender issues within German research communities. Initial results and recommendations of this study are expected in 2011. We hope to further improve our program for the promotion of women in science based on recommendations emerging from this project.

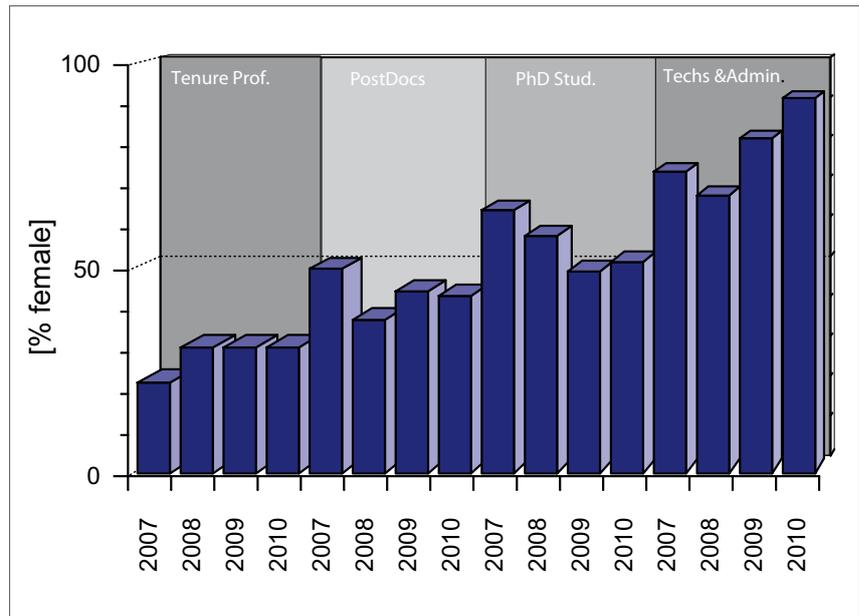


Figure 3
Percentage of female employees in different status groups throughout the course of the Future Ocean.

Outlook

The measures on family and employment will mainly focus on a better publicity of measures and offers for employees, as many may not be familiar with what the cluster offers and provides in terms of family support.

Promotion of Women in science will follow a number of new paths in 2011. In late 2010 a new group promoting women in science was formed, which plans to organize a special mentoring

program for women. As a start-up a meeting with Sally Chisholm from MIT Boston was arranged, which took place in December 2010. One goal is to provide training for women coping with a working environment characterized by male values and the other goal is to monitor decision making structures with regard to gender and minority biases, in order to improve gender literacy in all aspects of the cluster.



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The Research

*Give a man a fish,
and he'll eat for a day.
Give a fish a man,
and he'll eat for weeks!*

Takayuki Ikkaku,
Arisa Hosaka
and Toshihiro Kawabata



Ocean Acidification and Marine Animal Physiology

The members of the ocean acidification group are interested in understanding 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 $p\text{CO}_2$. By comparing characteristics of more tolerant model groups (e.g. cephalopods) with those of more sensitive groups (e.g. bivalves) they aim at identifying traits that promote sensitivity vs. tolerance. The working group is following a dual strategy by carrying out laboratory based CO_2 perturbation studies to assess physiological responses and by simultaneously studying physiological adaptations of animals exposed to naturally elevated seawater $p\text{CO}_2$ levels. In the following, two current projects on bivalve and cephalopod mollusk model systems are highlighted.

Energy Budget vs. Carbonate Chemistry?

The ocean acidification research group is using Kiel Fjord as a model system ('natural analogue') of a future, more acidic ocean. Due to upwelling of CO_2 -rich waters in summer and autumn, Kiel Fjord shallow water (<10 m water depth) mussel bed communities (*Mytilus edulis*) come into contact with acidified water during longer periods of the year. Peak $p\text{CO}_2$ values of >2000 μatm and average summer (July-August) values of ca. 1000 μatm were encountered in 2008/2009 (Thomsen *et al.* 2010). We were able to demonstrate in laboratory studies that mussels maintain high rates of calcification at high $p\text{CO}_2$ of 1400 and 4000 μatm , thus in waters severely under saturated with aragonite and calcite, despite not being able to control the pH value of their extracellular fluids (Thomsen *et al.* 2010). However, we also found that

increased seawater $p\text{CO}_2$ leads to increased metabolic rates, potentially due to elevated energetic demands of cellular homeostasis (Thomsen & Melzner 2010). In order to test, whether naturally CO_2 -rich regions inhibit calcification and biomass production, we carried out a transplantation experiment with calcifying communities freshly settled on 5 x 5 cm PVC plates. Surprisingly, mussel shell growth was much lower (by a factor of seven) in communities transferred to a high pH site (Schilksee, S in Fig. 1) in comparison to plates suspended at the low pH site in the inner Kiel Fjord region (station F in Fig. 1). This very large difference in biomass and carbonate production is due to improved food supply; we measured about twofold higher particulate carbon and nitrogen concentrations at station F in comparison to station S. These results indicate that mussels are able to compensate for lower ambient

pH when the food supply is high. Laboratory studies support this idea. Our studies demonstrate that in relation to the large effects of nutritional supply within a given habitat, elevated $p\text{CO}_2$ only constitutes a moderate stressor for blue mussel populations.

Cephalopod Embryos and High $p\text{CO}_2$

Adult cephalopods can fully maintain rates of somatic growth, metabolism and calcification even at very high $p\text{CO}_2$ (>5000 μatm). This could be related to the strong extracellular pH regulatory machinery these animals possess. Using surgically implanted catheters we were able to continuously monitor extracellular acid-base status in these animals: unlike in bivalves, exposure to elevated $p\text{CO}_2$ leads to an extracellular accumulation of bicarbonate (HCO_3^-), which helps compensate for blood

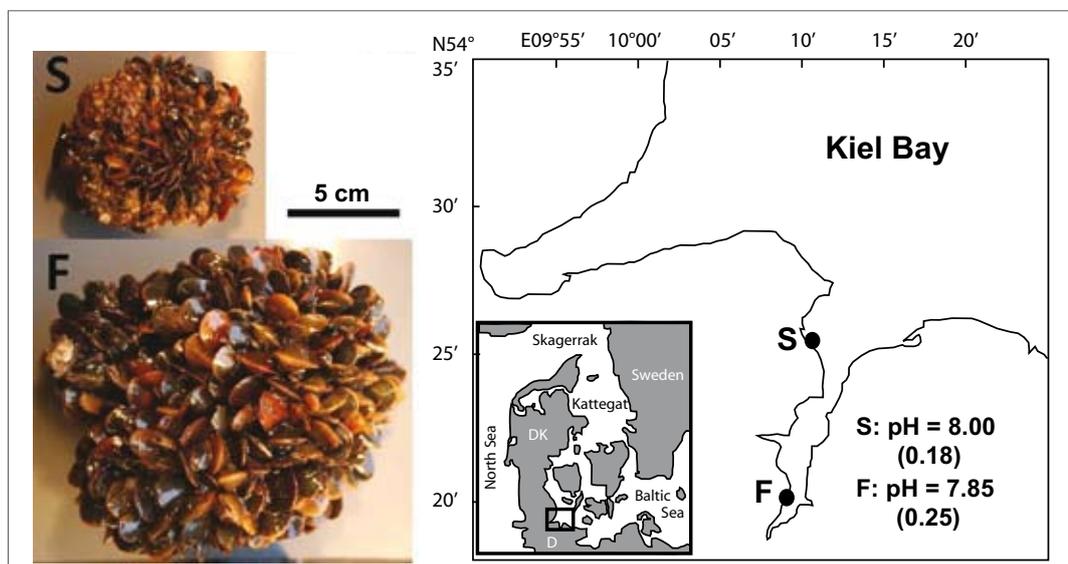


Figure 1

Representative settlement plates from Schilksee (S) showing a mixed coverage of *M. edulis* and *Amphibalanus* sp. and the inner fjord region (F) with complete dominance of *M. edulis* and much larger individual sizes. Plates were suspended from July to November 2010. Figures are drawn to scale, scale bar = 5cm. Mean shell mass growth of mussels was greater at the low pH site by a factor of 7. Mean pH_{NES} values (standard deviations) and location of stations are given in (B).

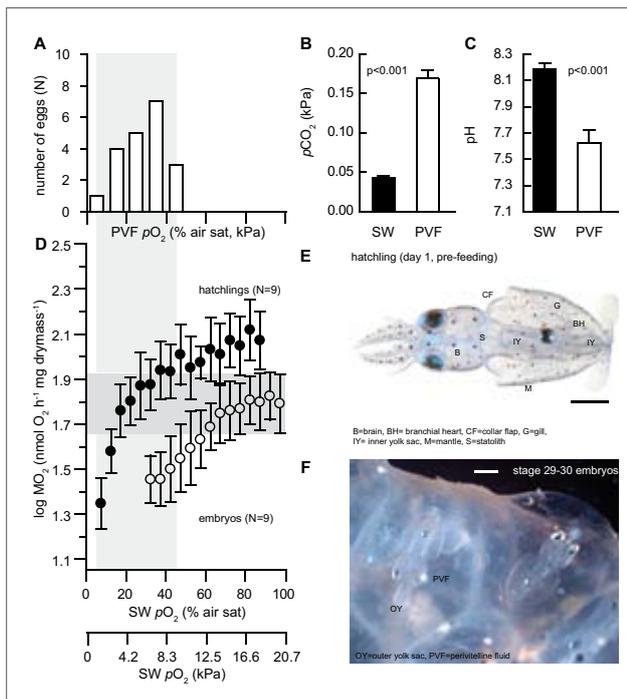


Figure 2

Egg fluid (perivitelline fluid, PVF) pO_2 , mean: 5.5 kPa, seawater (SW) pO_2 , mean: 20.7 kPa; (B) PVF pCO_2 , mean: 0.17 kPa / 1700 μatm , SW pCO_2 , mean: 0.04 kPa; (C) PVF pH, mean: 7.63, SW pH, mean: 8.19; (D) \log_{10} respiration rates (MO_2 , $\text{nmol h}^{-1} \text{mg}^{-1}$ dry mass) in hatchlings (black symbols) and embryos (white symbols) in relation to SW pO_2 , means and 95% confidence intervals. Embryos are metabolically depressed while trapped inside the low oxygen egg fluid; (E) late hatchling, collar flaps and mantle provide the ventilatory flow over the gills and aid in convection of the PVF within the egg capsule, (F) embryos in capsules in egg strand, note that conditions for diffusive gas transport are even more impaired in the intact egg strand due to the dense arrangement of embryos. Scale bars in E, F = 1mm.

acidosis. This is important, as hemocyanin, the extracellular pigment of cephalopods, is highly pH sensitive. We have begun to characterize the gill ion regulatory epithelia that are most likely involved in extracellular pH regulation. We have cloned and localized several gill ion transporters that are potentially related to extracellular pH regulation in cephalopods (e.g. NBCe, NDCBE, cCA2, Na^+/K^+ -ATPase, V-type H^+ -ATPase, NHE3). Judging from the mRNA expression patterns and the localization of these transporters, it seems possible that HCO_3^- import is regulated in a similar fashion as in the proximal tubule of the human kidney. We were also able to demonstrate that embryonic cephalopods are exposed to elevated seawater pCO_2 during the final stages of development: low pO_2 and high pCO_2 in the egg capsule fluid enables diffusive gas exchange with the environment (Fig. 2). As gills, the major sites of ion and acid-base regulation, only become fully functional in late stage embryos, we tested for alternative sites of ion regulation in early embryonic stages. Surprisingly, we were able to identify epidermal ionocytes on head and yolk sac (Fig. 3) which probably fulfill the role of the gill in acid-base

regulation in these stages, analogous to the situation in teleost fish. We could co-localize key ion transporters (Na^+/K^+ -ATPase and Na^+/H^+ exchangers, NHE3) within specific cells on the yolk sac epithelium and in the head region and measured net outward proton fluxes. Our findings indicate that even embryonic cepha-

Working Group



Ulrike Panknin, Skadi Lange, Steffi Syre, Marian Hu Agnes Heinemann, Isabel Casties, Jörn Thomsen [Frank Melzner](#), Rainer Kiko, Meike Stumpp.

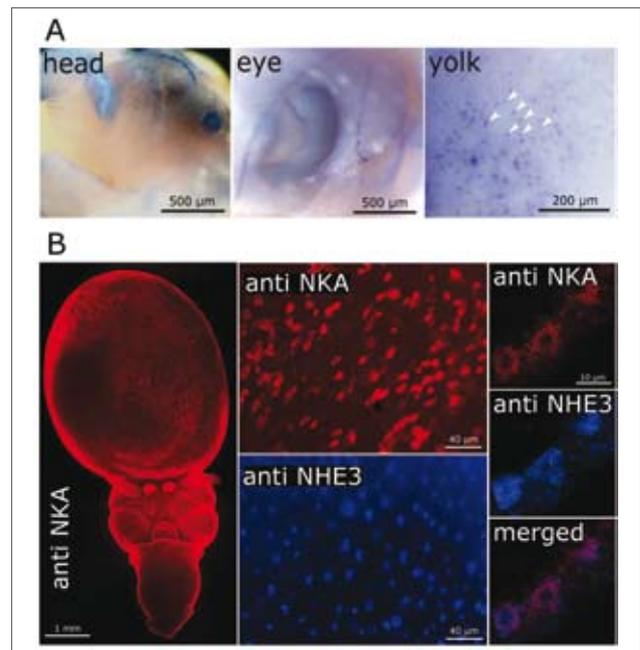


Figure 3

Whole mount *in situ* hybridization of Na^+/K^+ -ATPase (NKA) mRNA in cephalopod (*Sepia officinalis*) embryonic epithelia. In stage 27 embryos, single NKA expressing cells are scattered on the ventral side of the head. Additionally, cells of the oval shaped olfactory organ are rich in NKA mRNA. Dorsal view of the head of a *S. officinalis* embryo, showing sensory cells of the head line system and scattered cells below the eye with high NKA expression. Expression of NKA on the yolk epithelium (arrows). (B): Immunohistochemical localization of Na^+/K^+ -ATPase and NHE3-rich cells on the cephalopod yolk sac epithelium (stage 27 embryos). Ionocytes are scattered over the entire yolk epithelium. Higher magnification images of several ionocytes with positive Na^+/K^+ -ATPase (NKA) and Na^+/H^+ -exchanger (NHE3) immunoreactivity on the ventral side of the yolk with densities of 40–60 cells per $100 \mu\text{m}^2$. NKA-rich cells are approximately $10 \mu\text{m}$ in diameter and are co-localized with NHE rich cells.

lopods have the molecular capabilities to regulate blood pH while inhabiting a challenging ontogenetic habitat. However, we could also demonstrate that additional CO_2 due to ocean acidification is additive to the high pCO_2 in the egg fluid. This can lead to delayed embryonic development.

Selected Publications

- 1 | Thomsen, J., Gutowska, M.A., Saphörster, J., Heinemann, A., Fietzke, J., Hiebenthal, C., Eisenhauer, A., Körtzinger, A., Wahl, M., Melzner, F. (2010). Calcifying invertebrates succeed in a naturally CO_2 enriched coastal habitat but are threatened by high levels of future acidification, *Biogeosciences* 7:3879–3891.
- 2 | Thomsen, J. & Melzner, F. (2010). Moderate seawater acidification does not elicit long-term metabolic depression in the blue mussel *Mytilus edulis*, *Marine Biology* 157:2667–2676.
- 3 | Hu, M.Y., Sucre, E., Charmantier-Daures, M., Charmantier, G., Lucassen, M., Himmerkus, N., Melzner, F. (2010). Localization of ion regulatory epithelia in embryos and hatchlings of two cephalopod species, *Cell and Tissue Research* 339:571–583.



Seafloor Warming

Within the Seafloor Warming research group potential consequences of temperature increases at the seafloor in response to climate change are being investigated. One major objective is the dissociation of gas hydrates and the fate of released methane. Other topics in conjunction with seafloor warming include benthic processes in seasonally developing oxygen minimum zones, growth of microbial biofilms on macroalgae and microbially induced mineralization/ weathering.

PERGAMON and FROZEN HEAT Initiatives

In February 2010 the project “Permafrost and gas hydrate related methane release in the Arctic and impact on climate change: European cooperation for long-term monitoring” (PERGAMON, Fig. 1) funded within the EU-COST (European Cooperation in Science and Technology) program was launched with the aim of bringing together international experts on methane in Arctic gas hydrates and permafrost. The project has currently sixteen European and four associated (non-European) members and meets on a bi-annual basis to discuss ongoing research, to plan joint field work and to synchronize methods and analytics. More information can be found at www.cost-pergamon.eu. The research group has been actively involved in the project from the initial proposal writing to ongoing management duties. Another gas hydrate initiative launched in March 2010 with the involvement of the Seafloor Warming research group is the preparation of an international report “FROZEN HEAT – A Global Outlook on methane hydrates” (Fig. 1) organized by United Nation Environmental Programme (UNEP) and the Global Recourse Information Database (GRID) in Arendal, Norway. The report (hard copy and e-book) will be made available to policy makers, media, and education. For more information visit www.methanegashydrates.org

Benthic Methane Filter Challenge

In the 2009 annual report we introduced a sediment-flow-through system, which was developed to study the potential and limits of the microbial anaerobic oxidation of methane (AOM, the “benthic methane filter”). In a first long-term setup, sediments from two different methane-bearing environments were compared: gassy sediments from Eckernförde Bay (Baltic Sea) and advective sediments from the center of the North Alex Mud Volcano (Eastern Mediter-

anean). For both, two different fluid (10.9 and 109 cm yr^{-1}) and methane flow rates (15.3 and $153 \text{ mmol cm}^{-2} \text{ yr}^{-1}$) were applied in replicate cores. Geochemical parameters were measured along depth gradients as well as in the inflow and outflow of the system. Preliminary results (Fig. 2) revealed: a vertical uplift of the sulfide peak (a product of AOM activity) and an increase in sulfide concentration (Eckernförde Bay only) with higher fluid and methane flow. Furthermore, sulfide peaks in the Eckernförde Bay sediments were found to be shifted closer to the sediment surface than those from the mud volcano. This difference indicates that sediments from more advective systems such as mud volcanoes are pre-adapted to changes in methane flow, whereas originally diffusive systems could offer loopholes for methane if flux increases. This observation is an interesting aspect in light of abrupt gas hydrate melting scenarios. As part of the SFB 574 the research group participated in two additional research expeditions in 2010 (Costa Rica, SO206; Chile, SO210, Fig. 2) to collect supplementary sediment samples from cold seeps, which will allow a broad comparison between different advective systems.

Microbially-Induced Mineralization During Organic Matter Degradation

Microbes in the marine environment play a key role in the formation of authigenic carbonates in sediments, which constitute a long-term sink of atmospheric and oceanic carbon. Details of microbially-mediated carbonate nucleation, however, remain enigmatic. The marine sulfate-reducing bacterium *Desulfobulbus mediterraneus* was chosen as a model organism to study the microbial effect on the nucleation process of carbonate crystals. Biofilms of *D. mediterraneus* were investigated using various imaging and analytical technologies including scanning electron microscopy (SEM), confocal laser scanning microscopy (CLSM), microprobe and energy dispersive X-ray (XRD) analysis. Research was carried out in collaboration with the Swiss Federal Institute of Technology (ETH) in Zürich and the CAU Kiel. High-resolution imaging of biofilms revealed that carbonate crystals precipitated within a matrix of extracellular polymeric substances (EPS) produced by the bacteria (Fig. 3). Element analysis of crystals with XRD indicated the formation of carbonate with a high magnesium concentration typical for



Figure 1

Launched projects on gas hydrates. Logos of the EU-COST Project PERGAMON and the UNEP-GRID initiative FROZEN HEAT.

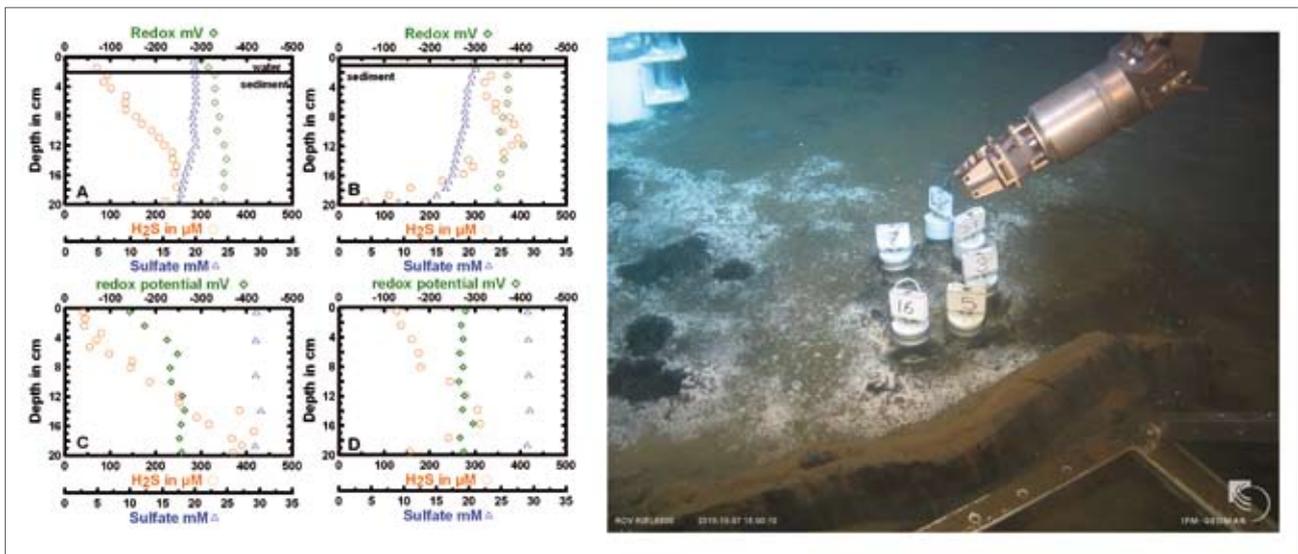


Figure 2

Sediment-flow-through-system. Vertical profiles of sulfide concentration and redox potential measured with micro-electrodes in sediment cores from Eckernförde Bay (A and B, 44 days run time) and North Alex Mud Volcano (C and D, 9 days run time), under low (A and C, $15.26 \mu\text{M cm}^{-2} \text{yr}^{-1}$) and high methane flow (B and D, $152.6 \mu\text{M cm}^{-2} \text{yr}^{-1}$). On the right a picture of cores sampled by the ROV Kiel 6000 from an active methane seep site off Chile covered with white sulfur bacteria mats (SO210, CHIFLUX expedition). The cores D1 and D2 will later be installed in the sediment-flow-through-system.

dolomite. Although dolomite is very abundant in the rock record, formation in modern environments is limited. Our study suggests that the physical-chemical environment created by EPS may have a considerable influence on the process of dolomite-type ordered carbonate formation altering adjacent chemical properties and providing templates for initial nucleation.

Outlook: Svalbard Expedition to a New Methane Seepage Area

In August 2011 the research group will take part in an expedition with the RV Poseidon to investigate the recently discovered methane seepage area off NW-Svalbard. It is currently debated whether the methane vents are fueled by gas hydrate dissociation, because the region has experienced a dramatic warming over the past decades. Geochemical and microbiological measurements in the sediments could provide more profound evidence to decide whether the venting is connected to recent gas hydrate melting or if it was established already before the onset of anthropogenic warming.

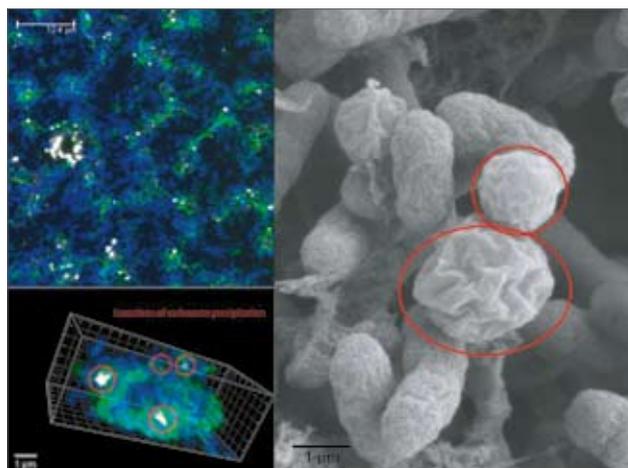


Figure 3

Microbial carbonate precipitation. Top left: CLSM image of carbonate crystals in EPS produced by *D. mediterraneus*. Cells are stained blue (DAPI), EPS is depicted in green (Wheat germ agglutinin with Alexa Fluor 488). Crystals appear white (reflection mode). Left: CLSM 3-D stack image of *D. mediterraneus* biofilm showing areas of carbonate formation at EPS rich areas within the biofilm. Right: SEM image of two adjacent crystals (red circles) in biofilm.

Working Group



Manuela Teupe, Philip Steeb, Stefan Krause, Johanna Schweers, Marion Liebetrau, Julia Hommer, Victoria Bertics, [Tina Treude](#)
Missing: Lihua Liu, Julia Farkas, Kerstin Kretschmer

Selected Publications

- 1 | B. Orcutt, S.B. Joye, S. Kleindienst, K. Knittel, A. Ramette, A. Reitz, V. Samarkin, T. Treude, and A. Boetius (2010): "Impact of natural oil and higher hydrocarbons on microbial diversity, distribution and activity in Gulf of Mexico cold-seep sediments", *Deep-Sea Research II*, 57: 2008-2021.
- 2 | T. Treude, W. Ziebis (2010): "Methane oxidation in permeable sediments at hydrocarbon seeps in the Santa Barbara Channel, California", *Biogeosciences*, 7: 1-14.
- 3 | V. Bertics, J.A. Sohm, T. Treude, C-E.T. Chow, D.G. Capone, J.A. Fuhrman, W. Ziebis (2010): "Burrowing deeper into the benthic nitrogen fixation: the impact of bioturbation on nitrogen fixation coupled to sulfate reduction", *MEPS*, 409: 1-15, Feature Article.
- 4 | S. Sommer, P. Linke, O. Pfannkuche, H. Niemann, T. Treude (2010): "Benthic respiration in a novel seep habitat dominated by dense beds of ampharetid polychaetes at the Hikurangi Margin (New Zealand)", *Marine Geology*, 272: 223-232.



CO₂ Uptake of the Ocean – Optimizing Biogeochemical Models Using Mathematics

The amount of CO₂ in the ocean is mainly determined by ocean currents and biogeochemical processes. The simulation of these processes is important, e.g. to investigate the future behavior of the ocean as a CO₂ buffer for the increasing emissions in the atmosphere. Models of CO₂ uptake consist of equations for different tracers such as nutrients, phytoplankton and zooplankton. These models use many parameters that are fitted to measurement data. Methods of mathematical optimization, high performance computing, and uncertainty analysis are used for this purpose. The main challenge is the huge computational effort needed to spin up 3-D models to steady seasonal cycles in order to optimize them. Different optimization techniques, the algorithmic generation of sensitivities, and Newton-like methods for the computation of periodic states are some of the methods used in the project.

The Role of CO₂ in the Ocean

CO₂ is one of the main topics in the discussion about climate change and climate protection strategies. It is one of the main greenhouse gases, i.e. it holds back part of the radiation reflected from the Earth's surface in the atmosphere.

Thus, on the one hand, CO₂ is responsible for the comfortably warm climate on Earth allowing us to survive at all. On the other hand, the increase of CO₂ emissions in the last 200 years has caused a temperature rise with consequences such as sea ice melting, changes in vegetation, etc. Climate model simulations

indicate that these effects, summarized as global warming, will continue and become even greater.

Even though atmospheric CO₂ is discussed the most, the amount of CO₂ in the oceans is also very important. In fact, much more of this gas is dissolved in the oceans, and two thirds of the CO₂ emitted is taken up from the atmosphere via the sea surface. This effect thus mitigates the greenhouse effect, but, naturally, it 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.

Modeling CO₂ Uptake

The amount and distribution of CO₂ in the ocean is determined by ocean circulation, by biochemical processes – namely the assimilation of CO₂ by phytoplankton (algae) and its mineralization by zooplankton (animals) – and sedimentation. A well-accepted theory describes the relation of the amounts of CO₂ and nutrients that are converted to biomass by photosynthesis. Thus CO₂ uptake is usually modeled in a system of transport (or advection-diffusion) equations for so-called tracers. The coupling relations between the tracers in these models are more or less empirical, i.e. it is not very clear what the coupling terms look like mathematically, and, moreover, how many tracers need 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.

General Optimization and Validation Strategy

We developed a strategy to combine state-of-the-art optimization methods (stochastic and deterministic) to optimize model parameters. Since optima - that lead to a perfect data fit - are hard to find for ecosystem and climate models, we exploit the hardware infrastructure using a so-called random-restart method to prevent optimization in suboptimal local minima. Based on this method, uncertainty estimates can also be generated without additional linearity assumptions on the models.

For a one-dimensional model of an inorganic nitrogen, phytoplankton, zooplankton, and detritus (NPZD) type this was successfully done with respect to model parameters and initial values.

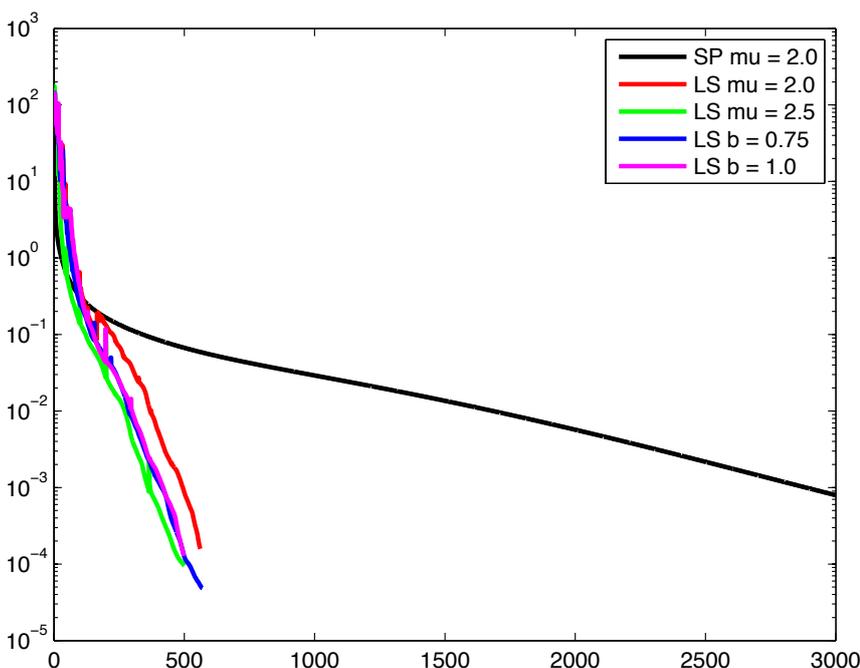


Figure 1

Acceleration of model spin-up into a periodic state by a Newton iteration [color lines for different parameters] compared to usual pseudo-time-stepping (black line). The Newton method needs less than 500 model years compared to 3000 to reach the same accuracy.

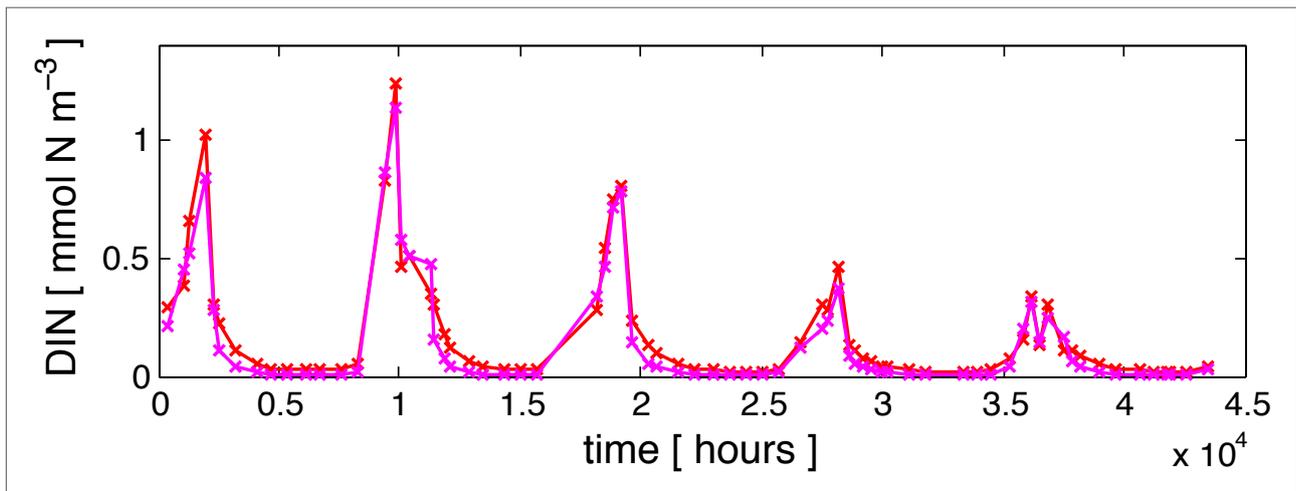


Figure 2

Comparison of an exemplary ecosystem model output with the original model (red) and a surrogate (magenta) using a 40 times larger time step and needing only 5 % computation time. It is important to guarantee numerical stability of the coarse model.

3-D Results

For the more realistic spatially three dimensional models, we currently work with Khatiwala's Transport Matrix Method (TMM) that provides a discretization of the ocean circulation forcing of the ecosystem in matrix form.

We study the dependency of the model output with respect to the time discretization from a mathematical viewpoint, and found out that the models' spin-up phase can be significantly accelerated. This was also achieved by applying a Newton method to compute a periodic state. A flexible software framework Marine Ecosystem Toolkit for Optimization and Simulation in 3-D (METOS3D) was developed that allows for coupling the TMM with a wide range of ecosystem models.

One-Shot Optimization

The above mentioned work is a prerequisite for the method of simultaneous analysis and design. It allows us to perform a model improvement already during the sign-up phase. The method that was proven successful in aerodynamics and for ocean box models, is currently being applied to the full 3-D problem.

Model Predictive Control

Linear-quadratic Control Theory is used to incorporate timely variant parameters. For this purpose, linearizations of full nonlinear models are obtained algorithmically by the method of Automatic Differentiation (AD). This control approach extends the models by introducing periodic parameters which lead to a better fit, by now at least in the piecewise linearized model.

Surrogate-based Optimization

Working with model hierarchies (in temporal and spatial resolution, number of space dimensions, different numbers of tracers) can be a useful tool if one optimizes a coarse model and uses the results in a fine model.

Here 1-D tests lead to computer time reductions of up to 95 %. This perspective is even more promising in 3-D.

The Consequences of Fukushima

The software METOS3D enabled our group to easily simulate the distribution of radioactive water released in Fukushima in March 2011 in the Pacific. It can be observed in these simulations that traces of iodine-131 vanish in a little while and are not going to be distributed widely

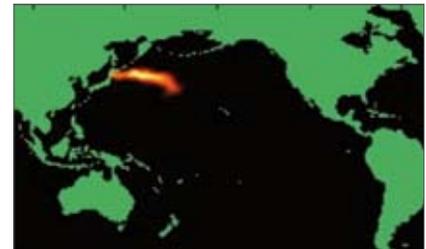


Figure 3

Example for the distribution of radioactive water released during March-June 2011.

into the ocean. On the other hand, cesium-137 will take a couple of years to arrive at the North American coastline.

Working Group



Johannes Rückelt, Henrike Mütze, Malte Prieß, Mustapha El Jarbi, Anna Heinle, Jaroslaw Piwonski, [Thomas Slawig](#). Missing: Claudia Kratzenstein

Selected Publications

- 1 | Heinle A., Macke A., Srivastav A.: Automatic cloud classification of whole sky images. *Atmospheric Measurement Techniques* 3, 269-299 (2010).
- 2 | Rückelt J., Sauerland V., Slawig T., Srivastav A., Ward B., Patvardhan C.: Parameter Optimization and Uncertainty Analysis in a Model of Oceanic CO₂-Uptake using a Hybrid Algorithm and Algorithmic Differentiation. *Nonlinear Analysis B, Real World Applications* 11 (5), 3993-4009 (2010).
- 3 | Prieß M., Slawig T.: Surrogate-based Optimization of Biogeochemical Transport Models. *AIP Conference Proceedings* 1281, 612D615 (2010).



Biogeochemical Oceanography and Climate

The research group combines expertise from ocean biogeochemical and paleo climate modeling in order to enhance our understanding of past, present and future climate mechanisms. A state-of-the-art coupled atmosphere ocean climate model (KCM – Kiel Climate Model) in combination with a marine biogeochemical model is applied to different warm climates from the present and the geological past. Focusing on ocean circulation, the atmospheric hydrological cycle, and marine biogeochemical cycles, the aim is to test the performance of the model in representing climate conditions fundamentally different from today.

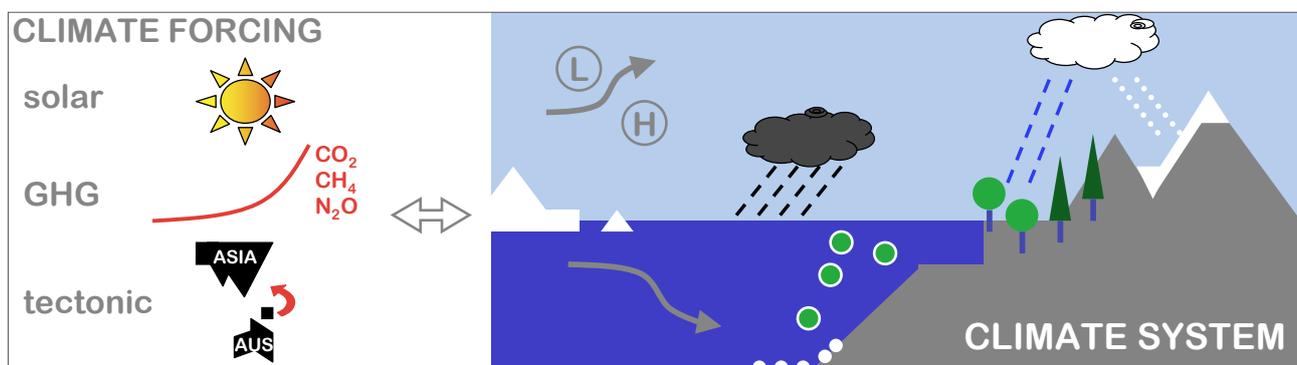


Figure 1

Components of the climate system and forcing mechanisms considered by the research group.

Simulating Past Climates

To simulate past climates, KCM is run with boundary conditions typical for past warm periods. These are, for example, changes in incoming solar radiation, tectonic setting and/or the concentrations of atmospheric greenhouse gases (Fig. 1). Some of the experiments are following standard protocols of the international Paleo Modeling Intercomparison Project (PMIP) to allow for joint analysis and comparison with other climate models.

Comparison of Modeled and Reconstructed Sea Surface Temperatures

A model-data comparison of sea surface temperature (SST) trends over the Holocene (last 10 kyrs) revealed systematic discrepancies between model results and paleo data. With the help of a newly developed seasonality index, it could be shown that the reconstruction of past climate trends can actually go beyond the explanation of annual mean climate conditions and

resolve the evolution of internal climate variability, such as the seasonal cycle. However, the results also show that the KCM model underestimates Holocene climate trends, even when potential seasonal signals in the proxy records are taken into account. (Schneider *et al.*, 2010)

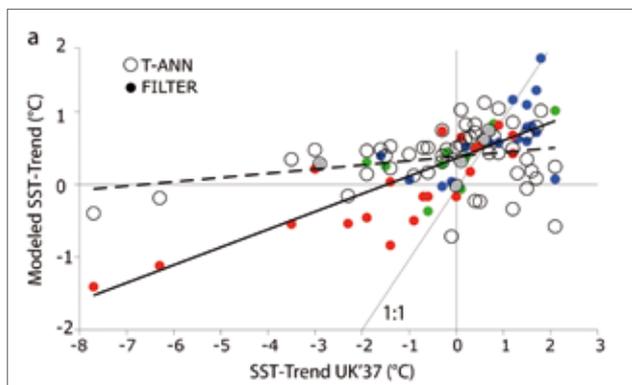


Figure 2

Regression of reconstructed (proxy: UK'37) versus modeled SST trend, shown for the annual mean values [T-ANN, open symbols] and the respective seasonally subsampled value that yielded the best match with the data at each location (gray, T-ANN; green, SI-WEIGHT; red, T-MAX; blue, T-MIN). Regression lines are shown for the annual mean values (dashed line) and the trends based on the best filter (black line).

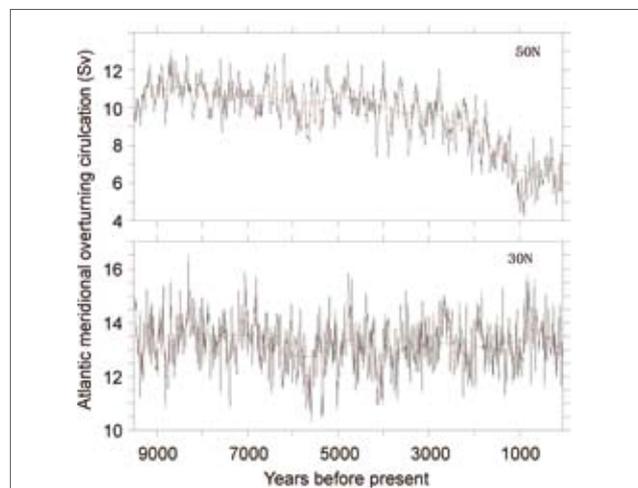


Figure 3

Variation of the Atlantic meridional overturning circulation during the Holocene.

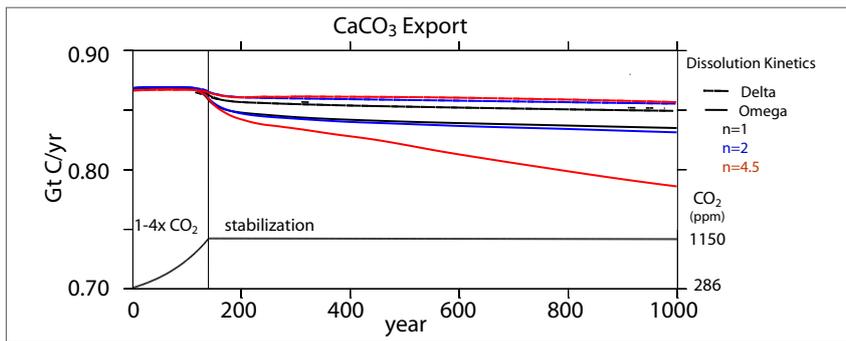


Figure 4

Calcite export flux (across 100m) in response to a CO_2 -scenario with 1% CO_2 -increase per year over 140 years and stabilization at $4\times\text{CO}_2$ afterwards. Colors indicate the different CaCO_3 dissolution kinetics. The atmospheric CO_2 concentration is given by the lower black line on the right scale (data unpublished).

Linking Ocean Circulation Changes with Large Scale Climate Patterns

A transient simulation of the Holocene showed a pronounced reduction of the Atlantic Meridional Overturning Circulation (AMOC) at 50°N during the late Holocene, whereas the transport at 30°N remained remarkably constant (Fig. 3). To what extent such internal variations are potentially related to changes in the strength of the Asian Monsoon is presently under investigation. (Jin *et al.*, work in progress) Furthermore, quasi steady-state (time slice) simulations of distinct periods during the Holocene and the Eemian revealed a robust link between changes in the mean climatic state of the tropical Pacific Ocean and the strength of El Niño Southern Oscillation (ENSO). The findings imply that in a future warming climate an intensification of the ENSO amplitude at a constant frequency of 3-4 years can be expected.

Changing Characteristics of the Atmospheric Hydrological Cycle

A combination of Holocene and Eemian time slice simulations with a global warming sensitivity experiment has shown an intensification of the Asian Monsoon, but with different moisture sources for solar and CO_2 forcing (Khon *et al.*, 2010). In a future warming climate on a millennial time scale both effects will act together.

Over millions of years, tectonic movements of the continents have an influence on climate. In agreement with proxy evidence we find that a narrowing of the Indonesian Gateway (around 5 Ma BP) caused a reduction and change in characteristics of the water masses transported from the Pacific into the Indian Ocean. It could be shown that resulting precipitation changes largely explain the observed late Pliocene desertification of Australia. (Krebs *et al.*, 2011)

Ocean Carbon Cycling Under Increasing CO_2

A special focus of the research group is on marine biogeochemical cycles, especially the oceanic sink for (anthropogenic) carbon. The offline biogeochemical model PISCES is used for sensitivity experiments of the organic and inorganic carbon cycle to ocean acidification. One study examines the impact of different formulations of CaCO_3 dissolution kinetics on the vertical flux of CaCO_3 , which may result in different particle ballasting and thereby affect the ocean carbon sink (Fig. 4). (Dürkop *et al.*, in prep.)

A second study investigates the influence of changes in the organic matter turnover on particle aggregation and thus the vertical flux of organic matter through the water column. Based on results from mesocosm experiments, a potential CO_2 -sensitivity of the rate of dissolved organic matter formation is applied to the model. We find that this has a small but positive feedback on atmospheric CO_2 (Bordelon *et al.*, work in progress).

Working Group



Laura Bordelon, Anke Dürkop, Uta Krebs-Kanzow, Vyacheslav Khon, Liya Jin, Stefanie Maack, [Birgit Schneider](#), Opeyemi Salau.

Next Steps

Besides orbital forcing, both transient and time slice experiments will also be forced with varying greenhouse gas concentrations to isolate the individual and combined effects on climate variability and climate change. These experiments will be provided to the international Paleo Modeling Intercomparison Project (PMIP) data base. Concerning tectonic forcing, the closure of the Panama Gateway will be included in order to get a more realistic sequence of tectonic forcing events from the late Miocene into the Pliocene. With respect to biogeochemical modelling, a ballast parameterization will be implemented as an alternative way to simulate vertical particle settling in the water column, which allows for feedbacks between organic and inorganic carbon and nutrient cycling.

The Research Group

The research group unites expertise in oceanography, atmospheric and environmental physics and geology. Two PhD students (one from BMBF funding) and four postdocs (three in part-time positions) from five different countries, supported by a project manager and two student assistants, constitute the highly interdisciplinary and international research group (Fig. 5).

Selected Publications

- 1 | Khon, V., Park, W., Latif, M., Mokhov, I.I., Schneider, B. (2010): Response of the hydrological cycle to orbital and greenhouse gas forcing. *Geophysical Research Letters*, No. 37, pp. L19705, doi: 10.1029/2010GL044377.
- 2 | Schneider, B., Leduc, G., Park, W. (2010): Disentangling seasonal signals in Holocene climate trends by satellite-model-proxy integration, *Paleoceanography*, No. 25, pp. PA4217, doi: 10.1029/2009PA001893.
- 3 | Schneider, B. & R. Schneider (2010): Palaeoclimate: Global warmth with little extra CO_2 . *Nature Geoscience* No. 3, pp. 6-7, doi:10.1038/ngeo736.
- 4 | Steinacher, M., F. Joos, T. L. Frölicher, L. Bopp, P. Cadule, S. C. Doney M. Gehlen, B. Schneider, and J. Segschneider (2009): Projected 21st century decrease in marine productivity: a multi-model analysis. *Biogosciences Discussions*, 6: 7933-7981.



Physicochemical Methods for Ocean Surface Research

The biogeochemical coupling of the ocean and the atmosphere takes place at the air-sea interface – a vast chemical reactor where many heterogeneous and photochemically initiated processes occur. Modern optical, mostly laser-based detection tools help to unravel the structure, composition, and chemical reactivity of such interfaces. Molecular level resolution combined with high detection sensitivity allows one to study ocean surface chemistry on spatial scales and in concentration ranges where interface mediated processes ultimately happen. Whereas non-linear sum-frequency generation spectroscopy (SFG) offers a detailed look into the molecular structure and reactivity of the organic nanolayer, the ultrasensitive cavity-ringdown spectroscopy (CRDS) measures the absorption of trace gases such as N_2O and CO_2 with isotopic resolution. A novel fluorescence sensor is used to investigate the dynamics of biofilm formation on submerged substrates.

Optical Detection Methods for Marine Research

Modern optical detection methods find many applications in environmental sciences. The Ocean Surface Chemistry research group aims to (1) identify and study heterogeneous chemical processes taking place at environmental interfaces – in particular the water-air interface – by using sensitive laser spectroscopic methods and (2) to provide modern optical detection technologies for use in marine research applications such as trace gas detection or biofilm monitoring. Current activities include the development of state-of-the-art laboratory instrumentation for basic research, the use of versatile laser spectrometers to analyze field samples, and the testing of robust sensors to make on-site detection capabilities available.

A Molecular View of the Ocean Surface

The uppermost molecular layer directly at the air-sea interface is called the ocean

nanolayer. It is part of the sea surface microlayer representing the top 1 to 1000 μm of the ocean water column. The microlayer is enriched by organic material of biological and anthropogenic origin and is known to hinder air-sea gas exchange, especially at low wind speeds. Due to its small vertical dimension and the tiny amount of substances, nanolayer sampling and chemical analysis still pose challenges. For the first time, we successfully applied non-linear sum-frequency generation (SFG) spectroscopy to analyze water samples collected in the Baltic Sea. SFG spectroscopy is surface selective (only the uppermost molecular layers at the interface are measured), species selective (different substance classes can be identified by measuring their vibrational spectra), and orientation selective (the structural order of the interface can be investigated).

Typically, partly soluble “wet” surfactants have been found to form amazingly dense layers of organic molecules at natural seawater interfaces. Observed spectral signatures are

consistent with the predominance of lipopolysaccharides (surface active carbohydrate-containing molecules) or other lipid-like compounds embedded in colloidal matrices of polymeric material (Fig. 1). In order to further clarify these preliminary conclusions, we have now set out to systematically study relevant interfacial properties of lipopolysaccharides. Specific proxy molecules are synthesized in collaboration with organic chemistry (T. K. Lindhorst). Another project is concerned with the reactivity of the nanolayer, which is known to be subject to degrading processes driven by photolytic, chemical, and biological transformations. Time-resolved SFG studies of ozone oxidation of unsaturated lipids have been performed showing that SFG is a valuable tool for investigating surface kinetics.

Ultrasensitive Absorption Measurements

Cavity-ringdown spectroscopy (CRDS) is an ultrasensitive detection method for molecular

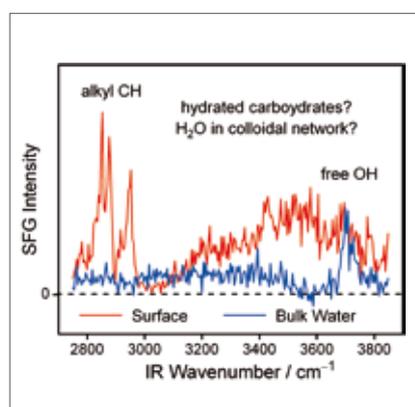


Figure 1

SFG spectra of Baltic Sea water samples. In contrast to the bulk water spectrum, the surface water sample shows considerable amounts of organic material.

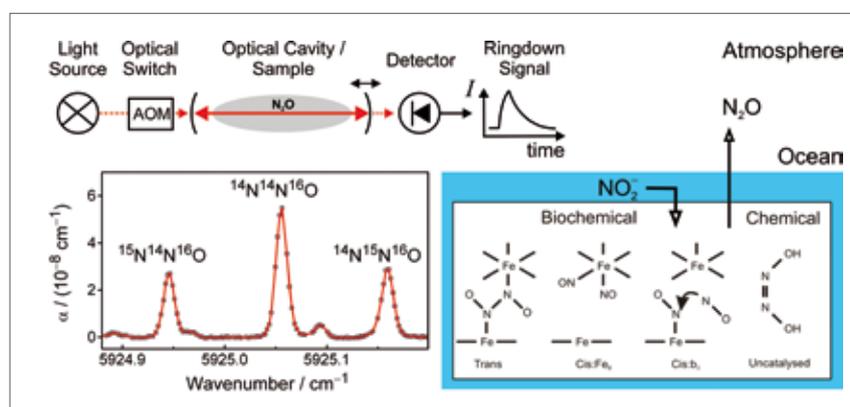


Figure 2

Cavity ringdown spectroscopy (CRDS): Isotomer resolved detection sheds light on biochemical and chemical formation mechanisms of N_2O .

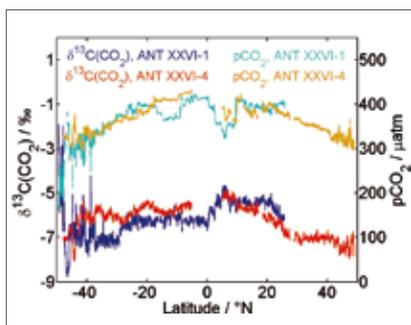


Figure 3
Online measurement of the isotopic composition, $\delta^{13}\text{C}(\text{CO}_2)$, and partial pressure, pCO_2 , of CO_2 dissolved in ocean surface water during two Atlantic crossings [Polarstern cruises ANT XXVI-1 and ANT XXVI-4].

absorption. The high detection sensitivity is primarily based on long absorption pathlengths (> 10 km) arising from multiple reflections in a resonant cavity. We have designed a new modular spectrometer, which is based on a continuous wave (cw) near-infrared (NIR) tunable diode laser light source, and can be used both for gas phase and surface sensitive measurements. The spectrometer operates in the CH-overtone spectral region at wavelengths of $\lambda = 1625 - 1690$ nm and targets the detection of gas phase species such as N_2O , CH_4 , CO_2 , and halogenated hydrocarbons. The spectrometer is equipped with a very precise wavelength calibration scheme that enables quantitative absorption measurements of different isotopologues of the same molecule. The calibration scheme is based on a second narrow-bandwidth laser that is stabilized to a known absorption transition of CO_2 as an internal reference.

The new instrument has been applied to measure the “site-preference” δSP of N_2O samples, $\delta\text{SP} = ([^{14}\text{N}^{15}\text{NO}]/[^{15}\text{N}^{14}\text{NO}] - 1)$. The knowledge of δSP allows one to figure out sources and sinks of environmental N_2O formed in microbial processes via denitrification and nitrification pathways (Fig. 2). Surprisingly, no internationally recognized standard reference material of accepted site preference is available yet. Therefore, absolute measurements of absorption cross sections of purified isotopomer samples have been performed at first and a new “chemical” standard for N_2O site preference based on nitrite reduction in aqueous systems has been developed. Moreover, in collaboration with microbiology (R. Schmitz-Streit, C. Löscher), N_2O samples generated by a new class of denitrifying marine bacteria have been characterized.

Field Deployable Optical Instrumentation

Seasonal time-series of dissolved inorganic carbon and its isotopic composition allow separation of physical and biological processes important for the surface layer carbon budget. So far, isotope ratio mass spectrometry is the conventional method for accurately measuring isotope ratios, but sample collection, shipping, and processing is labor intensive and costly. In a highly interdisciplinary endeavor involving several research groups and local industry (A. Körtzinger, F. Temps, D. Wallace, CONTROS GmbH), a CRDS based CO_2 isotopic analyzer has been (i) lab-tested, (ii) fully spectroscopically characterized, and (ii) successfully operated aboard the research vessel Polarstern on two Atlantic crossings. For the first time, ten weeks of online $\delta^{13}\text{C}(\text{CO}_2)$ data could be collected (Fig. 3). Considerable variations and spatially dependent correlations between CO_2 partial pressure, pCO_2 , and isotopic composition, $\delta^{13}\text{C}(\text{CO}_2)$, have been identified. Such data are needed to work out details of global carbon cycling pathways and hence to derive sound estimates for the ocean’s capacity for current and future mitigation of atmospheric CO_2 increase.

Another project is concerned with the development of an autonomous field sensor to monitor the dynamics of biofilm formation (Fig. 4). In the sea, all submerged non-living (biofouling) and living surfaces (microepibiosis) are rapidly colonized by bacteria and unicellular algae. Being able to study biofilm formation dynamics with fine temporal resolution helps to unravel complex underlying mechanisms. In cooperation with benthic ecology (M. Wahl), a submersible sensor for quantitative detection

Working Group



Kristian Laß, Gernot Friedrichs, Meike Becker, Joscha Kleber, Nancy Faßheber, Matthias Fischer, Carsten Fehling, Johannes Dammeier.

of biomass was designed. Briefly, the output of a narrow-bandwidth UV-LED excites tryptophan fluorescence, which is efficiently collected by a bunch of optical fibers. The sensor head principle, which has been filed as a patent, allows for large-area illumination and detection and thus ensures the required averaging over the patchy structure of fresh natural biofilms. The spatial arrangement of the fibers has been optimized in terms of illumination and collection efficiency by detailed simulations of the optical system. Laboratory as well as field tests revealed linear signal response, satisfactory background suppression, high sensitivity, and wide dynamic range.

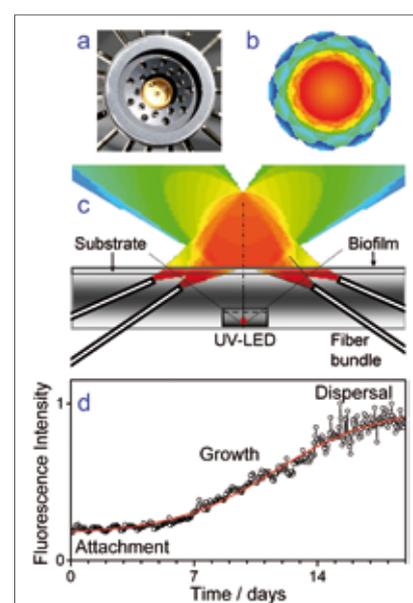


Figure 4

Patent pending biofilm sensor design and Baltic Sea field deployment. a: sensor head, b: biofilm detection efficiency (lateral cut), c: fluorescence collection efficiency (longitudinal cut), d: time-resolved measurement of biofilm growth.

Selected Publications

- 1 | K. Laß, J. Kleber, and G. Friedrichs [2010]: Vibrational sum-frequency generation as a probe for composition, chemical reactivity, and film formation dynamics of the sea surface nanolayer, *Limnol. Oceanogr.: Methods* 8, pp. 216-228.
- 2 | C. Fehling, and G. Friedrichs [2010]: A Precise High-Resolution Near Infrared Continuous Wave Cavity Ringdown Spectrometer using a Fourier Transform based Wavelength Calibration, *Rev. Sci. Instrum.* 81 053109/1-8.
- 3 | G. Friedrichs, J. Bock, F. Temps, P. Fietzek, A. Körtzinger, and D. Wallace [2010]: Toward Continuous Monitoring of Seawater $^{13}\text{CO}_2/^{12}\text{CO}_2$ Isotope Ratio and pCO_2 : Performance of a Cavity Ringdown Spectrometer and Gas Matrix Effects, *Limnol. Oceanogr.: Method* 8, pp. 539-551.
- 4 | M. Fischer, G. Friedrichs, and M. Wahl [2010] [Patent pending]: Großflächiger Biofilmsensor | Large area biofilm sensor, DE 102011101934.4.



Valuing the Ocean: Accounting for CO₂ Emissions from International Shipping

The ocean provides a number of ecosystem services, which are used by mankind in multiple ways but which have not been considered systematically in economics so far. Our working group evaluates the different ecosystem services provided by the ocean by integrating them into economic models. The Future Ocean research group on Valuing the Ocean considers the following topics: Carbon management including ocean acidification and impact assessment, energy and mineral resources and shipping. In the following we provide detailed information on a study related to the last topic.

CO₂ Emissions from International Shipping

CO₂ emissions from international shipping, which are currently unregulated, are predicted to rise from 2.7% today to 18% in 2050. International bunker fuel emissions have been excluded from any commitment in the Kyoto Protocol; the United Nations Framework Convention on Climate Change (UNFCCC) conference in Copenhagen also failed to bring about clear directions on how to proceed with these emissions.

The present lack of regulation can be traced to the truly global nature of the shipping sector. In 2005, the world merchant fleet counted 90,662 million ships of 100 gross tons (gt) or more, transporting 7 billion tons of cargo between 160 countries. A significant part of the emissions caused by international shipping therefore takes place on the high seas outside of the jurisdiction of any country. Here only the United Nations

Convention on the Law of the Sea (UNCLOS) and those International Maritime Organization (IMO) conventions that have been ratified by member states apply. Moreover, regulation of shipping emissions is difficult due to the multiple nationalities of transporting ships. Often ships are registered in one country, their flag state, but their owners may be citizens of another country, while the operating company is based in a third country. Regulating this global business therefore requires a global approach that includes as many countries as possible in order to limit the options for free-riders seeking to avoid emissions regulation (Heitmann and Khalilian, 2010).

Regulation of Emissions from International Shipping

There are essentially two ways in which emissions from international shipping can be regulated: a UNFCCC-based versus a sectoral

approach. If regulation by the UNFCCC framework is chosen, emissions would have to be allocated to individual countries, adding to their total national emissions. It would then be the choice of the individual countries how to reduce their total national emissions. They will probably opt for those sectors and methods that are most cost-effective. Hence, regulation of the shipping sector may or may not be the consequence, depending on what national policy makers consider the most efficient method. Alternatively, a sectoral approach could be aimed for, which would focus only on shipping sector emissions and allocate them within the shipping sector. It would set emission reduction targets specifically for that sector which would result in a regulation of the shipping industry. A global approach should be pursued to avoid free-riding. Otherwise shipping regulations introduced in some countries could easily be avoided if other non-committed countries provide safe havens for free-riders. From an economic perspective, an allocation to total national emissions combined with a global carbon price – e.g. within an international emissions trading system – would be most efficient. For this reason we focus in the following on regulations based on the UNFCCC framework. We compare three (options 2, 3 and 4 with three sub cases) out of the eight options proposed by the UNFCCC to allocate shipping emissions to individual countries.

Option 2 under the UNFCCC is a pragmatic approach which would proportionally add marine bunker fuel emissions to the domestic emissions inventory of all countries, i.e. if shipping emissions make up 2% of global emissions, then each country would add 2% to its total national emissions. On a global scale this option distributes the burden equally, but, in doing so, disadvantages small countries and land-locked countries.

Option 3 suggests an allocation to Parties

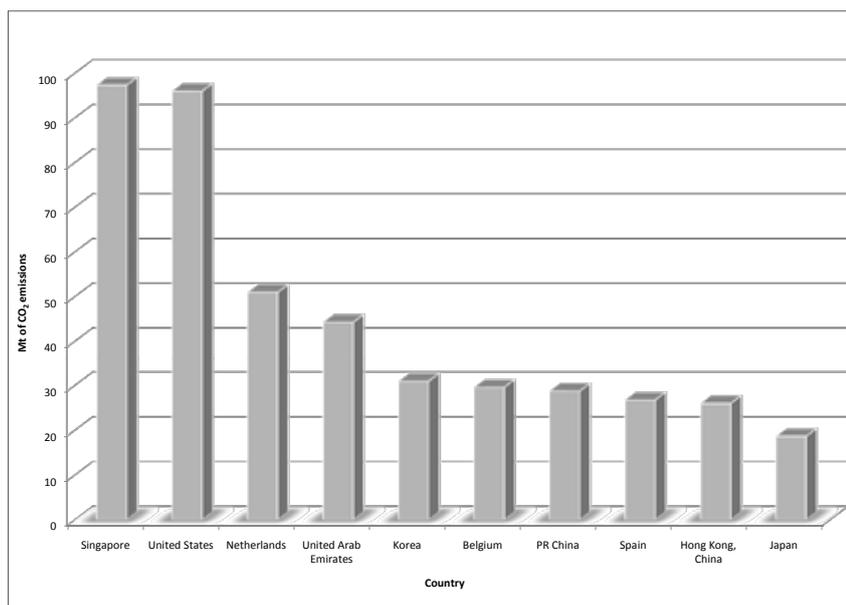


Figure 1

Top 10 countries in CO₂ emissions from IMB fuel sold in 2007.

on the basis of where the marine fuel is sold. Since fuel will become more expensive in countries who implement this option, fuel sales are likely to move to cheaper locations very quickly, thereby transferring emissions to either non-Annex I countries or non-parties of an IMO convention. Figure 1 provides an overview of the top 10 countries in terms of CO₂ emissions.

Option 4 advocates an “allocation according to the nationality of the transporting company, or to the country where the vessel is registered, or to the country of the operator”. These three cases must be disentangled because a ship may have owners and operators of different nationalities and be registered in a third country. Vessels are often owned by investment vehicles such as Limited Partnerships (UK), which are currently based mostly in Organisation for Economic Co-operation and Development (OECD) countries but can easily relocate to another country at little cost – thereby potentially evading obligations.

Comparison of Results

Figure 2 shows the relative shares of the respective top ten countries in total international shipping emissions per allocation option in comparison to the rest of the world. The results show that all three sub cases of option 4 would allocate roughly 50% of the emissions to the top ten countries and the other 50% to the rest of the world. This is considerably lower than allocation options 3 and 2 (70% and 65% respectively). However, the distribution of emissions varies significantly among options. Option 4c (owner) would allocate the highest CO₂ shares to Germany, Japan and Greece - all three have agreed to emission reduction targets under the Kyoto Protocol - followed by China and the US. Option 4b (operator) allocates the highest share to Japan, Greece and China, followed by Denmark and the US. Both options have a decent share of OECD countries amongst those most highly burdened, as well as countries that have signaled their willingness to reduce emissions. The third case of option 4, allocation according to flag state, is not as balanced because Panama and Liberia alone would have to account for roughly 25% of all emissions – whilst both countries have small economies and a small amount of total national emissions overall. In this case, only two out of the top ten countries have agreed to emission reduction targets under Kyoto. As a consequence, only few emissions would be controlled compared to a global climate regime (100% controlled emission). This would be environmentally ineffective.

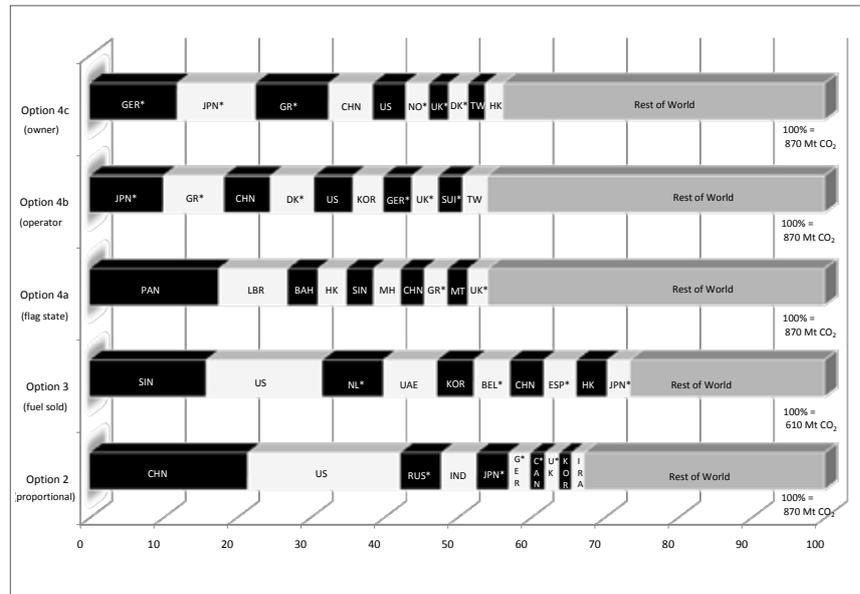


Figure 2

Top 10 countries according to relative share in total international shipping emissions per option in comparison to the rest of the world. Countries that have agreed to emission reduction targets under the Kyoto Protocol are marked with an asterisk.

Outlook

Members of the research group are involved in a number of other research projects. In 2008, the EU adopted the Marine Strategy Framework Directive (MSFD), which aims to guide future maritime policy and achieve/maintain a good environmental status of European seas by 2020. To this end, the MSFD requires the development of measures, which must be assessed using cost-effectiveness and cost-benefit analysis before implementation. We are investigating the appropriateness of economic approaches to valuing benefits provided by marine ecosystems. Other examples of research activities include an analysis of the economic aspects related to

the use of ocean pipes for mitigating climate change. Is there an economic rationale for this climate engineering option? Another area of research is directed to the ocean's potential to provide mineral resources. What is the economic potential and how can these resources be exploited optimally? How do environmental impacts influence optimal extraction policies? A third line of research addresses the valuation of economic impacts where we investigate the economic impact of ocean acidification.

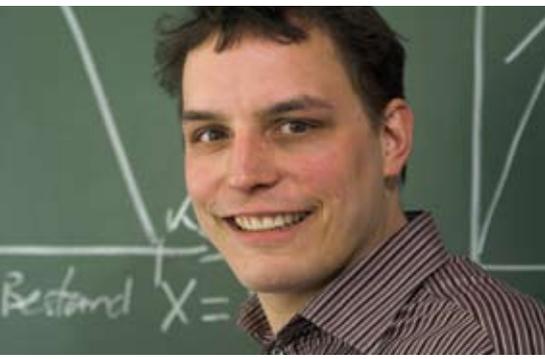
Working Group



Daiju Narita, Christine Bertram, Sebastian Petrick, [Katrin Rehdanz](#), Wilfried Rickels, Nadine Heitmann.

Selected Publications

- 1 | Bertram, C. (2010), Ocean iron fertilization in the context of the Kyoto protocol and the post-Kyoto process, *Energy Policy* 38(2), 1130-1139.
- 2 | Güssow, K., A. Proelß, A. Oschlies, K. Rehdanz and W. Rickels (2010), Ocean Iron Fertilization: Why further research is needed, *Marine Policy* 34, 911-918.
- 3 | Heitmann, N. and S. Khalilian (2010), Accounting for CO₂ Emissions from International Shipping: Burden Sharing under Different UNFCCC Allocation Options and Regime Scenarios, Kiel Working Paper No. 1655, Kiel Institute for the World Economy, Kiel.



Sustainable Fisheries

More than three quarters of all marine fish stocks worldwide are deemed fully exploited or overfished. The fisheries 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 2010, research has focused on how to manage multi-species fisheries in the Baltic Sea and on the general question of how to conceptualize sustainability.

From Overfishing to Sustainable Fisheries: Research Topic and Methodical Approach

The overall objective of our research is to provide the scientific basis for a more sustainable use of ecosystem services, in particular for more sustainable fisheries. Our focus is ecosystem-based management of fisheries, because no efficient and sustainable use of natural resources is possible without taking the relevant processes and interactions in marine ecosystems into account. In our research, we study the effects of the age structure of fish populations, uncertainty in fish recruitment, multi-species interactions, and spatial heterogeneity and migration of fish. Conceiving strategies for more sustainable fisheries also requires an economic approach, for two complementary reasons: First, economic incentives determine how resources are used in a market economy. Second, unlike ecology, economics provides sound methods to operationalize normative societal objectives such as welfare and sustainability. Both, incentives and operational normative objectives, play an important role in our research on how to design instruments and institutions for the sustainable management of fisheries.

Methods: Integrating Economic and Ecological Expertise

Integrated mathematical models of ecosystems and the economy are among the most powerful scientific methods to analyze the current management of the environment and natural resources and to develop novel management concepts that promote sustainable fishery. Our approach is to develop such models in an interdisciplinary collaboration between economists and ecologists (Fig. 1). The focus is on generic models that retain enough structure to be applicable to realistic

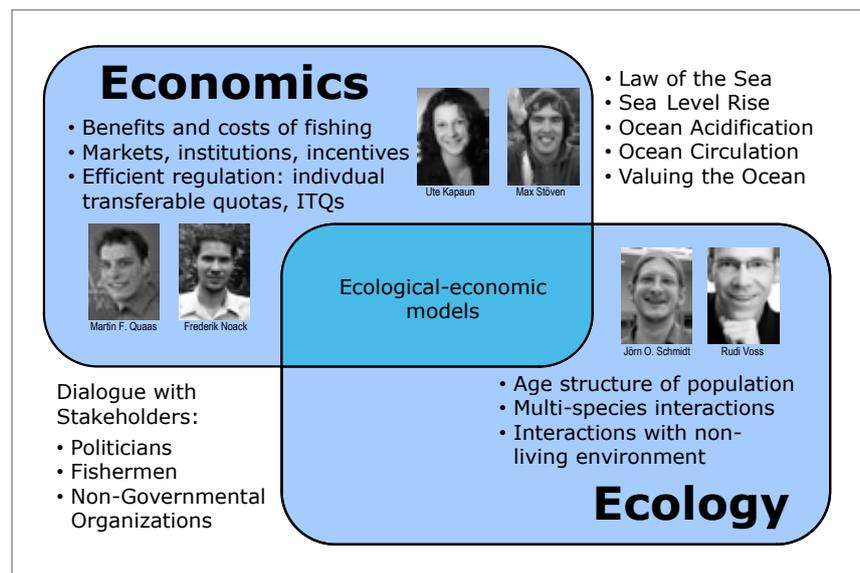


Figure 1

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

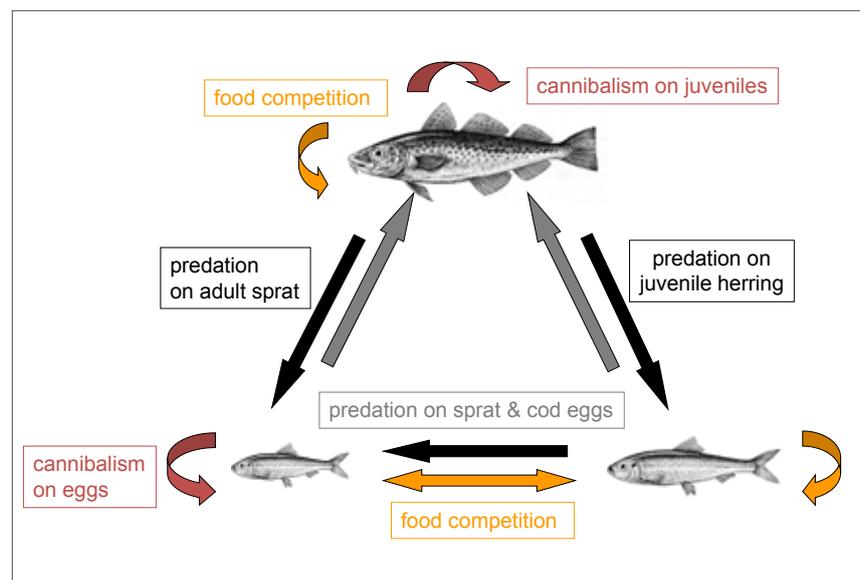


Figure 2

Schematic diagram showing major ecological interactions of the three dominant fish species in the open Baltic Sea ecosystem.

systems, for example, the Baltic fisheries, but are general enough to enable insights of broad relevance. We continuously discuss research questions and results with fishermen (e.g., Deutscher Fischereiverband), politicians and representatives from non-governmental organizations. This transdisciplinary dialogue with stakeholders is crucial in order to develop management strategies suitable for practical implementation.

Multi-Species Management of Baltic Sea Fisheries

In the Baltic Sea, the three dominant fish species cod, herring and sprat are strongly interlinked by predation and competition (Fig. 2). We developed an age-structured ecological-economic model that includes the effects of cod predation on herring and sprat and computed the multi-species management strategy that optimizes the net present value of resource rents. Results show that the stocks of cod and herring should be rebuilt to levels far higher than currently exist, while sprat remains currently above the long-run optimal level (Fig. 3). Future work will take into account uncertain recruitment, competition and feedbacks of herring and sprat on cod.

Conceptualizing Sustainability

Sustainability aims at justice in the domain of human-nature relationships, taking into account the long-term and inherently uncertain future. Modern economics has developed a focus on efficiency, i.e. non-wastefulness, in the use of scarce resources to achieve the normative goal of an ever better satisfaction of human needs and wants. Against this background, we have clarified the economic contribution to questions of sustainability and formulated general research questions on the sustainable use of ecosystem services to be addressed in the interdisciplinary collaboration between economists, ecologists and philosophers (Baumgärtner and Quaas 2010a,b).

2011 and Beyond

In 2011 we will further develop the approach of interdisciplinary collaboration between ecologists and economists to develop sensible management strategies for sustainable fisheries. We will model multi-species interactions in marine ecosystems more properly and take environmental uncertainties into account. We will moreover intensify the collaboration with philosophers to address questions of distributional justice arising in fisheries management, in particular when distributing fishing rights.

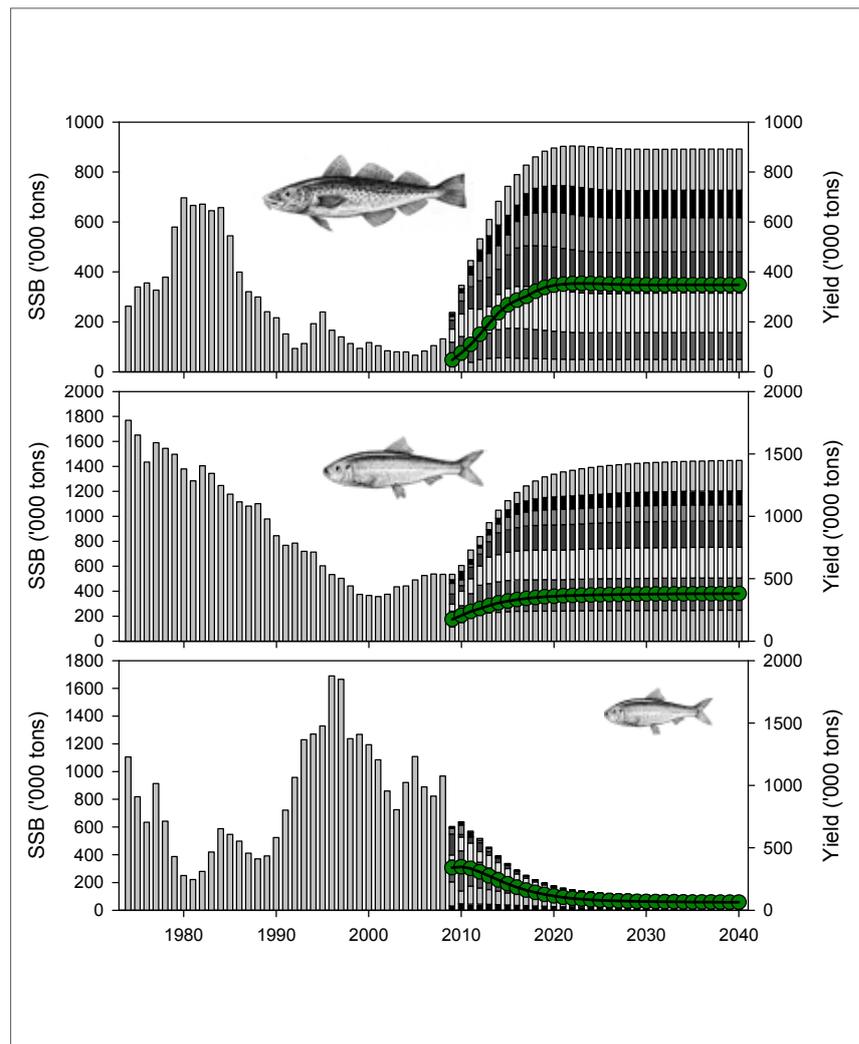


Figure 3

Optimal multi-species management in the Baltic Sea: Historic spawning stock sizes [SSB, 1974-2008, grey bars], future stock sizes, including age-structure [2009-2040, stacked bars] as well as future yield [green dots] for cod, herring and sprat, when optimizing net present value of resource rents for combined fishery, taking species interactions into account.

Working Group



Katrin Walther, [Martin Quaas](#), Frederick Noack, Christian Wendt, Rüdiger Voss, Jörn Schmidt, Max Thilo Stöven, Ute Kapaun, Anita Hartz.
Missing: Sandra Derissen, Lorena Gola, Lewe Bahnsen, Sabrina Leinert.

Selected Publications

- 1 | Baumgärtner, S. and Quaas, MF. Sustainability economics-general versus specific, and conceptual versus practical, *Ecological Economics*, 69: 2056-2059.
- 2 | Baumgärtner, S. and Quaas, M.F. What is sustainability economics? *Ecological Economics* 69: 445-450.
- 3 | Hinrichsen H-H, Peck MA, Schmidt JO, Huwer B, Voss, R., 2010. Survival probability of larval sprat in response to decadal changes in diel vertical migration behavior and prey abundance in the Baltic Sea. *Limnology and Oceanography* 55(4): 1485-1498.



Marine Medicine

Epithelial linings and the underlying immune system form biological barriers, which are of pivotal importance for the defence of the organism against facultative pathogens of an hostile environment, but also form the ecological niche for a complex resident microflora, that participates in essential physiological functions of the host. Under normal conditions, such barriers are maintained without any development of inflammatory damages. However, in humans these barrier organs can be affected by chronic inflammatory disorders (e.g. asthma, inflammatory bowel disease or psoriasis). A genetic risk map of chronic inflammatory diseases has recently been deciphered mainly by genome-wide association studies (GWAS) that pinpoints the involvement of genes in basic cellular processes that evolved either at the unicellular or early multicellular level, e.g. mucus, secretion, cytoskeletal dynamics, autophagy, regenerative capacity of epithelial cells and primordial (innate) immune responses. Interestingly it seems that many of these physiological properties including the stability of the individual microbial communities are altered with increasing age (e.g. the phenomenon of “immunosenescence”). The main objective of the group is to describe the role of these genetic elements for the maintenance of the integrity of the metaorganism, i.e. the animal with all its associated microorganisms. Investigating the contribution of stable host-microbiota interaction and epithelial homeostasis as life span regulatory principles has been developed as a novel focus of the group. Several model organisms from the ocean are used in a translational approach in order to understand general principles of human health, i.e. epithelial homeostasis, immunological integrity and maintenance of the resident microbial diversity.

Background

Evolution is a major unifying principle in biology and its understanding may serve as a fundamental basis for understanding health and the etiology of diseases. In recent years it has become increasingly clear that most of the genes constituting the molecular risk maps of human diseases are of phylogenetically ancient origin. The fields of inflammatory disorders and cancer represent attractive precedents as many of the identified genes are involved in basic biological processes that evolved either at the unicellular or early multicellular level, e.g. cytoskeletal dynamics, autophagy, altered structural integrity of epithelial cells, the related secretion and composition of extracellular matrix components and primordial (innate) immune responses. Many of the cellular programs govern the interaction between the host and the environment and are pivotal for survival. The host is in continuous contact with a microbiota-laden environment and clear evidence for a host-genetic control of the resident microflora has been presented already in basal metazoans. Conversely, the physiological co-evolved microbial communities on epithelial interfaces are important for cellular fate decisions and, ultimately, for the fitness of the host. Over the past year the group has added mechanisms of ageing and senescence as an additional focus.

The group investigates the following major biological questions:

- ▶ What are the genetic and molecular kernels of human chronic inflammatory diseases and inflammation-associated cancer ?
- ▶ How can we use knowledge on phylogeny, diversification and function of immune genes during animal evolution to understand human inflammatory diseases ?
- ▶ Are different principles of life span determination and/or longevity assurance realized in invertebrates and higher vertebrates ?
- ▶ What is the molecular language of host-microbe interkingdom signaling networks at host/environment interfaces. A special focus is the investigation of invertebrate marine organisms to understand basic principles of innate immune responses and inflammation.
- ▶ What do we learn from full genomic sequences and transcriptomal response profiles in different organisms and cellular systems using ultra-fast sequencing (gs-flx massively parallel pyrosequencing and Solid sequencing by ligation)

Genetic and Functional Risk Maps of Human Chronic Inflammatory Barrier Disorders

The group has made progress in the understanding of human chronic inflammatory barrier diseases in humans with a special focus on genome-wide understanding of genomic

variation and disease-associated landscapes of transcription. We have contributed to the international 1000 Genomes consortium that aims at the population-based delineation of genetic variation in the human genome (*Nature*, 2010; *Science*, 2010; *Nature*, 2011). We have described novel functional concepts of microbiota recognition via NOD-like receptors (Billmann *et al.*, *J Immunol* 2010) and have demonstrated the importance of the crosstalk between NLRs and mitochondrial signals in the defense against intracellular infections and have identified CARD8 as a novel modulator of NOD2 signaling (Abdul-Sater *et al.*, *JBC* 2010; Kampen *et al.*, *JBC* 2010). We have concluded the first study on NOD2 as a master switch of the temporal

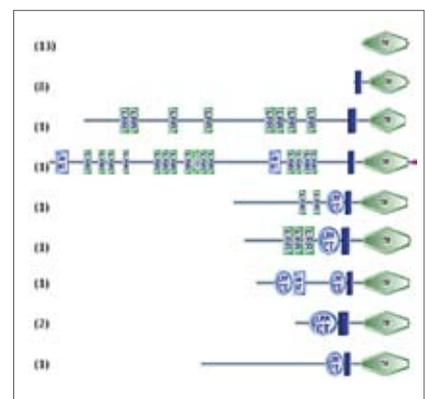


Figure 1

Protein domain structures of toll-like receptors identified in the *Mytilus edulis* transcriptome. Number in brackets represents the quantity of different contigs showing the respective structure.

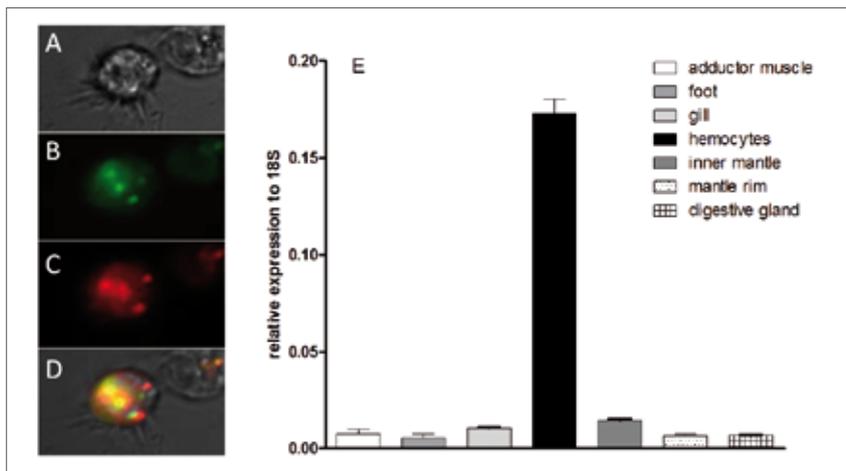


Figure 2

Analysis of the mechanisms of reactive oxygen species (ROS) generation in *M. edulis* hemocytes during bacterial challenge. A) *M. edulis* hemocytes phase contrast, B) ROS fluorescence (DCFH-DA), C) red fluorescent *Vibrio anguillarum*, D) merge, E) tissue specific mRNA expression of a *M. edulis* dual-oxidase transcript.

development of the stable gut flora in mice and humans. We could show that an altered gut flora is present in NOD2-deficient individuals and may affect the immunological life history. We have replicated the shifts in intestinal microbiota communities in human individuals by barcoded 454 sequencing; thus, the deficiency of a single innate immune receptor already (Rehmann *et al.*, Gut in press). A major focus has been the investigation of sense-antisense transcription as a regulatory mechanism in tissue identity and disease (Klostermeier *et al.*, BMC Genomics in revision).

Understanding Immune Responses in Marine Invertebrates

A focus of the past year has been the identification and functional analysis of immune system parameters in the blue mussel (*Mytilus edulis*). We have generated and analyzed 2,400,000 EST sequences with an average length of 280bp from 4.5 454 runs representing different stress and inflammatory conditions and including different tissues. The sequences were assembled into 74,622 transcript contigs (average length 645bp). We have developed a data mining tool and were able to systematically describe the network of innate immune genes in this species. Currently, we are using these data sets to understand gene regulatory networks in *Mytilus hemocytes* upon stimulation with different bacterial molecular structures in vitro and in animals under inflammatory stress conditions (infection and DSS colitis) in vivo. In more detail we investigated the composition and function of the toll-like receptor (TLR) pathway in *Mytilus edulis*. A high number of TLRs could be identified (Fig 1). Currently the regulation of selected TLRs

and pathway members is investigated in in-vivo whole animal and in-vitro hemocytes experiments using quantitative real-time PCR. Further the role of NADPH-oxidases for the free radical (ROS) generation of the bivalves' immunocytes during bacterial challenge was analyzed in more detail. ROS generation was investigated using different fluorescent dyes (Fig 2) and 2 NADPH-oxidases (NOX) and 2 dual oxidases (DUOX) were identified in the *M. edulis* transcriptome. One DUOX member was highly expressed in hemocytes (Fig 2) and therefore represents a promising candidate for the immune related ROS generation in this cell type. In-vitro hemocytes experiments using siRNA are currently being undertaken to prove this hypothesis deduced from the expression analysis.

A second focus has been on the start towards the investigation of the molecular ageing process in the long lived bivalve *Arctica islandica* (life span >400years). Being the longest lived non-colonial species of earth, this species is a currently emerging model organism

for aging research. *A. islandica* individuals were sampled from the Baltic Sea population and around Iceland and the individual ages determined by year-ring counts in the shell. From the long-lived population around Iceland (life span >400 years) animals up to 224 years of age and from the shorter lived Baltic Sea (life span ~40 years) individuals up to 38 years of age were identified. Transcriptomes of gill tissue of young and old individuals from both stations were generated and are currently analyzed for age-related expression changes and the identification of genes involved in the ageing process, including immune system related genes, for further detailed functional analysis.

2011 and Beyond

With current advances in genomic technologies it becomes feasible to expand the investigations on two levels: (i) Although several hurdles of de novo genome assembly and annotation exist, it will become possible to sequence complete individual genomes and to use this information for a deeper understanding of the molecular basis of genome dynamics in response to selective pressures. This is being investigated in cosmopolitan marine species (e.g. *Aurelia aurita*, *Mytilus spp.*, *Mnemiopsis*, *Thalassiosira*). The projects are carried out in close cooperation with partners from the cluster network (Bosch, LaRoche, Reusch, Schmitz-Streit and Melzner). (ii) A second focus will be on the elucidation of mechanisms that are involved in life span regulation in different marine animals. We will try to identify shared and unique principles of life span determination and/or longevity assurance, delineate regulatory principles of senescence in the long-lived mud clam *Arctica islandica* from different habitats and will decipher transcriptomal signatures associated with extreme age.

Working Group

Philip Rosenstiel, Gunnar Jacobs, Eva Philipp, Simone Lipinski, Susanne Billmann, Ulrich Klostermeier, Christina Lange, Julia Saphörster, Niels Grabe, Gunnar Husmann, Matthias Barann, Lars Krämer, Tanja Kaacksteen, Melanie Schlapkohl.

Selected Publications

1 | Cao, A., Mercado, L., Ramos-Martinez, J. I. and Barcia, R. (2003). Primary cultures of hemocytes from *Mytilus galloprovincialis* Lmk.: expression of IL-2R[alpha] subunit. *Aquaculture*, 216(1), 1-8.

2 | Quinn, B., Costello, M., Dorange, G., Wilson, J., & Mothersill, C. (2009). Development of an in vitro culture method for cells and tissues from the zebra mussel [*Dreissena polymorpha*]. *Cytotechnology*, 59(2), 121-134.

3 | Rinkevich, B. (1999). Cell cultures from marine invertebrates: obstacles, new approaches and recent improvements. *Journal of Biotechnology*, 70(1-3), 133-153.



Seafloor Resources

The Research Group Seafloor Resources continued in 2010 to study the physics of the geological processes controlling the formation of natural resources at the ocean floor. These resources include massive sulphide deposits surrounding submarine hydrothermal vent sites and methane hydrates found in the thick sedimentary covers of continental margins. Research on massive sulphide deposits has focused on the likely sub-surface flow pattern at mid-ocean ridges, while gas hydrate studies explored the global distribution of methane hydrates and the possible dissociation of Arctic gas hydrates in response to warming bottom waters.

Deep Sea Hydrothermal Systems

Economically interesting minerals and metals are situated at the seafloor of active plate margins around the globe. Submarine hydrothermal activity is intimately related to the formation of such Submarine Massive Sulphide deposits. Exceptional high ore grades of up to 6.7 ppm Au and 1000 ppm Ag for precious metals have been reported locally. Active, so called black and white smokers are primarily studied at mid-ocean ridges, where hot hydrothermal fluids, enriched with dissolved minerals and metals, are expelled. The contact of hot hydrothermal fluids with cold seawater causes the dissolved metals to precipitate sulfide minerals around the vent chimneys as well as to deposit metalliferous sediments on the seafloor around the vent sites. The Seafloor Resources research group studies hydrothermal systems on different scales, from the global over-ridge scale to individual vent systems using tailored numerical models of various complexities.

Global Heat And Hydrothermal Cooling at Mid-Ocean Ridges

On a global scale, the Seafloor Resources research group uses worldwide data sets to learn more about the global distribution of vent sites, their geodynamic relevance, and the volumes of seawater passing each year through the hydrothermal systems of the mid-ocean ridge systems. Submarine hydrothermal systems cluster at plate-boundaries (Fig. 1) and their black smoker systems are the spectacular manifestations of seawater circulation through the newly created young seafloor. In fact, the first sighting of submarine hydrothermal vent sites in the late 1970's at the Galapagos Rift and the East Pacific Rise was preceded by a decade of theoretical speculations that hydrothermal circulation is responsible for a discrepancy between measured and predicted heat loss from the near-ridge young ocean floor. Today, the Seafloor Resources research group has returned to these early studies and compiled global datasets on the estimated hydrothermal oceanic heat loss and the distribution of known

vent sites (Fig. 1). In many areas a good correlation of discovered vent sites and areas of high convective heat flow, where hydrothermal activity is theoretically expected, can be seen. Other areas, e.g. the southern Mid Atlantic Ridge and the South East Indian Ridge, show marked heat flow anomalies but no active hydrothermal systems have yet been discovered. These are areas where hydrothermal vent systems are very likely to exist but their discovery has been hindered, not least, by regional weather conditions, which makes these areas unfavorable for research cruises. The Seafloor Resources research group will continue to use global datasets to explore and quantify the likely fluxes of fluids and dissolved metals between the Solid Earth and the Global Ocean.

Coupled Simulations of Crustal Accretion and Hydrothermal Cooling

Aside from the global perspective, the Seafloor Resources research group studies the interrelations between the accretion of oceanic crust at mid-ocean spreading centers and hydrothermal cooling. The genesis of oceanic crust at intermediate to fast spreading ridges results from the crystallization of mantle melts accumulated in at least one shallow melt lens situated below the ridge axis. Seismic reflection data suggest that the depth of this melt lens is inversely correlated with spreading rate and thereby magma supply. The heat released in it by crystallization and melt injection is removed by a combination of hydrothermal cooling and diffusion. Due to the different time scales of hydrothermal cooling and crustal accretion, numerical models have so far focused on only one of the two processes. In 2010 we finalized our development of a coupled mechanical and hydrothermal model that solves simultaneously for the processes of crustal accretion and hydrothermal cooling at fast to intermediate spreading ridges (Fig. 2). We have found

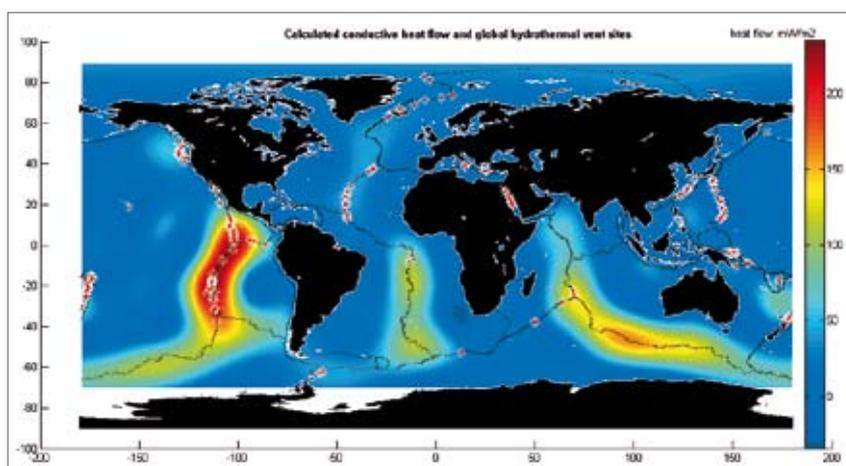


Figure 1

Estimated oceanic heat loss due to hydrothermal cooling and known hydrothermal vent sites on the seafloor.

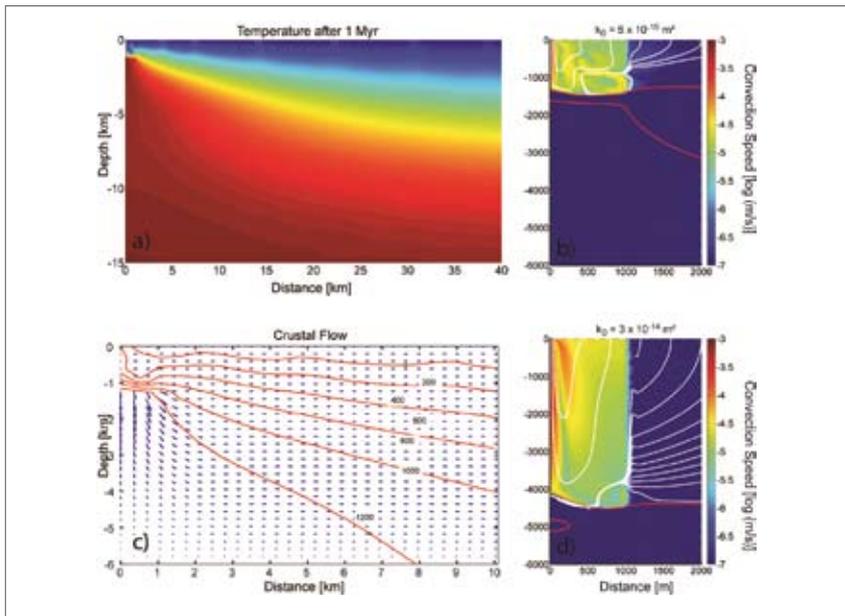


Figure 2
Feedbacks between hydrothermal convection and crustal accretion. In a) the predicted temperature field is plotted; c) shows the solid flow field along with isotherms; b) & d) shows two different predicted permeability structures along with porous convection flowlines.

that the depth of the melt lens and the shape of hot (potentially molten) lower crust are highly dependent on the ridge permeability structure. The predicted depth of the melt lens is primarily controlled by the permeability at the ridge axis, whereas the off-axis permeability determines the width of hot lower crust. A detailed comparison of the modeling results with observed locations of the melt lens shows that only a relatively narrow range of crustal permeability is consistent with observations. In addition, we find significant deviations between models that resolve or parameterize hydrothermal cooling: the predicted crustal thermal structures show major differences for models that predict the same melt lens location. This illust-

rates the importance of resolving hydrothermal flow in simulations of crustal accretion. Our improved model, though, will allow us to make better predictions on the likely flow pattern at mid-ocean ridges and thereby on the key hydrological parameters relevant for metal resources estimates: flow rates, flow pattern, fluid residence times, and fluid-rock ratios.

New Global Gas Hydrate Inventory

In order to improve our global estimates on marine gas hydrates, we have continued to develop reaction-transport models and formulated a new parameterization for Holocene and Quaternary sedimentation. These mass balanced sedimentation models provide global

estimates at interglacial times (Holocene) and glacial times (Quaternary), when sedimentation was likely shifted to deeper water settings down the continental slope. We have explored these two sedimentation scenarios using our multi 1-D approach, which resolves hydrate formation due to in-situ organic matter (POC) degradation. Our new estimates confirm our earlier statements that POC-degradation is at present not an efficient hydrate forming process. Presently observed hydrates are likely to have formed at times of higher sedimentation (Quaternary) or in response to active upward fluid flow.

Response of Arctic Gas Hydrates to Warming Bottom Waters

The question of whether the warming climate we are currently experiencing can cause Arctic hydrates to dissociate has been one major focus of integrative research in 2010. By a joint modelling effort involving high resolution ocean circulation models, the Kiel Climate Model, and newly developed tools for estimating how the hydrate stability zone in the Arctic will evolve over the next 100 years, we have been able to show that a warming climate will result in Arctic hydrate dissociation. However, due to sluggish thermal diffusion rates, the amount of methane release from melting hydrates will be limited over the next 100 years not having a positive feedback on global warming. Nevertheless, enhanced ocean acidification around methane vent sites appears to pose a real threat of bottom water warming induced hydrate dissociation. This case study on the interface between the Arctic Ocean and the seafloor illustrates the potential and importance of performing interdisciplinary research on this key ocean interface.

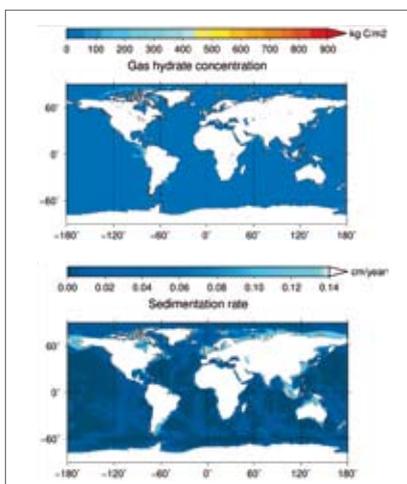


Figure 3
Predicted present day gas hydrate inventory (left panel plots) and new parameterization of Holocene sedimentation (right panel plot).

Working Group



Sonja Theißen, Karthik Iyer, Volker Schenck, Dominique Lattard, Kaj Hoernle, Françoise Boudier, [Lars Rüpke](#), Larry Cathles, Adolphe Nicolas (photographer).
Missing: Ewa Burwicz, Nasser Bani Hassan, Christine Andersen and Jörg Hasenclever.

Selected Publications

- 1 | Biastoch A., Treude T., Rüpke L.H., Riebesell U., Roth C., Burwicz E.B., Park W., Latif M., Böning C.W., Madec G. and Wallmann K. (2011): Rising Arctic Ocean temperatures cause gas hydrate destabilization and ocean acidification. *Geophysical Research Letters* (accepted)
- 2 | Iyer, K., Rüpke, L. H. and Phipps Morgan, J. (2010): Feedbacks of mantle hydration on hydrothermal convection at ocean spreading centers. *Earth and Planetary Science Letters*, 296, 34-44, doi:10.1016/j.epsl.2010.04.037.
- 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*, doi:10.1111/j.1365-2117.2009.00437.x.



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 the location for a large proportion of major industrial installations, including increasingly offshore installations. Scientists involved in this project have focused their activities on the following two themes:

(1) Assessment of the link between the structure and dynamics of subduction zones and the megaequake cycle, and (2) Slope stability issues at continental margins. The main emphasis of the Research group on submarine hazards at continental margins is the analysis of submarine slope failures and associated hazards. The global distribution of major slides and the main working areas of the research group are shown in Fig. 1. We have investigated numerous slides in different tectonic settings including active and passive margins, as well as lakes by means of hydroacoustic, seismic, sedimentological and geotechnical methods. This report will focus on first results of a RV Poseidon cruise to the headwall area of the Sahara Slide (Northwest Africa) and a drilling campaign in Lake Van realized within the framework of the International Continental Scientific Drilling Program (ICDP).

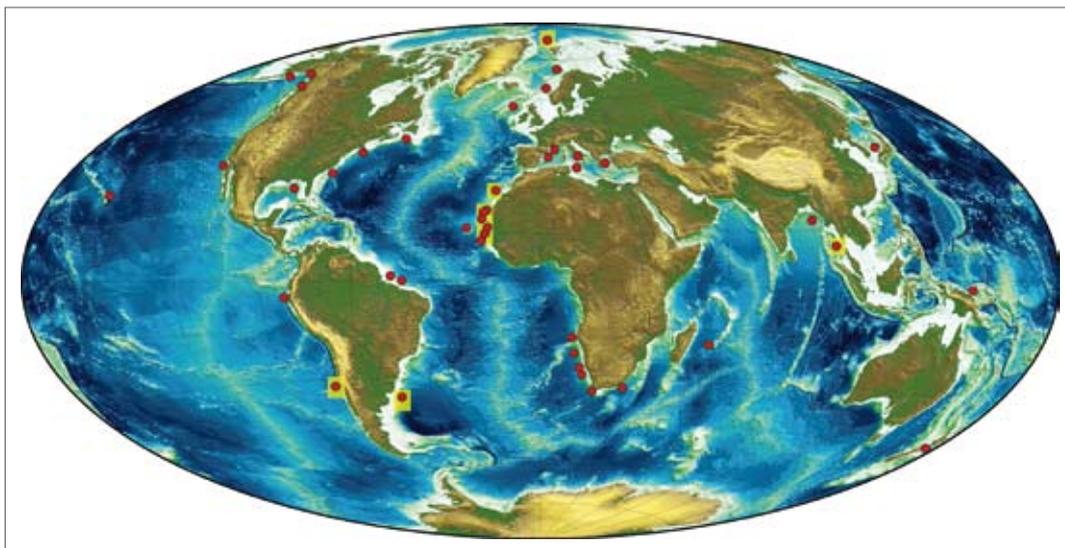


Figure 1

Map showing the distribution of major slides along continental margins. Note that the distribution of slides is biased by the availability of data. The yellow boxes show the main working areas of the research group.

The Sahara Slide, NW-African Continental Margin – New Geophysical and Sedimentological Data From the Headwall Area

The passive continental margin off Northwest Africa is dominated by low terrigenous sediment input and high primary production in upwelling areas. It is characterized by very large but infrequent slope failures. Some sections of the margin show repeated instabilities, while other regions are stable for long time periods. The Sahara Slide is a mega slide with a length of ~900 km and an estimated volume of ~600 km³ off the coast of the Western Sahara. Poseidon cruise P395 in early 2010 aimed in investigating the morphology and evolution of the Sahara Slide headwall area. Detailed images of the headwall (Fig. 2) reveal a complex morphology

typical of a retrogressive slab-type failure, with multiple headwall incisions and at least three glide planes. Some areas are characterized by elongated blocks, which have not moved far, while other areas are characterized by quickly disintegrating sediment masses. Seismic data show older mass transport deposits and giant downslope striking mound-like features, which are aligned with the sidewalls. We speculate that migrating fluids along and on top of the mound-like features control the location of the failure. The well-studied distal deposits of the Sahara Slide yield an age of 60 ka for the main slide event, which is a period of global sea level rise. Major slides off NW-Africa are all dated at periods of global sea level rise. Direct linkage between sea level and slide occurrence is not well understood, but indirect effects include

spatial variations in primary productivity and hence the maximum sedimentation rate. The risk for future large-scale slope failures during the current high stand is generally considered to be low. This observation is challenged by new findings made during Poseidon cruise P395. Gravity cores taken beneath the upper headwall complex suggest an age of only 1 – 2 ka for the reactivation or formation of the upper headwall (Fig. 2). This event is most likely the largest submarine failure in historic times. We are currently investigating whether this age represents a major re-activation of an existing headwall or a major failure of undisturbed slope sediments. The young age of this slide calls for a re-assessment of the risk potential of this and other passive margins.

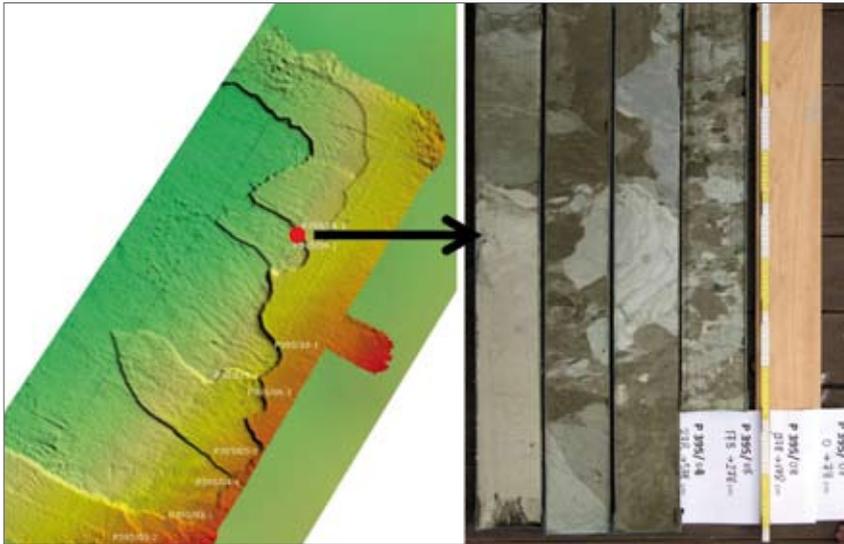


Figure 2

Left: Bathymetric map of the Sahara Slide headwall showing a complex morphology typical for a retrogressive slab-type failure. Right: Core taken immediately beneath the headwall showing a typical debrisite. A hemipelagic drape of less than 5 cm indicates a late Holocene age of the debrisite.

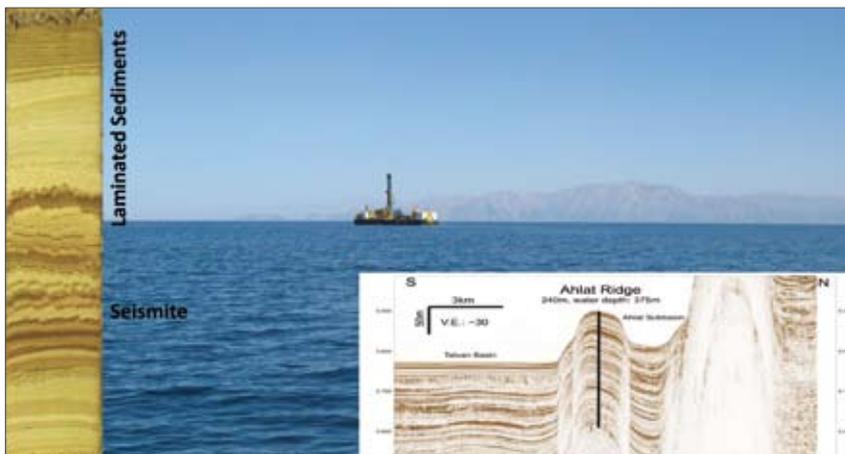


Figure 3

Drilling platform used during the 'PaleoVan' drilling project. Left: Core showing a seismite embedded in laminated sediments. Lower right: Seismic section crossing Ahlat ridge and Tatvan Basin. The elevated location of Ahlat Ridge allowed recovering a high-resolution continuous archive for the past 500 ka.

evolution of the Near East, an ICDP drilling campaign was carried out in summer 2010. In addition, Lake Van shows numerous subaquatic landslides, which occur at specific stratigraphic levels. The occurrence of slides at the same stratigraphic horizons suggests a joint trigger, most likely an earthquake. Hence, the ages of the slides can be used as proxy for paleoseismicity around the lake. Seismites identified in the cores (Fig. 3) further support the reconstruction of paleo-seismic and earthquake activities.

Two sites were drilled in summer 2010. The most important site was the Ahlat Ridge site (Fig. 3), which was drilled in order to recover a high-resolution continuous archive for the past 500 ka. Ahlat Ridge is almost free of any slide deposits due to its elevated location but the reflectors embedding landslides in the Tatvan Basin can easily be traced to this location. Hence a dated landslide history will be available soon. The 'Northern Basin' Site is located in a small basin close to the northern shore of Lake Van. The proximity to the Quaternary volcanoes resulted in abundant tephra deposits at this site. Synthetic seismograms calculated based on core logging, wire-line logging, and check shot data will allow accurate correlation between seismic and drill data. This approach aims at extrapolating the stratigraphy from the wells to 3D-space by using the seismic data. Additional features identified on seismic data all over the lake include prograding deltaic sequences, numerous unconformities, submerged channels, as well as closely spaced U and/or V shaped depressions, reflecting the variable lake level history of Lake Van.

Lakes as Models for Oceans: First Results from a Joint Interpretation of Seismic and Drilling Data of the 'Paleovan' Drilling Project, Lake Van, Turkey.

Lakes can be used to study mass wasting events on a small scale. 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 basin-wide quantifications.

Lake Van in Eastern Anatolia (Turkey) is the fourth largest of all terminal lakes in the world. Lake Van has an excellent potential as a high resolution paleo-climate archive due to the presence of annually laminated lacustrine sediments. As Lake Van can act as a key site for the investigation of the Quaternary climatic

Working Group



Andrea Anasetti, Maxlimer Vallee, Mathias Meyer, Stephanie Koch, [Sebastian Krastel](#), Katja Lindhorst, Daniel Winkelmann, Julia Schwab, Mathias Grün. Missing: Deniz Çukur.

Selected Publications

- 1 | Lindhorst, K., Vogel, H., Krastel, S., Wagner, B., Hilgers, A., Zander, A., Schwenk, T., Wessels, M., Daut, G. (2010) Stratigraphic analysis of Lake Level Fluctuations in Lake Ohrid: An integration of high resolution hydro-acoustic data and sediment cores. *Biogeosciences*, 7, 3531–3548.
- 2 | Georgiopoulou, A., Masson, D., Wynn, R.B., Krastel, S. (2010) The Sahara Slide: Initiation and processes from headwall to deposit of a giant submarine slide. *G-cubed*, 11-7. doi:10.1029/2010GC003066.
- 3 | Pierau, R., Hanebuth, T.J.J., Krastel, S., Henrich, R. (2010) Late Quaternary climatic events and sea level changes recorded by turbidite activity, Dakar Canyon, NW-Africa. *Quaternary Research*, 73, 385-392.



Water-Sediment Interactions in River Mouth Systems and Other Coastal Hotspots

The Research Group on 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 complex interrelated and interacting coastal processes. Understanding of these processes is still lacking for many coastal hotspots nearby and abroad. Modern measuring techniques with high temporal and spatial resolution are used to fill the gaps in current data sets and to improve our understanding of coastal processes.

Background Information

Coasts are not only highly diverse and dynamic geological elements on Earth, most of them are densely populated, especially river mouth systems. Sea level variations, changes in storm intensity and duration and above all, manmade interferences force many coasts to adapt in an unintentional way. Consequences such as flooding, erosion, decrease in water quality, or habitat change often arise. Thus, comprehensive knowledge on coastal development and dynamics is needed to react to coastal changes and to provide reliable prognoses to enable high-quality coastal zone protection and management. Prerequisite is a detailed understanding of natural and anthropogenic influenced coastal processes, which act on various time scales, spanning seconds to thousands of years, and spatial scales ranging from centimeters to hundreds of kilometers. It is most challenging to resolve these processes, especially the highly diverse, physical and sediment-related interactions at the interfaces of land and sea, water column and seafloor, freshwater and seawater. A multi-methodical approach with modern, highly sophisticated measuring techniques is used in this group to specify these interactions in a qualitative and quantitative way.

Reduced Dune Migration Due to Water Damming

Many rivers are dammed to serve the growing demand for freshwater for domestic and industrial use. This reduces discharge and related sediment transport to adjacent coastal regions. Severe coastal retreat and a system adaptation from deltaic to estuarine conditions often occur. These effects are prominent at the North Brazilian São Francisco River (Fig. 1), facing annual retreat rates of ~ 25 m over the last 10 years. It is known, that the morphology

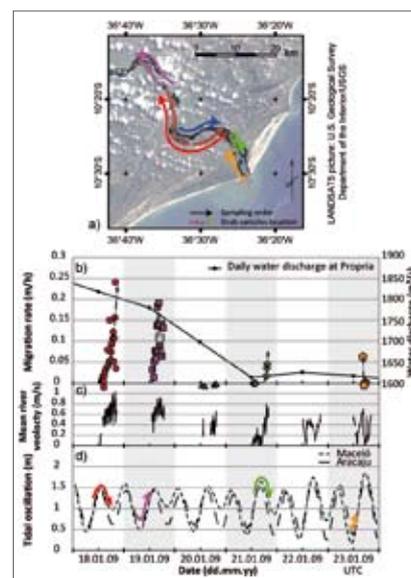


Figure 1

a) Aerial picture of the North Brazilian São Francisco River mouth with grab sample locations b) migration rates of subaqueous dunes related to water discharge c) mean river flow velocity and d) tidal oscillation.

of subaqueous dunes mirrors the equilibrium of flow characteristics and intensity, water depth, grain-size and sediment availability. Field data, which were collected in the frame of an international research program, strongly support the hypothesis of reduced and delayed seaward sediment transport, respectively (Fig. 1b). Bedform morphology seems to be unaffected by reduced river-discharge and sediment supply, as derived by new analyses of bedform geometry, but rates of dune migration, as calculated, are lower due to decreased discharge. Figure 1b-d highlights the close relationship between river discharge, flow velocity and rates of dune migration. At the same time, tidal impact is strengthened at the lowermost part of the river. These new findings put further emphasis on the consequences of river damming.

Anthropogenic Impact in Tidal Estuaries

Ship-based cargo transport is increasing worldwide, harbor sites, in particular at river mouth systems, are expanding. Thus, most navigation channels need further deepening and intensive maintenance, e.g. by dredging, to guarantee vessel access. This has economical and ecological side-effects due to the disturbance of natural sediment dynamics. The German estuary Ems is a perfect example for a tremendous increase of fine-grained deposits due to channel adaptation for shipping purposes, studied in a current project. There is still strong demand for answering questions related to sediment mixing processes and thus on the role of interfaces between water masses with different characteristics, such as suspended sediment concentrations. The dynamics of internal waves, appearing on these interfaces, is known to be highly important for vertical sediment mixing, but these processes are still not fully understood. New analyses of data sets from the Ems estuary highlight clear differences in the tidal-dependant evolution of internal waves, as shown in figure 2a-b by corresponding frequency spectra during low and high tide, for instance. Internal wave formation and characteristics can now be further linked to tidal dependant mixing processes. Detailed information on size, composition and distribution of suspended sediment over time and space is also greatly needed to verify estuarine particle flux. For this, a new comparison is made between in-situ particle sizes, including large particle aggregates, and primary, clastic particles, after sample treatment, to further resolve the evolution of particle flocculation as well as sediment transport and settling. The analyses of primary clastic particles are conducted by using a high-resolution laser-based particle-sizer. Based on this, new data

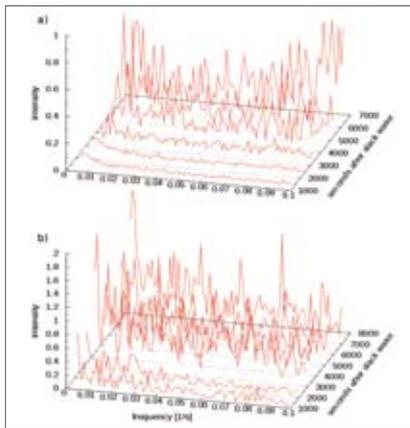


Figure 2

Development and growth of internal waves in the frequency domain after a) high water and b) low water; example of the German Ems estuary.

from the German Elbe estuary clearly reflect spatial, upstream directed differences in the size of primary particles (Fig.3a), whereas spatial changes in the size-distribution of *in-situ* particles do not occur (Fig.3b). It follows, that flocculation processes are ongoing within the entire river section shown, but particle aggregates seem to be composed of different primary clastic components. This new information is important to verify particle origin, settling behavior and the appearance of fine cohesive sediment accumulations. At times and places, where these deposits do not come and go with the tides, they can cause risks by reducing navigable water depths, which often results in cost-intensive dredging activities.

Dredging impact is another research focus of this group, especially of techniques, which seem to have fewer economical and ecological side effects. Studies are based on a joint measuring program with the participation of seven partner institutions. Different hydro-acoustic and laser-optics instruments have been deployed to detect dredging-induced sediment movement. Estuarine research is also complemented by the large joint-research program 'AUFMOD' with funding from the Federal Ministry of

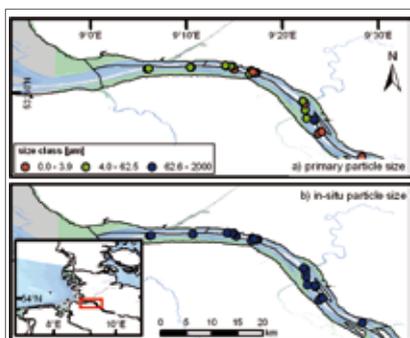


Figure 3

Spatial distribution of a) primary suspended particles and b) suspended particle aggregates in the lower part in the German Elbe estuary.

Education and Research for eight partner institutions with co-ordination of the program in Kiel. The aim is to set-up integrated model systems for the analysis of long-term morphodynamics in the German Bight (Germany) in order to deliver a reliable prognosis for future coastal development. The focus of this group is on morpho- and sediment dynamics of the estuaries Weser, Elbe and Ems, whereas one aim is to build-up a conceptual bed model, at the same time providing data for other model systems. Data on sedimentological and rheological bed behavior with high spatial coverage is being collected, based on hydro-acoustics and samplings to compile a sediment-classification tool. This task is complex, considering the large variability of bed constitution, as seen in side-scan sonar images of a channel cross section in the Elbe estuary (Fig. 4). Outcropping mud layers at the embankments are replaced by a sandy river bed with large subaqueous dunes in the centre of the main channel. Further, these facies are not only found side by side, but also get intermixed as shown in the picture of a sand bed surface with embedded mud pebbles (Fig. 4). Having found out that their occurrence is widespread in these environments, questions arise on their impact e.g. to bed roughness, which is one of the important parameters for numerical models.

Forcing Factors for the Wadden Sea

Another project focuses on changes in the largest tidal basin within the North Frisian Wadden Sea to study the impact of sea level rise and anthropogenic interferences, such as diking. Knowing that the Wadden Sea appears to be diminishing at sites by 'Coastal Squeeze', new results show that this development might be overprinted in the study area of the

Working Group



Rik Tjallingii, Andreas Jacobsen, Henning May, Kerstin Schrottke, Svenja Papenmeier, Christian Schiffer, Sarah Ohlemacher Missing: Roland Friedrich, Florian Huber, Michael Teucher, Jens Boczek, Camille Traini, Philipp Held, Nicole Kegler-Graiewski, Peter Richter, Angela Trumpf, student assistant are not listed here.

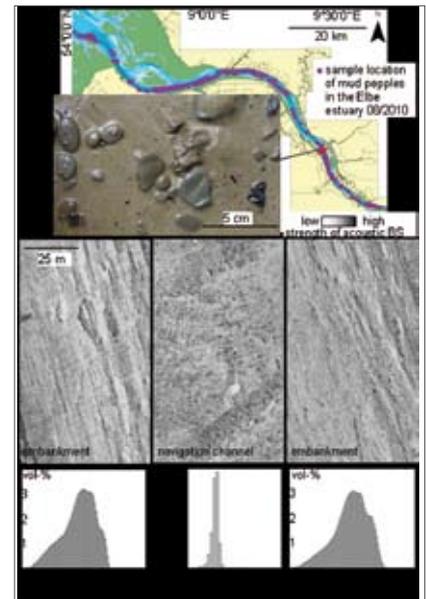


Figure 4

Sample locations and picture of mud pebbles in the German Elbe estuary as well as side-scan sonar images of a cross section, displaying the complex bed constitution at the embankments and at the channel centre with representative grain-size curves.

Norderhever-Heverstrom. Details on pages 50-51.

Coarse-Grained Sediment Transport

New results have been achieved in a project studying coarse-grained sediment transport. It is known that severe coastal retreat of many soft rock cliff coasts along the Southwestern Baltic Sea is ongoing with large sediment displacement. More information is needed on transport rates and patterns of pebbles, cobbles and boulders. New data show, that transport capacities are closely linked to the storm-related location of the main energy dissipation zone. This program is supported by the Scientific Diving Centre (SDC) of Kiel University, managed by the head of this group.

Selected Publications

- 1 | Traini, C., Schrottke, K., Statteger, K., Dominguez, J. M. L., Guimarai, J. K. Vital, H., Silva, A. G. A.: Morphology of subaqueous dunes at the mouth of the dammed river São Francisco (Brazil). – *J. of Coastal Res.* (accepted).
- 2 | Bartholomä, A., Holler, P., Schrottke, K., Kubicki, A.: Acoustic habitat mapping in the German Wadden Sea – Comparison of hydro-acoustic devices. – *J. of Coastal Res.* (accepted).
- 3 | Papenmeier, S., Schrottke, K., Bartholomä, A., Flemming, B. W.: Rheological and sedimentological properties of near-bed cohesive sediments in the Weser and Ems estuaries: Implications for fluid mud classification. – *Estuarine, Coastal & Shelf Science* (under review).



Risk Assessment in the Coastal Zone

Climate change is expected to significantly affect the world's coastal regions through increases in the magnitude and frequency of hazards. These increases will in turn lead to higher risks for people and the economy and to impacts which are expected to be overwhelmingly negative. At the same time, rapid socio-economic development in coastal areas results in higher exposure of population and assets, thus making the need for efficient management of those pressures imperative. Our work focuses on the assessment of potential impacts resulting from a combination of the above factors and on investigating the effectiveness of different types of adaptation responses. We examine different types of pressures and responses, at a range of scales, aiming to provide input for supporting long-term policy and management decisions. In the next paragraphs, highlights from three interdisciplinary projects are presented.

Maritime Boundaries and Sea Level Rise – Legal Implications and Conflicts

Disputes over access to and use of marine resources in the Arctic Ocean have revealed one of the less studied consequences of climate change - the effect of retreating coastlines, resulting from melting ice caps or rising sea levels, on the delimitation of maritime zones such as the exclusive economic zone (EEZ) in which a state has exclusive economic rights over all resources. Sea level rise (SLR) in particular can lead to coastline retreat due to coastal erosion and submergence of low-lying coastal areas or territorial islands. This retreat may significantly alter the baseline which is used for determining a coastal state's legal zones within the ocean and for resolving maritime claims between adjacent or opposite coasts. Extensive

rules that govern the delineation of this baseline are defined in the United Nations Convention on the Law of the Sea (UNCLOS) and corresponding customary international law. Yet, changes in the baselines resulting from changes in the physical realities have not been taken into account when formulating the UNCLOS regulations. Such changes may therefore lead to conflicts over natural resources, or intensify tensions in regions where maritime boundaries are already disputed. To explore the legal implications that could arise from coastline retreat with respect to the delimitation and extent of the EEZ, we assessed the potential response of coastal baselines to 1.5 m of global mean SLR in three geographically and legally distinct, different regions. The legal scenarios that we explored in this interdisciplinary study were:

- ▶ the renegotiation of maritime boundary agreements based on the principle of equidistance to correspond with new geographic realities between the U.S.A., the Bahamas and Cuba in the Caribbean (Figure 1);
- ▶ the re-evaluation of both equity and equidistance principles by international courts and tribunals in settling boundary disputes between Bangladesh and Myanmar in the Bay of Bengal;
- ▶ the reversion of the highly disputed EEZ claims to the legal status of high seas in the case of the Japanese island of Okinotorishima in the Philippines Sea.

The shoreline projections were derived by combining elevation data from national and global digital elevation models and assuming that all areas below 1.5 m and hydrologically connected to the sea will be permanently submerged. Adaptation measures, coastal erosion or land subsidence were not considered.

Our analysis shows how critical the changes can be in terms of the legal delimitation of maritime boundaries of coastal States and that extreme legal uncertainty is linked to those changes. The retreating coastline may have profound impacts on maritime boundary delimitation and therefore on rights and obligations with respect to natural resources located in the maritime boundaries such as the EEZ. From a legal point of view, the UNCLOS provisions on baselines will be subject to two interpretations: keep the baselines as they are, irrespective of changes in sea level, or adjust the baselines and along with them the delimitation and extent of maritime zones to reflect the changing

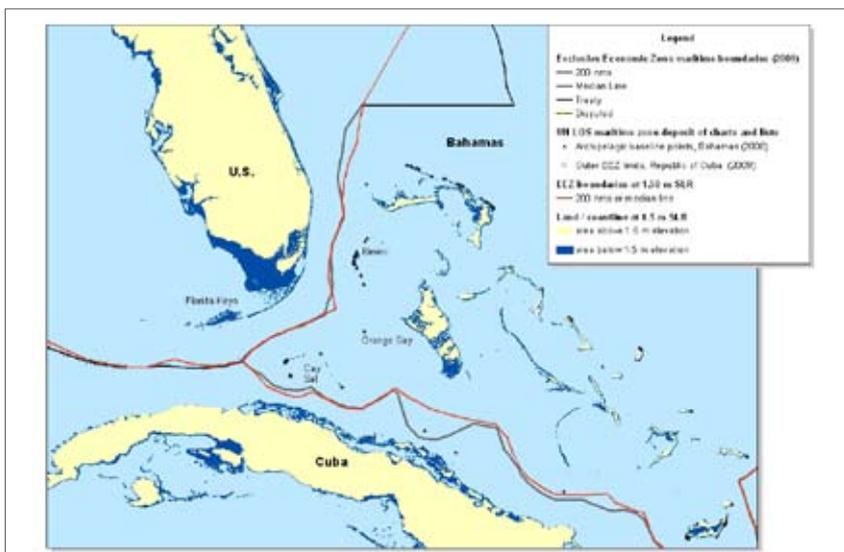


Figure 1
Exclusive Economic Zones between the U.S., the Bahamas and Cuba in the Caribbean.

physical realities. Adaptation to climate change therefore has a significant legal component which will become increasingly relevant as SLR accelerates and these issues might need to be addressed preemptively by the affected countries, as an adaptation measure.

Anticipatory Adaptation and Adaptation to Coastal Flooding and Sea Level Rise

It is expected that the increasing frequency and intensity of storms due to climate change and sea level rise will lead to more frequent and higher storm surge damages in coastal regions. However, the exact changes cannot be predicted. Public adaptation will become more cost intensive while private adaptation will become increasingly important. Uncertainty about flood risk changes might be reflected in the risk awareness of the coastal public, which is particularly vulnerable to flooding. Our work addresses the actual adaptation and adaptation intention to flood risk on the private level in vulnerable coastal regions in Argentina, Denmark and Germany. This study is based on an extensive questionnaire survey addressed to risk area residents. Work in 2010 focused on data collection analysis. Further work involved the quantification of anticipatory adaptation in all study areas. This approach allows for a different view on adaptation, which varies in detail. Various options of private anticipatory adaptation were classified by means of cluster analysis. From this analysis four different types of adaptation were identified: attention, approach, initiative and action (Fig.2). These four types seem to express a process of private adaptation, and show, at the same time, correlations to various other variables. Results are important for improving our understanding of adaptation behavior and can provide essential support for coastal risk management in the context of an involved coastal society and integrated management approaches.

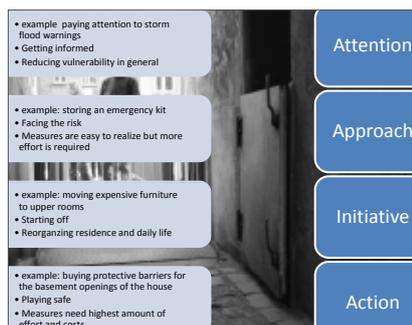


Figure 2

Four different types of anticipatory adaptation.

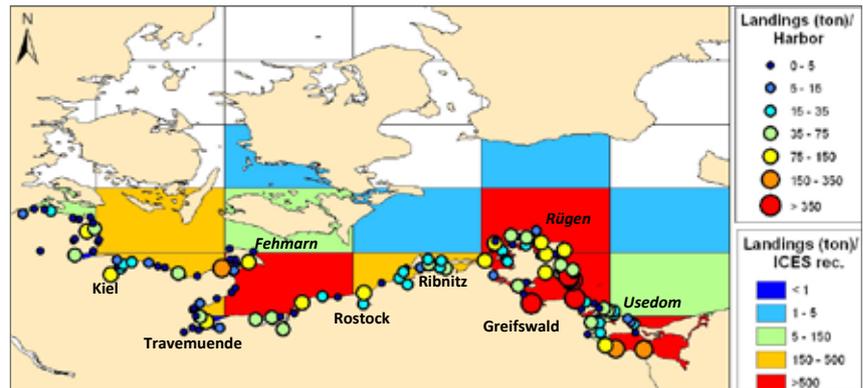


Figure 3

Total German Baltic Small-scale fishery landings (ton) (2007).

Small-scale Fisheries in the Baltic Sea

Small-scale fisheries have a limited range of operation, usually returning to their home harbor after the end of the fishing activity, and are thus integral elements of coastal waters. Climate change is likely to result in alterations in the abundance, distribution and size of fish species, which will in turn result in fluctuations in the productivity and profitability of the fishing sector, including the small-scale sector that is particularly vulnerable to such fluctuations. In the Baltic Sea region, coastal fish resources are considered important assets, particularly for fishery-dependent coastal communities. Our aim is the investigation of the impacts of climate change on the spatial dynamics of the German Baltic small-scale fishery sector. For this purpose, we have developed a spatially-integrated database that encompasses a time-series of various fishing indices of German Baltic small-scale fishery. The database is

currently employed to assess temporal and spatial trends in relevant fishing indices, and in particular, to investigate the extent to which observed changes in the distribution of fishing indices among fishing areas and landing harbors can be attributed to incidents of past environmental variability. Outcomes from this analysis will then be used to forecast/simulate the likely response of the sector under different scenarios of climate change. This research is conducted in close co-operation with the research group on Sustainable Fisheries (see page 34 in this report).

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

- Houghton, K., Vafeidis, A.T., Neumann, B. and A. Proelß (2010)*. Maritime Boundaries in a rising sea. *Nature Geoscience*, Vol. 3 (11), pp. 803-806. Doi:10.1038/ngeo1029.
- Lichter, M., Vafeidis, A.T., Nicholls, R.J., and G. Kaiser (2010). Exploring data-related uncertainties in analyses of land area and population in the Low Elevation Coastal Zone (LECZ). *Journal of Coastal Research*, In Press. Doi:10.2112/jcoastres-d-1000072.1
- Rapaglia, J., Di Sippo, E., Bokuniewicz, H., Zuppi, G.M., Zaggia, L., Galgano, A. and A. Beck (2010). Groundwater connections under a barrier beach: A case study in the Venice Lagoon. *Continental Shelf Research*, Vol. 30(2), pp. 119-126.



The International Law of the Sea

Any determination whether and under what circumstances ocean activities can be undertaken, be it marine scientific research, fishing, shipping, the exploitation of resources, laying pipelines or cables on the seafloor or the environmental protection of the ocean itself, requires a detailed examination of the legal issues linked to these activities. The legal framework within which such a determination can be made is provided by the international law of the sea, which constitutes one of the oldest and most practically relevant areas of public international law. The research group Law of the Sea has undertaken to comprehensively analyze the existing legal framework in light of current challenges deriving from climate change, increasing energy resource scarcity and the increased exploitation of the seas. It has done so in close cooperation with the other research groups as well as with senior scientists from other disciplines involved in marine sciences.

Methodology: Following a Realistic and Comprehensive Approach

Since its inception, the group has followed a “realistic” approach to investigating and answering legal questions concerning the law of the sea. This approach is based on the premise that attention should first of all be directed at the existing law before asking what international law should say, i.e. that an identification of the pertinent legal rules and their interpretation based on a stringent application of the accepted methods of interpretation should first be carried out before speculating as to further possibilities for development or change. By so doing, the research group Law of the Sea aims to further the international understanding of existing norms, thereby highlighting those areas where there is a genuine need for reform. This approach takes as its starting point the provisions of the United Nations Convention on the Law of the Sea of 1982 (UNCLOS). Based on the regulatory requirements contained therein, the group comprehensively examines the legality of individual ocean activities against the prerequisites of the concept of sustainability.

In order to achieve this aim, the research group has continued to collaborate closely with other research groups within the cluster. For instance, aspects of fisheries biology and economics played a central role in a recent proposal of a set of intuitive harvest control rules that are economically sound, compliant with international fishery agreements, based on relevant international experiences, supportive of ecosystem-based fisheries management and compatible with the biology of the fish stocks (Froese *et al.* 2010). The members of the research group also participated in a working group on the future common fisheries policy

of the European Union (EU), which included stakeholders from all relevant branches, and which submitted a comment to the European Commission's green paper “Reform of the Common Fisheries Policy”. The need for multi-disciplinary approaches is further reflected in the involvement of the research group in the “Sub-seabed CO₂ Storage: Impact on Marine Ecosystems (ECO₂)” project, which was funded under the EU Framework Program 7 (FP7) Cross Thematic Call on The Ocean of Tomorrow, and within which the research group is responsible for dealing with the legal prerequisites of a proper application of the precautionary principle.

National and International Cooperation

Contacts with State authorities, non-governmental organizations and other stakeholders have been developed further. In 2010, Alexander Proelß and Kerstin Güssow accepted an invitation from the German Federal Ministry of Education and Research to write a sounding-opinion concerning the international legal rules applicable to climate engineering. The study, which was submitted in February 2011, forms part of a series of disciplinary studies on climate engineering, whose main results will be compiled in a multidisciplinary study to be published on the request of the Federal Ministry of Education and Research in summer 2011. The research group is continuing its cooperation with the Federal Maritime Agency as a sub-partner in the “North Sea Ballast Water Opportunity Project” (sponsored by the Interreg IVB North Sea Region Program).

Alexander Proelß acted as external referee in two PhD evaluation committees on studies



concerning issues on the law of the sea. He also served as external evaluator in an appointment procedure (junior professorship for international and European law) at the University of Potsdam and in the context of a request for internal promotion to the position of a reader in law at the University of Southampton. He has repeatedly acted as external examiner in the masters program “law of the sea” of the Faculty of Law of the University of Tromsø, Norway. Alexander Proelß is one of the two German members of the International Law Association's Committee on “Baselines under the International Law of the Sea”.

Research: Protection and Sustainable Use of the Oceans

Research activities undertaken in 2010 comprised several invited talks on law of the sea-related topics in Rostock (biannual Conference of the European Cetacean Society), Vilm (workshop organized by the Federal Agency for Nature Conservation), Alta, Norway (seminar organized by the Scandinavian Institute for Maritime Law), Swansea (colloquium organized by the Institute of International Shipping and Trade Law at Swansea University), Hamburg

(conference at the International Tribunal for the Law of the Sea organized by the Law of the Sea Institute of Berkeley University) and Wageningen (seminar organized by the Dutch TWA network). Relevant publications included interdisciplinary papers on ocean iron fertilization (published in *Marine Policy*) and on the impact of sea level rise on maritime boundaries (published in *Nature Geoscience*). In addition, Alexander Proelß accepted an invitation to contribute a 100 page chapter dealing with international environmental law and the law of the sea in the 5th edition of the leading German textbook on public international law (date of publishing: September 2010).

As regards the other members of the research group Law of the Sea, in 2010 Katherine Houghton was conducting doctoral research on adaptation and the emergence of a risk management framework in international law in response to climate change. Her work looks at the relationship between environmental degradation, human vulnerability and disaster risk from a normative standpoint and incorporates interdisciplinary perspectives from the earth, technical and social sciences. Projected date of completion is September 2012. In addition to this work, Katherine Houghton co-authored the paper on the impact of sea level rise on maritime boundaries mentioned before (published in *Nature Geoscience*) and attended several conferences and summer schools dealing with disaster prevention and human vulnerability in light of the challenges of climate change.

Kerstin Güssow examined the rules and principles applicable to ocean fertilization as a means of climate change mitigation. Her dissertation focuses on the dilemma that international law obliges States to adopt mitigation measures to prevent dangerous climate change on the one hand, but that States are supposed to protect and preserve the marine environment and to act in a precautionary manner in the face of scientific uncertainty on the other. She introduces a potential reading of the precautionary principle which enables States to balance the risks arising out of ocean fertilization activities with the potential benefits in terms of decreasing atmospheric CO₂. The dissertation was submitted in April 2011 and is currently under evaluation. Kerstin Güssow is the lead author of the aforementioned paper on ocean iron fertilization (published in *Marine Policy*) and has co-written a sounding-opinion on international legal rules applicable to climate engineering.

Killian O'Brien analyzes the international regulation of operational emissions by ocean-going vessels. In 2010, a large part of the

empirical background information concerning the topic was collated and brought into a form that is somewhat more understandable for the lay reader. Also, a substantial part of the chapter concerning the issue of port-State influence on the control of pollution was completed along with a chapter outlining the diverse theories of jurisdiction underlying the law of the sea regime. These theories were subjected to a rigorous examination based on the example provided by the practical problems of international shipping. Aside from the specific PhD project, Killian O'Brien published articles on "Refugees on the High Seas: International Refugee Law Solutions to a Law of the Sea Problem" (*Göttingen Journal of International Law*), "Völker- und europarechtliche Anforderungen an Abgasemissionen von Seeschiffen" (*Zeitschrift für Öffentliches Recht in Norddeutschland*, with Alexander Proelß) and "Humanitas in Seenot" (*MARE*). A paper on "Metalliferous Sediments in the Atlantis II Deep – Assessing the Geological and Economic Resource Potential and Legal Constraints" (*Resources Policy*, with Christine Bertram, Anna Krättschell, Warner Brückmann, Alexander Proelß and Katrin Rehdanz) is currently under evaluation. As of 1 July 2011, Killian O'Brien accepted the offer of the full position of a course director at the Europäische Rechtsakademie (ERA) in Trier.

Monika Krivickaite is in the final stage of her doctoral thesis entitled "Submarine Pipelines in International Law of the Sea and Environmental Law: The Case of the Nord Stream Project". Since January 2010, she has been working on the chapter concerning European environmental law. She first identified the applicable European legal regime for laying and permitting the Nord Stream Pipeline. In particular, the purpose of

this research was to look into the Habitats and Birds Directives in order to assess whether these instruments are capable to assure that the Nord Stream Pipeline will not cause serious environmental or transboundary damage in the Baltic Sea area. She is currently analyzing how these instruments were implemented in Germany. Intended date of submission is 1 September 2011.

2010 and Beyond: Governing the Future Ocean

Effective from 1 October 2010, Alexander Proelß accepted the offer of a full professorship (W3) for public law, in particular public international law and European law, at the University of Trier. Since 1 January 2011, he has been the director of the Institute for Environmental and Technology Law (IUTR) of that University. Notwithstanding this change of position, he will continue to act as supervisor of the PhD projects of the members of his former research group, who have remained in their positions within the Cluster of Excellence. He will also pursue the successful cooperation with his former colleagues from other disciplines within the Cluster. His successor is likely to resume office in Kiel in summer/autumn 2011 and will, with the support of the Faculty of Law, the Cluster of Excellence "The Future Ocean" and the Office of the President of the Christian Albrechts University at Kiel, continue the further development of research on the field of the international law of the sea, in close collaboration with the members of the Kiel marine sciences.

Working Group



Monika Krivickaite, Petra Gnad, [Alexander Proelß](#), Kerstin Güssow, Ursula Blanke-Kießling, Killian O'Brien.

Selected Publications

- 1 | Generic Harvest Control Rules for European Fisheries. *Fish and Fisheries* 2010, DOI: 10.1111/j.1467-2979.2010.00387.x (with Rainer Froese, Trevor Branch, Martin Quaas, Keith Sainsbury and Christopher Zimmermann)
 - 2 | Ocean Iron Fertilization: Why further Research is Needed, *Marine Policy* 34 (2010), pp. 911-918 (with Kerstin Güssow, Andreas Oschlies, Katrin Rehdanz and Wilfried Ricketts)
 - 3 | Maritime Boundaries in a Rising Sea, *Nature Geoscience* 3 (2010), pp. 813-816 (with Katherine Houghton, Anastasios Vafeidis and Barbara Neumann)
-

Selected Projects

Submarine Landslides and Associated Tsunami Risk: Combining Observations and an Integrated Modeling Approach

Submarine mass wasting is a global phenomena occurring at active and passive continental margins. Submarine landslides represent a major geological hazard because they have the potential to destroy offshore infrastructure and trigger tsunamis. To assess the tsunami-genetic potential of a slide based on acoustic and sedimentological/ geotechnical data alone is problematic because the slide kinematic is difficult to reconstruct. Most modeling approaches focus on the characteristics of the generated tsunami waves, but usually do not combine the free surface wave with a free development of the slide at the bottom. In addition, several modeling approaches lack the link to observed data in the field. In the framework of this project we employ an integrated model that combines the simulation of landslides and related tsunamis, and compare model results to measured slide geometries. If a specific model run produces a terminal slide geometry that is similar to the observed slide geometry, we assume that we have selected realistic parameters for the slide, which then in turn allows us to assess the height of the associated tsunami. We consider this approach to be the most promising quantitative possibility to assess the tsunami risk related to mass wasting.

First Results

The hydrocode iSALE was employed for the landslide simulations. iSALE is widely used for simulations of meteorite impacts. Weiss *et al.* (2009) adopted the code for landslide modeling and showed by comparing with laboratory

experiments by Fritz *et al.* (2001) that all necessary processes for the interaction of slide bodies with a water column are incorporated correctly. The geometries involved in laboratory experiments were inclined slopes and triangular shapes of the initial slide masses.

We selected the Valdes Slide as a case study for our investigations. The Valdes slide is a medium-sized submarine landslide off Chile located on the landward facing eastern slope of a submarine ridge. An integrated acoustic data set allowed a detailed reconstruction of

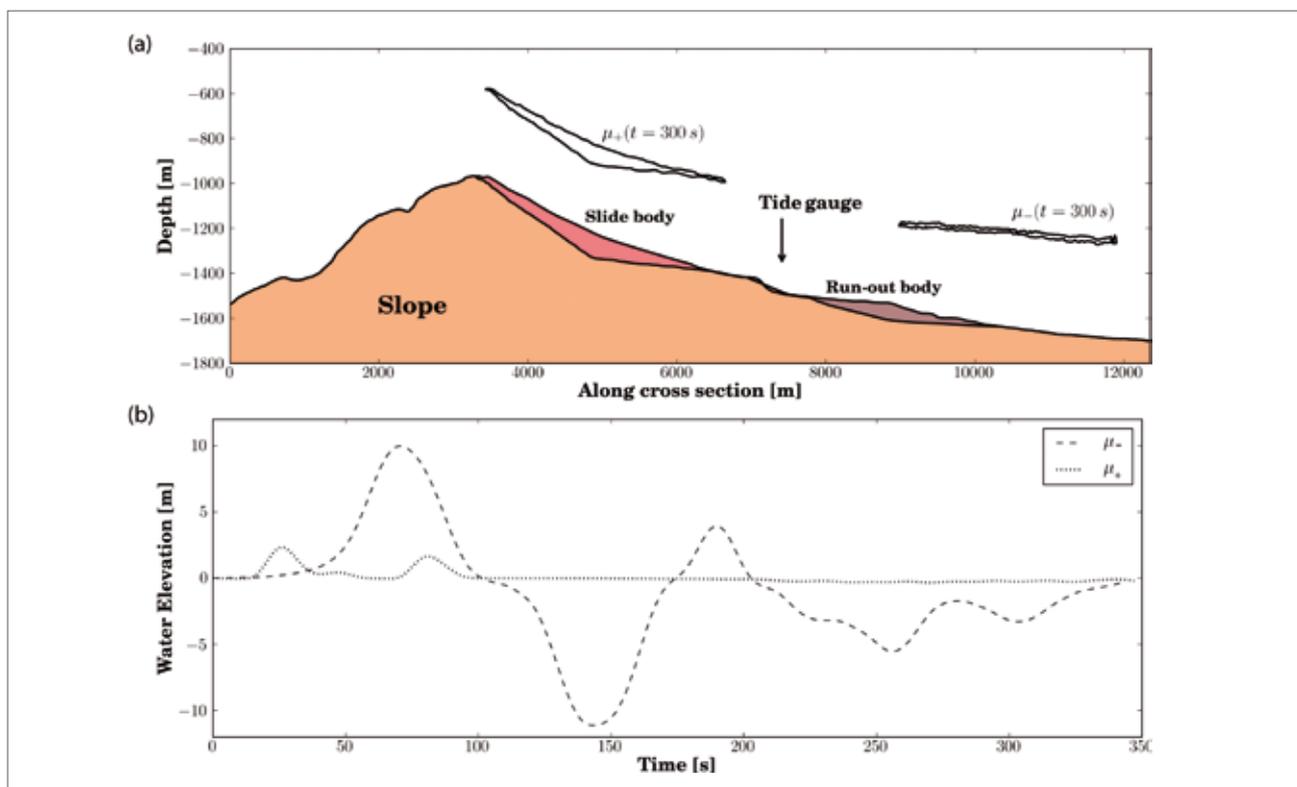


Figure 1

a) Reconstructed pre and post slide morphology based on seismic data. The outlined slide bodies labeled μ_+ and μ_- show the modelled slide body after 300 s using different viscosities (see text for details). B) Generated wave heights for the two scenarios outline in a).

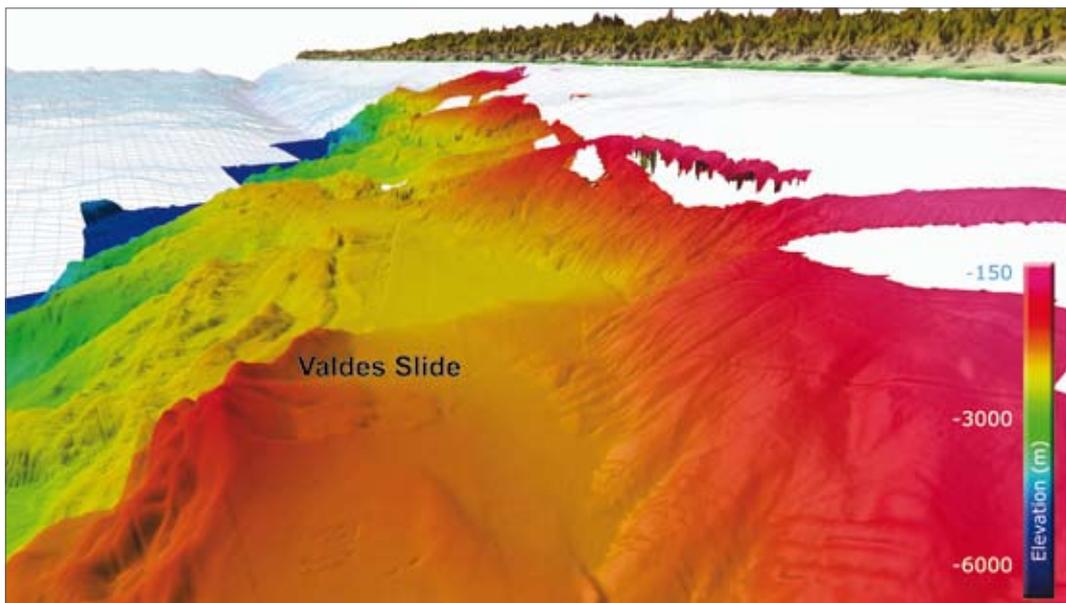


Figure 2
3-D-view of the Valdes submarine slide and parts of the continental margin off Chile. Due to its position at the landward facing wall of a ridge, we consider the tsunami potential of this slide as higher than for other slides of similar size.

the pre-and post slide morphology. The slide affected an area of 19 km² between 1000 m and 1800 m water depth. It is 6 km long, up to 3 km wide and involved a total sedimentary volume of about 0.8 km³. Over-steepening of rapidly accumulated sediments and the huge uplift of the ridge seem to be the most important preconditioning factors of this slide. Seismic data and core analysis suggest that a weak layer acted as a sliding surface. The most likely trigger can be assumed to be one of the frequently occurring strong earthquakes in this area.

Due to the confined geometric characteristics, it is appropriate to simulate the Valdes slide with a two-dimensional model. However, the cross-section is complicated compared to Fritz's laboratory experiments. Therefore, it was necessary to enhance iSALE to be able to define complex morphologies of the seafloor and of the slide body. A software tool was developed to produce the inputs for the seafloor and the slide body. Figure 1a shows the initial condition for the Valdez slide (seafloor in orange and slide body in red).

Also depicted in Fig. 1a is the thickness distribution of the run-out masses. To reproduce the thickness distribution to the first order is the main objective of this proposal. The simulated thickness distribution – if the comparison between simulated and observed thickness distribution is reasonable – serves then as a constraint for the tsunami waves generated at the water surface. We define the comparison between simulated and observed run-out masses as reasonable if the simulated run-out masses end within 15 % of the entire length of observed run-out masses, and if the large-scale surface curvatures are the same. For the Valdes

slide the surface curvature is convex.

The dynamics of the slide body are mainly a function of the material parameters. For the sake of simplicity, we consider a slide mass as a viscous fluid at this point. To produce a reasonable comparison between the simulated and observed run-out masses, we vary the viscosity of the slide body from $\mu_0=10^6$ Pa s to $\mu_0=10^8$ Pa s. Also outlined in Fig 1a are the geometries of the slide bodies after 300 s. Respective time series are shown in Fig. 1b. For μ_0 , the slide body adjusted very little to reach another gravitationally stable position. This adjustment generated a wave of about 2 m in amplitude, but with a period of about 12 s. A wave with such characteristics will dissipate very quickly by dispersion and other nonlinear processes. For case μ_0 , the slide masses exceeded the location of the run-out masses, and the geometry is very long. However, the slide motion created a 10 m wave with a period of about 174 s. This wave would be able to propagate some distance without losing too much of its initial energy. However, because the simulated run-out mass spreads out over a longer distance and the slide body has not stopped even after 300 s, the wave characteristics remain unconstrained by the measurements. In an iterative process, a viscosity μ_0 is determined, for which the generated waves will be constrained by the observed run-out masses. The recent discovery of yet another bug in the code, combined with the significant run time of about two weeks for each simulation, rendered it impossible to present wave characteristics of the constrained case. However, an update to this report will be provided as soon as the optimal viscosity μ_0 is found.

Networking

The project is being carried out in co-operation between IFM-GEOMAR (S. Krastel, J. Behrmann) and the Department of Geography at Kiel University (H. Sterr). A central objective of the project is to establish a close co-operation with Prof. Dr. R. Weiss from Texas A&M University, who is an expert in tsunami modeling. R. Weiss visited Kiel in summer 2010 for two periods of 3 weeks each. S. Krastel visited Texas A&M University for one week in December 2010.

Outlook

Two additional research visits of R. Weiss in Kiel are scheduled for 2011 in order to improve the combination of model results and field observations of the Valdes and other slides. A DFG-proposal for a joint PhD student of S. Krastel and R. Weiss is in preparation.

Research Stays

R. Weiss at CAU/IFM-GEOMAR
(17.05 – 04.06.2010; 27.07 – 17.08.2010)

Sebastian Krastel at Texas A&M University
(30.11-06.12.2010)

References

- Fritz, H.M., W.H. Hager, and H.-E. Minor (2001)
Lituya Bay case: Rockslide impact and wave runup.
Sci. Tsunami Hazards, 19, 3–22.
- Weiss, R., Fritz, H.M., Wünnemann, K. (2009)
Hybrid modeling of the mega-tsunami runup in Lituya Bay after half a century. *Geophys. Res. Lett.*, 36, L09602, doi:10.1029/2009GL037814.

Selected Projects

Response of Tidal Basins to Sea Level Rise and Climate Change

The Norderhever-Heverstrom tidal basin (Germany) is part of the largest joined Wadden Sea environment worldwide and serves as a representative example of the North Frisian coast. Responding to sea level rise and anthropogenic influences such as diking, large parts of the Wadden Sea seem to be diminishing due to “coastal squeeze”. But natural and anthropogenic induced hydrological, sedimentological and morphological interrelations between the subtidal part of the basin and the adjacent intertidal areas are far from being fully understood, which is the aim here. New results have been obtained, identifying changes in the sediment distribution pattern by combining new and old sediment data and by quantifying changes in the spatial distribution of tidal channels, based on analyzes of aerial photographs. According to these results the development of the northern part of the Norderhever-Heverstrom tidal basin seems to contradict what is generally assumed for coasts affected by coastal squeeze, because instead of a depletion of fine grained material a considerable accretion has been detected.

Background Information

The Norderhever-Heverstrom (NHS) tidal basin is located at the German North Sea Coast (Fig. 1a-b). It is part of the largest joined Wadden Sea environment worldwide, which has been recently declared a ‘UNESCO world heritage area’. Due to strong interactions between hydro-, sediment- and morphodynamics, the Wadden Sea and thus the NHS is

considered to be extremely sensitive to forcing factors such as sea level rise (SLR) and climate change. Under natural conditions a landward displacement of the coastline would occur due to SLR. This development is mostly inhibited by diking, which is generally assumed to result in a diminishment of inter- and supratidal areas and a concomitant seaward loss of fine sediment. This phenomenon is known as coastal squeeze. Further effects, such as channel deepening, are currently the subject of discussion. There are still many open questions to answer considering the future evolution of such environments, especially with respect to global warming, which will not only trigger sea level rise, but also strengthen storm intensity, duration, frequency and thus hydro-dynamic forcing.

by the Schleswig-Holstein Government Owned Company for Coastal Protection, National Parks and Ocean Protection, was investigated. Changes in the spatial distribution of tidal channels and gullies were estimated, which had not been documented before. The lateral offsets of these gullies, implemented in a predefined grid were analyzed to identify areas with small and large offset intensities, respectively. Hydro-acoustic devices (e.g. side-scan sonar, sub-bottom profiler), were deployed during one cruise in 2010 to analyze the sediment transport pattern within the subtidal channel system. These data are used to clarify interrelations with the intertidal part of the basin.

Sedimentological Changes

The overall sediment distribution pattern found within the study area in summer 2010 reveals particle-size refinement from the outer to the inner section of the Norderhever and the Hever sub basins (Fig. 1). This can be seen in figure 2 by comparing the western coastal section of the peninsula Nordstrand where fine sand with grain sizes $>125\ \mu\text{m}$ dominates, with the northern coast in front of the Beltringharder Koog, where almost muddy sediments occur. Comparing the two sub basins, finer grain sizes occur in the Norderhever than were found in the Hever area. The latter region is characterized by an average grain size, which changes from $150\ \mu\text{m}$ in the outer more energetic to $80\ \mu\text{m}$ in the inner, more sheltered part.

Prior to the construction of Beltringharder Koog, the amount of mud in that region was substantially lower than it is nowadays (Fig. 2). Also in this case, the spatial sediment distribution in the area between Nordstrand and



Figure 1

a) Location of study area at the North-Sea Coast of Germany and b) Satellite image (modified after world wind 2002) showing a section of the North Frisian Wadden Sea area with the study area (see yellow dotted rectangle).

Project Content

The NHS was selected in this project as a representative example of the North Frisian Wadden Sea coast, for studying the complex interrelations between external forcing and response like systems' change. It is particularly applicable, because human interference by diking has a long history in this area. The last most prominent measure was the construction of the Beltringharder Koog, northwards of Nordstrand (Fig. 1), which was realized in 1987. An area of 3350 ha was reclaimed from the open North Sea, intending to shorten the dike line limiting the tidal prism of the NHS basin. Detailed sedimentological studies of the area were conducted in the 1980s by KÖSTER *et al.* These studies provide an important reference for systems adaptation by comparison with the data collected in 2010. A time series of aerial photographs, taken between 1979 and 2005

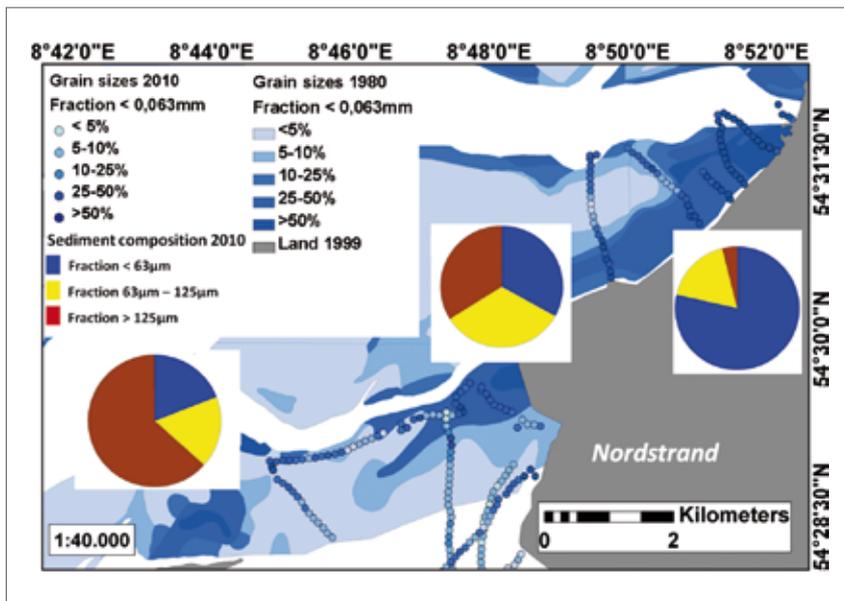


Figure 2

Comparison of recent grain size data with data from Köster et. al (1980, digitized and modified), focusing on the size fractions < 63 µm. Average sediment composition from 2010 is presented in pie charts.

the holm Südfall appears to be similar when comparing old and new data. This tendency of facing locally restricted sediment refining over time in the inner Norderhever sub basin, despite the seaward directed displacement of the dike line, is not characteristic of coasts affected by coastal squeeze. Although data sets for analyzing changes of grain-size distributions over longer time spans are not available for the Hever sub basin, the current condition of the grain-size spectrum seems similar to that of the Norderhever 30 years ago.

Morphological Changes

Tidal channels and gullies play an important role as sediment pathways. Thus, changes in their spatial distribution over time provide useful information about the morphodynamics in this area. Based on measurements of their spatial offsets, followed by an offset intensity classification and subsequent interpolation using Thiessen polygons, remarkable changes appear as displayed in figure 3. Areas with highest channel and gully dislocations over 500 m are found north westward of the island Nord-

strandischmoor, in front of the Beltringharder Koog, and at the junction of the Norderhever and the Hever sub basins. Low offset intensities are observed in the western coast of Nordstrand. This result is in agreement with the above-mentioned sedimentological findings, revealing stable conditions over longer time periods. The Hever subtidal area also faces low offset intensities. There, tidal channels and gullies are only slightly shifted in eastward directions.

Preliminary Conclusions

From the data presented here, we can conclude that the NHS is not only in a dynamic state, but has changed locally over decadal time spans with respect to surface grain-size distribution and spatial dislocation of tidal channels and gullies. This fits general postulations that the Wadden Sea reacts in a highly sensitive manner to external forcing, amongst anthropogenic interferences. Changes within the investigated NHS area do not yet reflect symptoms, which can be clearly associated with coastal squeeze. Furthermore, anthropogenic influence by the most recent diking measures seems to have a strong local impact directly in front of the dike, but extensive denudation of tidal flats or remarkable development of new gullies, as had been discussed for the Norderhever before the dike construction, are not yet noticeable.

Outlook

This project was set up to provide a basis for the development of a concept for a new interdisciplinary research program with partners, who have already announced interest. Sedimentological and morphological changes occur, as already shown, but further investigations need to be carried out in order to assess the impact of sea level rise and other climate induced forces in the near future.

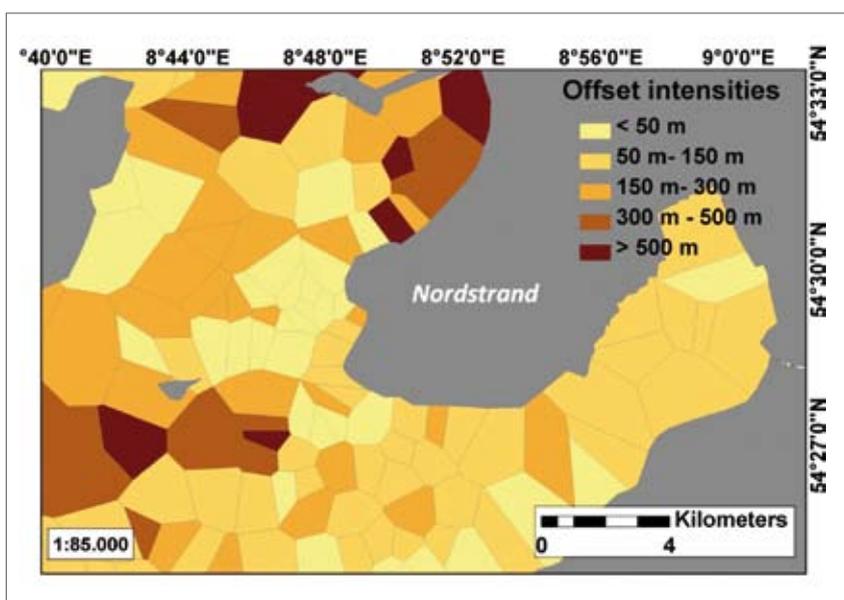


Figure 3

Voronoi - map, reflecting the spatial distribution of offset intensities from tidal channels and gullies over 16 years, derived from aerial pictures provided by the Schleswig-Holstein Government-Owned Company for Coastal Protection, National Parks and Ocean Protection.

Project Team

Peter Richter, Kerstin Schrottko, Athanasios Vafeidis, Klaus Ricklefs, Klaus Schwarzer

Selected Projects

Establishment of Marine Invertebrate Cell Cultures as a Tool for Immune System and Environmental Stress Research

Marine invertebrates are used as model organisms throughout the Cluster of Excellence (AG Schmitz-Streit, RG A1 Melzner). Primary cultures of these organisms open the field to a variety of new tools and methods not available for whole organisms. Furthermore, the use of cell cultures has several advantages over the use of whole organisms, since culture conditions can be tightly controlled and intra-individual variation is limited. The difficulty in culturing cells from marine invertebrates is that there is as of yet no established cell line and the cells of invertebrates have special requirements in contrast to vertebrate cell lines e.g. osmolarity and temperature. The aim of the project is to build up a stable marine cell culture of the blue mussel *Mytilus edulis* and to establish functional assays which will provide the basis for further work. In addition, cell culture experiments (together with currently generated transcriptome data) are being conducted to give new insights into marine invertebrate immune parameters and their functions.

Results and Discussion

During the course of this project cell culture conditions for *Mytilus edulis* hemocytes have been improved, but the viability of cell cultures is still very variable ranging from a few days up to 6 months. Due to this instability the goal of creating a working long-term marine invertebrate cell culture could not be fully met. Nevertheless, short term culture conditions have been improved and functional assays have been established, which are currently being used in short-term experiments.

As an object of study the blue mussel, *Mytilus edulis*, was chosen, since it is highly abundant in the Kiel Firth and exhibits well-characterized model organisms in the marine research community. Mussels were acclimated to 15 °C in a cooling chamber for at least 2 weeks and fed with *Rhodomonas* sp. 3 times a week to optimize culture conditions.

Plating of cells was optimized testing different well-plate formats and concentrations. Best results were obtained by plating 750 µl of about 1,000,000 cells ml⁻¹ in a 24-well plate. Additionally, different hemolymph treatments were tested to optimize adhesion to plates. The best cell adhesion was observed when hemolymph was directly applied to the culture plate and exchanged with media after an hour of incubation time.

The next step was to optimize the culture media. Culture conditions varying, e.g. in temperature and osmolarity were tested and the best results were in accordance with environmental data. Therefore, a pH of 7.4 of the medium

most closely resembled the natural pH of the hemolymph and the osmolarity of 500 mOsmol most closely resembled the yearly average of the natural habitat. An maximum natural temperature of 15 C was used to facilitate laboratory experimentation in the future. Investigating different sera inclusion revealed that the longest culture duration was obtained using 10 % new born calf serum. Furthermore, different media were tested with antibiotics added (Amphotericin, Kanamycin, Gentamycin, Penicillin and Streptomycin). Cells cultured in commercially available cell media i.e. DMEM, MEM and RPMI did not survive the first day. Leibovitz L-15 media resulted in optimal adhesion and vitality of the cells for up to 6 weeks. Two recipes were tested: media modified according to Cao *et al.* (2003) and according to Quinn *et al.* (2008). Both media were buffered using HEPES. The medium according to Quinn *et al.* (2008) resulted in a slightly better vitality and was therefore employed in further experimentation. For further improvement of adhesion to the culture dish different supplements and additives were tested (see table 1 for summary).

To detach the adherent cells from the culture dish for FACS analysis, various enzymes were investigated using different concentrations and incubation times including accutase, alfazym, trypsin and trypsin including EDTA. Best results were obtained using trypsin including EDTA at a concentration of 120 µl per well (containing 750 µl media) and an incubation time of 1 to 2 minutes. Together with Bianca Grunow and Dr. Marina Gebert from the Fraunhofer Institute for

Supplement	Viability
Collagen I	--
Collagen IV	--
FGF	-
EGF	o
Collagenase/Pronase	-
F-12	--
Sodium Pyruvat	+
NEAA	o
N2	-
B27	+
Bovine pituitary extract	-
MEMAA	++
F-10	o
Insulin	o
G5	o
MEM Vitamine	o
Lipumin ACDF	-
L-Polylysine (70-150 kDa)	o
D-Polylysine (30-70kDa)	o
Horse Serum (Lot: H1138)	o
NBCS (Lot: 16010)	+
FBS (Lot: P290211)	o
FBS (Lot: P291509)	o
Ca ²⁺ and Mg ²⁺	+

Table 1

Viability of hemocyte cell cultures treated with different supplements. Cells in basic medium without additives served as a control. Corresponding supplements reduced (-), enhanced (+) or showed no difference (o) in culture viability compared to the control. Strong effects are marked by double symbols (++ and --).

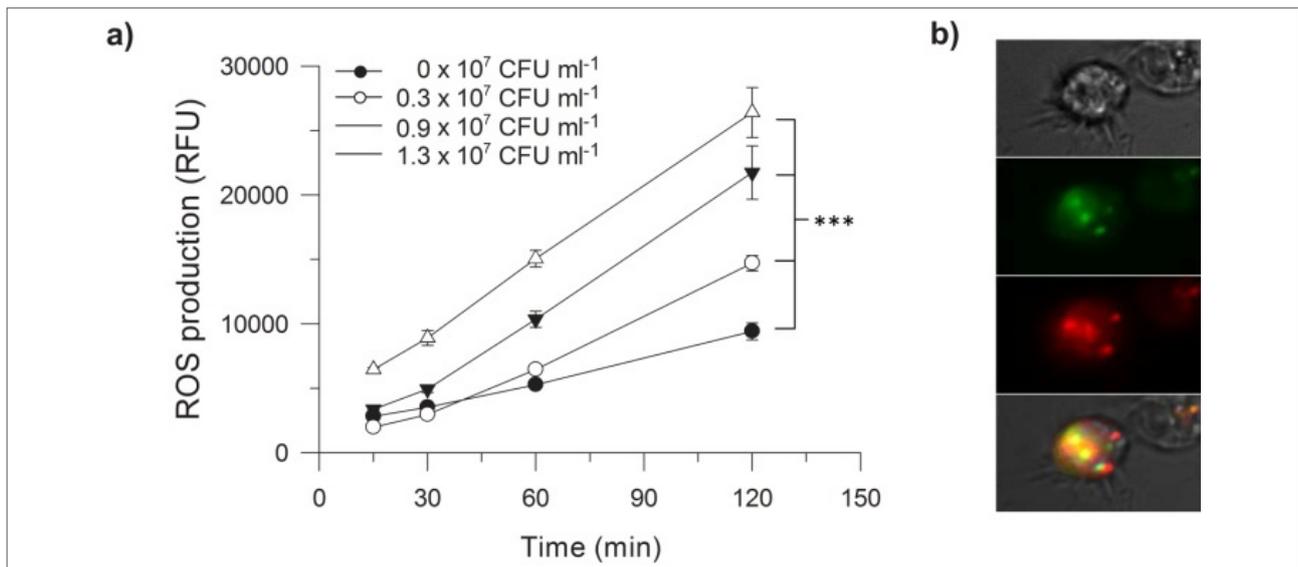


Figure 1

Time dependent (min) extracellular (a) ROS production [relative fluorescent units [RFU]] in hemocytes (n=3 wells) upon stimulation with different concentrations of *Vibrio anguillarum* [colony forming units [CFU] ml⁻¹]. Standard deviations are shown. ROS production is significantly dependent on incubation time and concentration of the stimulus ($p < 0.001$; Holm-Sidak, Two Way ANOVA). Intracellular (b) ROS production [green DCFH-DA fluorescence] by a hemocyte exposed to labeled bacteria, *Listonella anguillarum*, (red fluorescence) by microscopic observation. Transmission, fluorescence and merged pictures are shown.

Marine Biotechnology (EMB) in Lübeck, efforts are still underway to establish stem cell cultures of heart, digestive gland, gill and mantle tissue. The tissues and whole animals were dissociated with different enzymes, i.e. collagenase, TM and trypsin, and cultured in two different media, DMEM and L-15. In addition to this, explants of all tissues were also cultured. The best results (viability a few days up to 2 weeks) were obtained with the dissociation protocol according to Quinn *et al.* (2009) and the addition of MEM amino acids as well as 50 ng/ml EGF.

To investigate the viability of cells in culture we optimized the MTS (methyl-thiazol tetrazolium) assay (platereader analysis) or propidium-iodide (PI) staining (FACS analysis). To further characterize hemocytes in culture, additional functional assays were established using the FACS as well as the microscope, including a phagocytosis assay consisting of the ingestion of fluorescent beads as well as a lysosome stability assay by lysosome staining with LysoTracker. To investigate the immune system response in the form of reactive oxygen species (ROS) generation the Amplex Red and the cDCFH-DA assay were optimized to test for extra- and intracellular reactive oxygen species production, respectively (microscopic and plate-reader analysis). Uptake of pathogenic bacteria was also made visible using fluorescent labeling (see figure 1b). The first successful siRNA transfection assays were carried out using Alexa Fluor labeled siRNA and different transfection agents and *Mytilus edulis* specific siRNA experiments are currently being undertaken to investigate the

role of *M. edulis* dual-oxidase in the generation of ROS during bacterial challenge. A successful siRNA experiment would be a milestone for the work with marine cell cultures and facilitate the investigation of the biological function of genes identified in currently emerging marine invertebrate transcriptomes.

Conclusion and Outlook

Even though culture conditions have been improved, cell culture durations are very variable ranging from days to weeks. This is unfortunately in line with several previous studies of other working groups which tried to establish marine invertebrate cell cultures (for review see Rinkevich 1999, 2005 and 2011). A possible cause might be the lack of some unknown essential growth factors, for which the hemocyte transcriptome database, recently established, could provide promising hints. However, short term cultures are possible and the assays and cultures established in this project are already being used in different research projects, for instance to investigate ROS production in relation to different immune stressors (Figure 1a).

Project Team

Philip Rosenstiel, Stefan Schreiber

We have scheduled another 4 months for the final establishment of siRNA transfection, which could provide a very powerful molecular tool also for other cluster members (e.g. for investigating genes involved in host microbe interaction or calcification).

Last experiments are currently being undertaken to investigate the role of NADPH oxidases in the generation ROS during immune challenge.

Selected Publications

- 1 | Cao, A., Mercado, L., Ramos-Martinez, J. I. and Barcia, R. (2003). Primary cultures of hemocytes from *Mytilus galloprovincialis* Lmk.: expression of IL-2R[alpha] subunit. *Aquaculture*, 216(1), 1-8.
- 2 | Quinn, B., Costello, M., Dorange, G., Wilson, J., & Mothersill, C. (2009). Development of an in vitro culture method for cells and tissues from the zebra mussel (*Dreissena polymorpha*). *Cytotechnology*, 59(2), 121-134.
- 3 | Rinkevich, B. (1999). Cell cultures from marine invertebrates: obstacles, new approaches and recent improvements. *Journal of Biotechnology*, 70(1-3), 133-153.
- 4 | Rinkevich, B. (2005). Marine Invertebrate Cell Cultures: New Millennium Trends. *Marine Biotechnology*, 7(5), 429-439.
- 5 | Rinkevich, B. (2011). Cell Cultures from Marine Invertebrate: New Insights for Capturing the Endless Stemness. *Marine Biotechnology*, Epubl.

Selected Projects

A Glider Fleet to Observe Sub-Mesoscale Physical-Biogeochemical Coupling in the Tropical Ocean

For the most part, physical-biogeochemical submesoscale (SMS) coupling has been studied near ocean margins and ocean frontal systems. In contrast, we carry out an open-ocean study north of Cape Verde in the vicinity of the TENATSO observatory (Fig. 1, tenatso.ifm-geomar.de), where both surface chlorophyll and temperature display pronounced SMS structures (Fig. 1). Our objectives are (i) quantification of SMS variability of temperature (T), salinity (S), chlorophyll fluorescence (Chl), oxygen (O_2) and turbidity (Tu) in the surface mixed layer and the upper thermocline, and (ii) demonstration of the coupling between physical processes (lateral and vertical advection) and biogeochemical processes (phytoplankton biomass, oxygen production/consumption, fertilization by Saharan dust).

Project Goals

Horizontal de-correlation scales of T, S, Chl, O_2 , and Tu are computed at different depths to provide a statistical description of the SMS structures (Aim 1). Property advection is analyzed by means of the density fields computed from T and S, and by current-velocity-time series from the TENATSO mooring. The physical-biogeochemical coupling (Aim 2) is established based on both analyses of covariance between T / S and Chl, O_2 or Tu and dynamical concepts. Glider measurements of Tu and Chl are utilized in combination with satellite-derived dust deposition and chlorophyll concentrations. Together these data are used both to constrain the estimates of chlorophyll concentration and primary production otherwise obscured by dust and cloud signals, and to determine whether advection of nutrient

rich waters or fertilization during Saharan dust deposition events contribute most to stimulating primary production in this important area of the tropical Atlantic.

Field Work

To deploy six gliders (Fig. 2) of IFM-GEOMAR's glider fleet, an expedition took place from 5 – 19 March, 2010. During this time we were based in Mindelo, on the Island of Sao Vicente (Rep. of Cape Verde). During the first days, software updates, hardware checks, and verifications of the functionality and ballasting of the gliders on the premises of Instituto Nacional de Desenvolvimento das Pescas (INDP) were performed. The gliders were tested and deployed south of the Sao Vicente near the village of Sao Pedro in about 700 m water depth. The deployment location was near 16°46' N / 26°07' E. Of the

six gliders, four had completed the whole deployment period by May, 5, 2010, when they were recovered aboard *R/V Polarstern* by Arne Körtzinger. Two gliders failed prematurely before reaching the research area. Both units were recovered successfully. IFM06 was recovered by the expedition team. IFM03 failed after March 19, and was thankfully recovered by our colleagues Pericles Silva and Nuno Vieira from INDP.

To achieve the research goals, the glider-based observations of the SMS variability focused on an area of 50 x 50 km centered around the TENATSO ocean observatory. Each of the gliders carried out roughly 8 – 12 vertical profiles of T, S, Chl, O_2 and Tu per day along predefined tracks with a horizontal speed of about 25 km per day for a duration of eight weeks. Upon arrival at the site, the gliders followed butterfly-shaped tracks. The two pairs

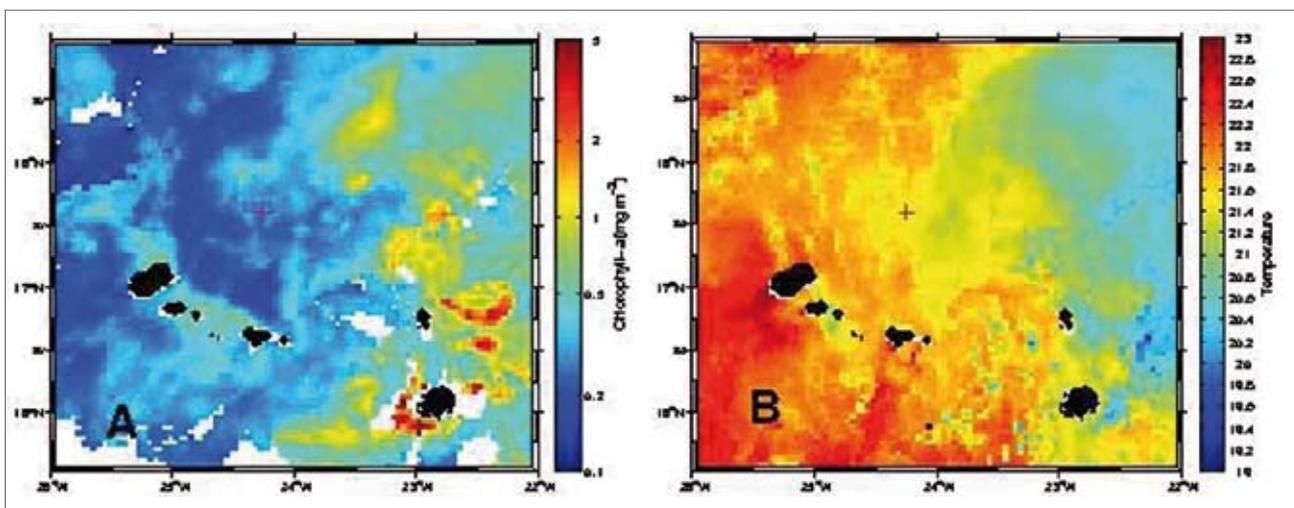


Figure 1

Sea surface chlorophyll-a (left) and temperature (right) near the Cape Verde Islands (black) based on remote sensing (MODIS, 8-day average, 4-km grid size). The red cross denotes the TENATSO mooring site.



Figure 2

A glider from IFM-GEOMAR's glider fleet in the water. The device is approximately 1,5m long and can dive down to 1000m water depth. It can collect oceanographic data autonomously for several months.

of gliders followed tracks that were rotated by 90°, assuring good coverage in both zonal and meridional domains. Each glider pair followed the butterfly course in opposing directions so that the whole range of variability over spatial scales from 0 to 50 km was gradually sampled.

Calibration

For multi-parameter measurements, calibration is a major task. The temperature and salinity processing and calibration were completed by Michael Schlundt and Rafael Abel. Careful processing showed that the T and S measurements on all gliders were of high quality with salinity offsets between the gliders less than 0.01. The processing and calibration of the oxygen sensors is still ongoing. Overall the oxygen data is of high quality. However, specific care needs to be taken because the oxygen sensor response times differ among the sensors. Knowledge of the response times is critical in the high gradient zone across the oxycline. To obtain absolute oxygen values the glider measurements will be referenced against a regional oxygen climatology prepared by Björn Fiedler. Wiebke Mohr carried out reference chlorophyll measurements aboard *R/V Polar-*

stern to be used to calibrate the chlorophyll measurements.

Vertical Velocities

In SMS dynamics, vertical velocities are instrumental in the supply of nutrient enriched waters to the euphotic zone. Gliders themselves can be used as a tool to observe vertical velocities. The idea is to compare modeled with observed flight characteristics during each of the dives. Assuming quasi-stationary flight, the force balance for the gliders can be calculated and a theoretical vertical velocity of the glider can be deduced. Comparing that with the vertical velocity observed by the glider's pressure sensors, one obtains an estimate of the ambient vertical water velocity. A non-linear optimization routine was employed by Gerd Krahnmann to determine the values. The coherent modal structures shown in Fig. 4 suggest that we are able to observe vertical velocities associated with internal waves. The vertical velocities shall be used to explain submesoscale anomalies in hydrographic and biochemical variables.

Small-Scale Features

By sampling all above-mentioned parameters during both upcasts and downcasts, the gliders have a horizontal resolution of 1-2 km. The multi-glider data set clearly shows that pronounced SMS anomalies in physical (T, S) and biogeochemical parameters (O_2 , Chl) are ubiquitous. We have documented many examples of physical – biogeochemical co-variability, as exemplarily demonstrated in Fig. 5. Here, an eddy carrying an unusually shallow low-salinity anomaly centered at 100 m water depth was detected, thus, clearly above the permanent oxygen minimum layer. The eddy was associated with

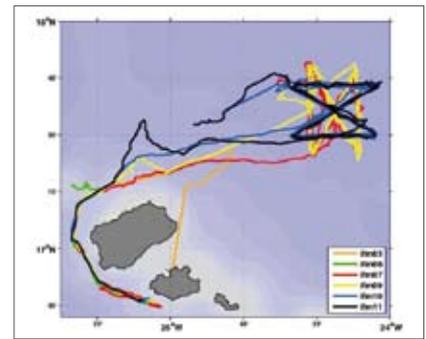


Figure 3

Glider tracks from the Spring 2010 campaign. The gliders were deployed south of Sao Vicente, and navigated autonomously towards Tenasco observatory, where they carried out missions, following predefined, butterfly-shaped courses. Together, the gliders covered a distance of 3800 km. The devices performed 3500 dives, during which 18,000,000 measurements of salinity, temperature, pressure, chlorophyll, turbidity and oxygen were carried out.

extremely low salinities, possibly pointing to waters of South Atlantic origin. Ongoing and future work will focus on the spatial scale of physical-biogeochemical co-variability.

Sahara Dust

Deposition of Sahara dust carried toward the tropical Atlantic during storm events might lead to fertilization of the ocean with micronutrients, and might explain the enhanced biological activity in the open ocean zone of the tropical North Atlantic. While Sahara dust storms can be observed by remote sensing (Fig. 6, left), the actual deposition in the ocean requires *in situ* measurements. One of the goals of the project is to study the potential of the turbidity sensors aboard the gliders to detect dust deposition events. The remote sensing based measurements (MODIS Aqua; provided by Thomas Ohde, IOW) suggest that five dust

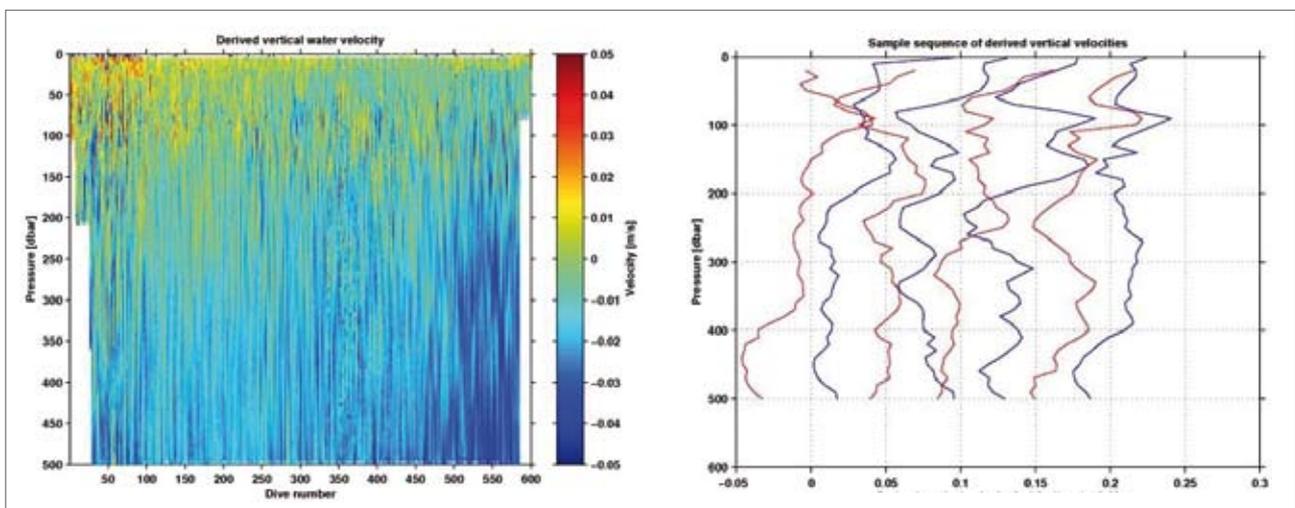


Figure 4

Right: Derived vertical water velocities for glider ifm09 north of Cape Verde. Left: Sequence of derived vertical water velocities. The traces are offset by 0.03 m/s.

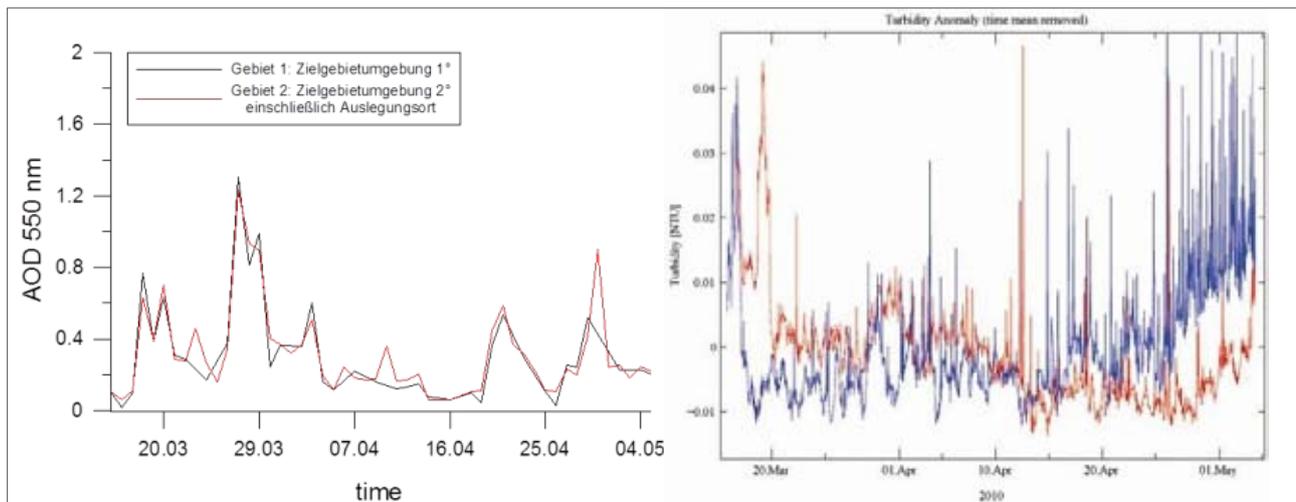


Figure 6

Left: Aerosol optical depth (AOD) from Modis Aqua (550nm) at the Tenatso site (courtesy of Thomas Ohde, IOW). Turbidity in the mixed layer measured by two gliders.

storm events took place during the deployment period of the gliders (Fig. 6, left). Our preliminary comparison between satellite-derived AOD and glider-based turbidity suggests that the skill of detecting dust deposition events varies from glider to glider (Fig. 6), with one of the two glider based turbidity time series (red line Fig. 6: right panel) showing increased turbidities during the two strongest dust events (IFM10), while the other (blue line) does not (IFM09). Future work will focus on the dust sensitivity of the glider measurements. For this, apart from ►► satellite derived AOD dust measurements from

the TENATSO atmospheric observatory (by ITF, Leipzig) shall also be used.

Collaborations

Our aims are multidisciplinary and are imbedded in several central topics of the Kiel Cluster of Excellence "The Future Ocean". SMS processes acting on T and S are fundamental for the stability of large-scale ocean circulation in a changing climate, which is a focus of topic A4 (Ocean Circulation Change). Processes changing biogeochemical parameters near the sea surface directly contribute to the topics A3 (CO₂ Uptake) and A6 (Marine Chemistry at the Sea Surface). Studies regarding the role of SMS activity in vertical oxygen fluxes across the upper boundary of the Oxygen Minimum Zone are furthermore important in the context of SFB 754 "Climate Biogeochemistry Interactions in the Tropical Ocean".

Our partners include:

- Thomas Ohde (IOW, Warnemünde)
Sahara Dust deposition (remote sensing)
- Hartmut Hermann (IFT, Leipzig)
Sahara Dust deposition (ground measurement)
- Péricles Silva (INDP, Mindelo)
hydrographic sampling, logistics
- Nuno Vieira (INDP, Mindelo)
hydrographic sampling, logistics
- Peter Brandt (IFM-GEOMAR)
small-scale variability
- Johannes Karstensen (IFM-GEOMAR)
spatio-temporal chlorophyll variability
- Christophe Eizaguirre (FM-GEOMAR)
physical – biological interaction

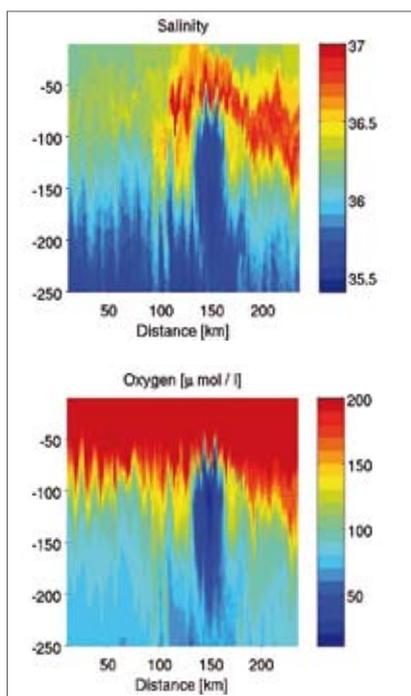


Figure 5

Shallow low-salinity, low-oxygen anomaly detected north of Santo Antao.

Conclusions and Outlook

The data acquisition phase was very successful and data processing has progressed quite far. We have successfully been able to demonstrate small scale physical – biogeochemical co-variability. We have implemented the methodology to infer vertical velocities from the gliders. Near term tasks in 2011 include the finalization of oxygen calibration and the calibration of the chlorophyll and turbidity measurements. We will analyze the spatial scales of physical – biochemical co-variability. The Bachelor thesis of Ms Eva Nowatzki will focus on this topic. We shall assess the potential of vertical velocities computed from the gliders to explain the small-scale variability of the biophysical parameters. In collaboration with Thomas Ohde (IOW) we shall intensify the work on the detectability of Sahara dust deposition. In collaboration with Johannes Karstensen (IFM-GEOMAR) we will assess the potential of remote sensing to infer vertically integrated chlorophyll contents. IFM-GEOMAR plans to carry out further glider fleet experiments. Experiences gained from this pilot study will help to conduct (and process and analyze the data from) future missions. The next experiment will be carried out by Peter Brandt in the equatorial Atlantic in summer 2011. T. Kanzow envisions carrying out a glider based experiment in early 2013 in the upwelling regime off Peru in the framework of SFB 754.

Project Team

Torsten Kanzow, Julie LaRoche, Arne Körtzinger

Selected Projects

Winners and Losers in the Future Ocean

Standardized range maps of 10,000 marine organisms were used to compare their current area of distribution with that under 2050 and 2100 future ocean scenarios. Prominent 'winners' and 'losers' at the level of species, taxonomic groups and regions were identified.

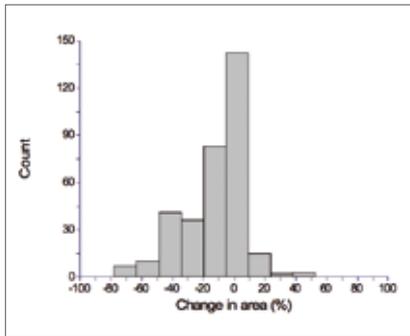


Figure 1

Change in area of suitable habitat between 2000 and 2050 for 342 marine fishes. For most species the change was negligible. But there are clearly more losers than winners, with median loss of area at 6% [95% CL 3.8 – 7.4], significantly different from zero.

Summary of Results in February 2010: More Losers than Winners

As planned a part-time PostDoc and programmer was hired and two workshops with international experts were conducted. The results of the analysis of the pilot study conducted by Kristin Kaschner investigating climate change impacts on marine mammal biodiversity have been accepted for publication in PlosONE (Kaschner et al, accepted). The map-generating procedures of AquaMaps

were improved and produced 11,549 maps. Of these, 671 maps were expert-reviewed in early February. Data for 342 fish species was preliminary analyzed with reviewed maps. The extent of core area with suitable habitat between 2000 and 2050 was compared, using the conservative IPCC scenario SRES A1B. As a first result, more losers than winners were found (Fig. 1): Over 100 species lost more than 20% of their suitable area, whereas less than 10 species gained more than 20%.

No significant differences with regard to loss of suitable habitat between taxonomic groups (here: sharks & rays versus bony fishes), phylogenetic rank or uniqueness, body size, or migratory behavior were found. Near-surface fishes (pelagic and reef-associated) lost more area than deep-sea and bottom fishes. Tropical, subtropical and polar species lost significantly more area than deep-water and temperate species.

These preliminary results were presented in an invited presentation at the EDIT Symposium, in Paris in January 20, organized by the major European Natural History Museums.

The global marine species richness map (Figure 2) resulting from this work is the most accurate and detailed of its kind, visualizing the

major trends in marine biodiversity, such as exponential richness decline from the equator to the poles, the center of diversity in the coral triangle, east-ward richness declines in the Mediterranean and the Baltic, lower diversity in large estuaries and the center of gyres, etc. This purely data-driven diversity map was meanwhile published in Nature Geoscience (Pauly and Froese 2010).

Outlook

The checking of 1000 maps needs to be finalized, then the winners and losers analysis for these species (including marine mammals, invertebrates and algae) and for all 11,000+ species needs to be redone.

For the future a number of tasks are planned regarding this project. These include to using a meanwhile more realistic IPCC scenario, do an analysis also for a year 2100 scenario, use a web-based GIS (e.g. Open Layer) for display of AquaMaps as well as the creation of Google Ocean layers from AquaMaps. The project is expected to run continue until November 2011.

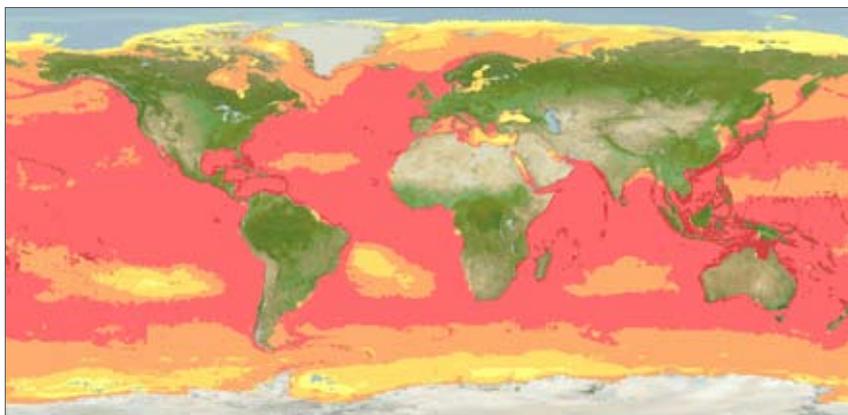


Figure 2

Global marine biodiversity, based on 11,000 range maps for fishes, marine mammals (all), marine reptiles (all), invertebrates and algae. Note the exponential decline of species richness from the equator to the poles, the decline left and right of the center of diversity in the Philippine, Malaysia, Indonesia triangle, the lower richness off estuaries such as Ganges or Amazon, the eastward decline of richness in the Baltic and the Mediterranean, the higher richness on the east side of continents and islands, and the low richness in the centers of ocean current systems.

*Species No.	
688	4844
164	887
31	163
6	30
1	5

Project Team

Rainer Froese and Wilhelm Weinrebe with
Nina Garilao, Kristin Kaschner, Kathleen Reyes
and Josephine Barile

References

Pauly, D. and R. Froese. 2010. A count in the dark. *Nature Geoscience* 3: 662-663.

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Kaschner, K., Tittensor, D., Ready, J., Gerrodette, T & Worm, B. (accepted). Current and future patterns of global marine mammal biodiversity, PlosOne.

Selected Projects

Consequences of Seafloor Warming and Salinity Decrease for Seaweed-Microbe Interactions

Background & Aim of the Project

This project aims to understand the dynamics of seaweed-biofilm interactions under a changing marine environment, using as a model the organism *Fucus vesiculosus*, a habitat forming macroalgae at North Atlantic and Baltic Sea coasts. Core questions to be addressed are:

- ▶ How are biofilms on *Fucus* affected by changes in temperature in terms of microbial diversity, growth, and metabolism?
- ▶ How do these changes in biofilm development affect the functionality of *Fucus* (decrease in photosynthesis through shading, bacterial infections)?
- ▶ Does *Fucus* respond to biofilm development by means of chemical defense and how does this up or down regulation of defense affect the diversity and growth of microorganisms?

Progress Report

Fucus individuals were incubated for three weeks in mesocosms at five different temperatures (5, 10, 15, 20 and 25°C). Associated microorganisms were sampled for quantification and community composition analysis both by surface swabbing and conservation

of thallus pieces. All algal individuals were surface extracted for analysis of chemical defense compounds and for antimicrobial activity bioassays. Also in 2009, an analysis of the bacterial community was conducted by Denaturing Gradient Gel Electrophoresis (PCR-DGGE) of 16S rDNA. In 2010 bacteria present in DAPI-stained surface swab samples were enumerated. A working protocol for selective quantification of different microbial groups on *Fucus* by Fluorescence *In Situ* Hybridization (FISH) was developed. Fucoxanthin was identified as a relevant deterrent of bacterial settlers on *Fucus* surfaces (Saha *et al.*, submitted) and quantified. A second relevant deterrent was isolated by means of bioassay-guided fractionation and is currently subject to structure elucidation. Sequencing works for the identification of bacterial species present on *Fucus* started in winter 2010/11.

Results & Discussion

Translocation of *Fucus* from natural stands into the climate room resulted in a reduction of mean numbers of associated microorganisms, followed by a recovery during the following weeks (Fig. 1). This response was temperature dependent, with the smallest decrease

(or fastest recovery) at 25°C and the slowest recovery at 5°C. Based on DGGE results the recovery phase was correlated with temperature-dependent changes in community composition (see interim report 2010). To understand these shifts in detail we are currently identifying the involved microbial species. Sanger-sequencing of 16SrDNA extracted from excised DGGE bands resulted only in unsatisfying results, as most bands obviously represented more than one bacterial species. An alternative approach (454 sequencing of bar-coded and pooled original 16SrDNA from all samples) is therefore underway.

A further goal of this project was the development of a working protocol for selective epifluorescence microscopy of bacteria associated with *Fucus* and other Phaeophyceae, which is now available. Due to the specific pigmentation of these algae, background fluorescence over a broad wavelength range has so far remained an unresolved problem. We first expected Catalyzed reporter deposition Fluorescence *In Situ* Hybridization (card-FISH) to be helpful to overcome these difficulties. However, card-FISH protocols generally require the bacterial outer envelope to be perforated with detergents such as EDTA, which also

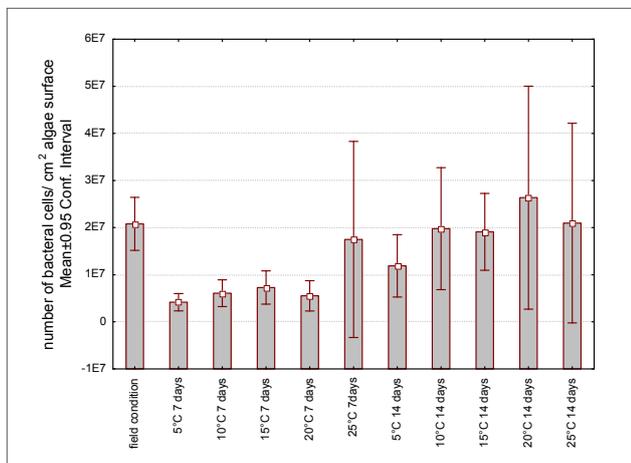


Figure 1

Quantification of DAPI stained bacteria from algae surface swabs [algae collected fresh from the field and after 7 and 14 d of incubation at different temperature levels, n=5]

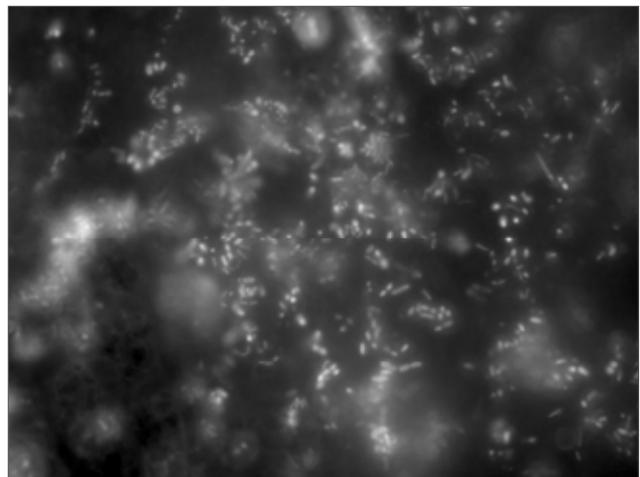


Figure 2

Bacterial assemblage on *Fucus*. Eubacterial cells were stained by FISH, using a mix of Cy3-labeled probes EUBI, EUBII and EUBIII.



Figure 3
Fucus vesiculosus in the Baltic Sea (Picture: Uli Kunz).

destroy the structure of *Fucus* cell walls. Simple FISH turned out to be a better solution, using the fluorescent dye Cy3 in combination with a monochromatic camera (Fig.2).

Fucoxanthin concentrations on the surface of *Fucus* increased with incubation temperature (Fig. 4). Thus they also correlated positively with bacterial densities. As Fucoxanthin is a confirmed deterrent this could indicate different bacterial sensitivities at different temperatures or bacterial induction of Fucoxanthin production. The result might also be due to increased presence of Fucoxanthin producing

diatoms at higher temperatures. Microscopy of conserved *Fucus* surfaces and complementary induction experiments in 2011 should clarify this point.

Outlook

The approach of exhaustive 454 sequencing of 16SrDNA - using the sequencing platform of "The Future Ocean" - promises a complete picture of all bacterial species associated with *Fucus*, both in our indoor experiment and in additional environmental samples. This will allow for the selection of FISH probes and

for subsequent analysis of our samples. In parallel the structure elucidation of settlement inhibiting compounds present on the surface of *Fucus* will be continued and concentrations of identified components will be determined.

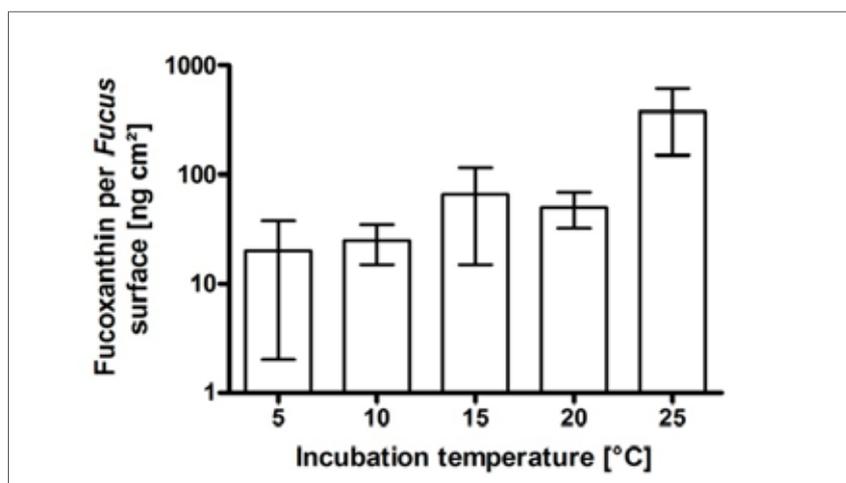


Figure 4
Fucoxanthin concentrations on surfaces of *Fucus* individuals after incubation of 4 weeks at different temperatures (avg +/- 95%CI, n = 5).

Project Team

F. Weinberger, S. Stratil, E. Rickert, M. Saha, T. Treude

Literature

M.Saha, M.Rempt, K.Grosser, G.Pohnert, F.Weinberger (2010): Surface-associated fucoxanthin mediates settlement of bacterial epiphytes on the rockweed *Fucus vesiculosus*. *Biofouling*, submitted.





The Services

*I'm terribly sorry,
but nature is not always
family friendly.*

Takayuki Ikkaku,
Arisa Hosaka
and Toshihiro Kawabata



Public Outreach and Knowledge Transfer – Goals and Measures

The increasing importance that public outreach and knowledge transfer are accorded within the Cluster of Excellence “Future Ocean” is part of a central strategy to actively communicate research content and findings. The selected target groups for this communication are on the one hand the general public, on the other hand, however, also representatives and decision makers from industry and politics. Within the project “Future Ocean” it is increasingly important to be in a position to comment on current events in a timely manner. These activities are gaining more and more in importance as the cluster prepares the renewal proposal for the German Science Foundation (DFG). Dynamic and multifaceted press and public relations work that aims at long-term effect is of fundamental importance for the Kiel Marine Sciences.

Tools

The public outreach work of the Future Ocean in 2010 could again contribute to increasing the positive perception of the cluster in the public eye and further raising public awareness of the critical condition of the oceans. In order to make the marine science topics of the Future Ocean communicable to differing target groups public outreach uses various tools. Among them is on the one hand active press work, with the goal of placing topical issues in the regional and supra-regional print media. Exhibitions and public lectures on marine science topics and equipment allow interested citizens a closer look at the Future Ocean. Specially prepared programs for school children provide information about current research. Events on current technical and scientific research developments provide information for decision makers and industry representatives on scientific findings which may influence for their planning. The portfolio is rounded off with general public outreach measures; from publications, such as the World Ocean Review, to an internal newsletter, which keeps project members informed, as well as a website, which provides important information about the cluster.

Targeted measures were also undertaken; a museum exhibition and presentations at trade fairs, publications, workshops, as well as programs for young children and school

children. Special emphasis was put on interdisciplinary collaboration and close cooperation with university and external partners for the successful development and implementation of these measures.

Exhibitions

One of the most visible activities outside of Schleswig-Holstein in the area of public outreach is certainly the exhibition on marine science. The big highlight in the area of museum presentations in 2010 was the exhibition “Future Ocean” in the Deutsches Museum in Munich. The exhibition developed especially for the Deutsches Museum was held in the Center for New Technologies and demonstrated how the world’s oceans will change in the future and what opportunities and risks the oceans hold for mankind. The special design, developed by the Muthesius Academy of Fine Arts and Design, makes the exhibition unique, as does its method of communicating marine science topics (see pages 64 in this report).

Directly following the presentation in Munich, part of the exhibition travelled to Berlin with the title “The Role of the Ocean in Climate Change”, which was shown in the Paul Löbe House of the Deutsche Bundestag (German Federal Parliament). The aim was to communicate not only the fascination of marine research to a broad public and politicians but also to illustrate the

fundamental importance of the oceans for a growing population (see pages 64-65 in this report).

In addition to the national exhibition, marine science topics were also presented locally, for example at the Kiel Week from June 19th to 23rd. In the science year on the topic “The Future of Energy” scientists of the Cluster of Excellence, among them Prof. Rüdiger Schulz, presented their prospects for future alternative energy sources on the ship “MS Wissenschaft” (Fig. 1). At information terminals visitors could learn about the use of microalgae for the production of bio-energy or the potentials of methane hydrates.

Publications

The Deepwater Horizon catastrophe of April 22nd in the Gulf of Mexico led to the second largest man-made oil spill contaminating the ocean and the surrounding coasts. This was reason enough for the scientists of the Kiel Marine Sciences to join in the discussion about the causes as well as the assessment of the ecological and economic consequences of the spill. With extensive background information the scientists of the cluster published a German language “Oil paper”, and with this publication they were able to contribute to a better understanding of the facts surrounding the spill, thus making it more likely that a future oil catastrophe can be prevented.

A second publication in November 2010 was the first "World Ocean Review" (WOR) with the motto "Living with the oceans". The stated goal of the WOR was and is to elucidate the current state of the oceans on a scientific basis and to focus the consciousness of the public on the needs of the ocean for the long term. In this first project initiated by the mare publication house and its maribus GmbH, the Cluster of Excellence was an essential partner. The outstanding expertise and the interdisciplinary approach of the cluster made it possible for over 40 scientists to contribute content to this first World Ocean Review, which appeared first in German. In the meantime the WOR has also been published in English. The WOR was presented at a large press conference on November 18th, which was reported on in the regional media and also in the ARD daily nationwide news program "Tagesschau".

Workshops /Trade Fairs

In addition to exhibitions and publications one of the central concerns of public outreach is to be present at regional, national and international conferences and fairs and to organize workshops. The first of these events was the "Algae workshop" on February 23, 2010 in the Kiel Science Park (Wissenschaftspark). More than 100 participants came on invitation of the Cluster of Excellence to the one day event. The aim of the initiative from the perspective of the cluster areas knowledge transfer and promotion of young scientists was the joint discussion between representatives of industry and science on various aspects of algae exploitation.

From March 9th to 11th the cluster exhibited with a booth at the OI Oceanology International in London. At the world's largest trade fair for marine technologies the Cluster of Excellence presented a model of a high-resolution seismic 3D system at the joint northern German stand organized by the WTSH – the Business Development and Technology Transfer Corporation of Schleswig-Holstein.

At the European Maritime Day of the European Commission 2010 from 19th to 21st May in Gijon Kiel Marine Sciences were also present with a stand about the cluster. In 2010 the Cluster of Excellence "Future Ocean" also presented several workshops in Kiel. In May and October the Kiel Marketplace was organized in cooperation with the Maritime Cluster Schleswig-Holstein. Begun in 2008, the event series has established itself in the Kiel event calendar. The one-day workshops support networking between science and industry and offer a forum

for information exchange on topical issues. The 3rd Biannual Symposium "Future Ocean" in September attracted over 250 marine researchers from 18 countries to the campus of Kiel University. The scientists were occupied with topics such as the dangers of rising sea level, the ocean as a CO₂ sink, the opportunities and dangers of climate engineering and research on tsunamis. At the three day symposium high quality global knowledge transfer took place.

Public Programs

The Cluster of Excellence does not wish to promote communication only among scientists or between scientists and industry or the broader public, it also seeks to waken enthusiasm in children and young people for marine science topics. True to the motto "What you know you will also be willing to protect" special programs and events were initiated.

Most importantly, the Children's University, which took place again from September to November. The program, started by the Cluster of Excellence in 2008, is no longer limited only to marine topics, but also includes many other research areas of Kiel University (CAU). In the coming years the Children's University at the CAU will be anchored as a permanent feature.

In its programs for children and youth the Cluster of Excellence is also committed to cooperation. Thus public outreach had a definitive part in the nomination of the state capital Kiel as "City of Young Researchers" in May 2010. "An

Expedition with the Research Ship through the Kiel Schools" was the title of the concept that was best received by the Körber, Robert Bosch and German Telekom Foundations. At the end of May 2011 the collaborations and school projects between science, industry and the schools will culminate in a big Kiel Science Festival on the "Hörn" in downtown Kiel.

At the end of August a collaboration was started for children between the ages of five and eight. The Mediendom of the University of Applied Sciences in Kiel and the public outreach unit of the Cluster of Excellence have developed a new 360° dome presentation based on the picture book story "The Little Polar Bear and the Whales". Aside from illustrating the story by Hans de Beer, the presentation explores the polar bears and their living environment, the Arctic. Climate change is most visible there where the polar bears are at home.

Important indicators for the success of public outreach work is the high number of visitors in the museum exhibits, at trade fair presentations and workshops, as well as the increasing number of hits on the website of the cluster. In addition the demand for print media such as flyers and brochures, which, in their well-received corporate design, are highly informative and striking, increased in 2010, ensuring that the Future Ocean in the area of public outreach and knowledge transfer is achieving an extraordinary position in Germany.



Figure 1

Prof. Rüdiger Schulz explains the potential of microalgae as a source of energy on the MS Wissenschaft.

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The Exhibition “Future Ocean” in the Deutsches Museum in Munich

From 25th March until 30th August 2010 the Cluster of Excellence “Future Ocean” presented the first marine science special exhibition in the renowned Deutsches Museum in Munich. Using a dark exhibition design and additional exhibits in an area of app. 300 m², the Kiel Cluster of Excellence presented the ocean’s impact on the climate and the earth as well as the opportunities offered and the risks posed by the ocean. Comprising around 36 exhibits this was the largest exhibition of the Cluster of Excellence up to now. A total of about 120,000 visitors were intrigued by the topics of the marine research

including ocean acidification, sea level rise, resources of the deep sea or overfishing. The exhibition was developed in cooperation between scientists of the Christian-Albrechts University Kiel, the Leibniz Institute for Marine Sciences (IFM-GEOMAR), the Institute for the World Economy (IfW) and the designers of the exhibition, the Muthesius Academy of Fine Arts and Design and was the high point of all the presentations of the Cluster of Excellence “Future Ocean” up to that point. The interest of the national press was great, which led to numerous inquiries from museums and science

centers regarding availability of the exhibition. An evaluation by the Technical University Munich (TUM School of Education) commissioned during the exhibition confirmed the success of the exhibition with the visitors.

An additional product for the exhibition was developed – in addition to the exhibition flyer and film for the opening on March 24, 2010 – a 111 page exhibition catalogue in German and English.



Figure 1
Bizarre creatures of the deep sea.

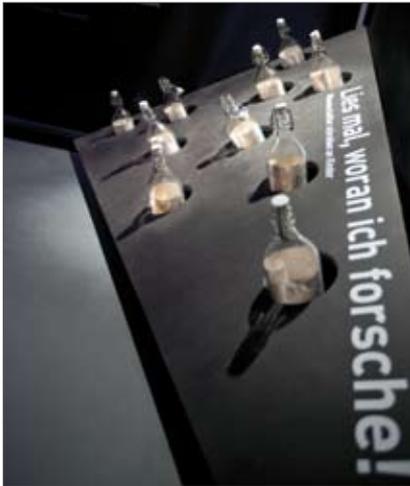


Figure 2
Message in a bottle.



Figure 3
View of the cluster exhibition at the Paul-Löbe Haus in Berlin.

New Modules

For the exhibition in Munich modules were newly conceived and developed by an interdisciplinary team. In this way for many topics of the Cluster of Excellence, such as coasts at risk, ocean observation, resources, ocean acidification, overfishing and law of the sea, new exhibits or further developments of existing modules were developed, which can now be used also independently from the exhibit as a whole. Many of the exhibits are also suitable for day lit spaces. In addition, modules for children were also developed for the first time.

Exhibition at Paul Löbe House

Following the exhibition in Munich, the exhibition was presented for four weeks in the Paul Löbe House of the Deutsche Bundestag (German Federal Parliament) in Berlin. In a 200 m² large, four meter high black cube the special deep sea atmosphere was brought into the middle of the wide inner space of the Paul Löbe House and thus into the daily routine of numerous politicians. The special exhibition "The Role of the Ocean in Climate Change" was officially opened for the general public on September 12, 2010 as part of the "Day of

Insights and Prospects" hosted by the Deutsche Bundestag and ran until October 8, 2010.



Figure 4
Deep-sea landers in front of the Paul Löbe Haus.

Contact

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Public Outreach – School Programs

The Cluster of Excellence The Future Ocean organizes, coordinates and plans the Kids' and Students' University and various other school activities for the Christian-Albrechts Universität zu Kiel as a whole. The major goal is, to communicate new scientific knowledge directly to schools and to reach out to the next generation of science students. The Future Ocean aids science education together with its partners through public lectures and also offers various opportunities for joint experiments for pupils/students in the laboratory and at sea. In 2010 the emphasis on reaching in particular younger pupils was continued. New media, such as a 3-D multimedia show designed for dome planetariums, were jointly organized and successfully produced with various partners. Other major activities in 2010 are summarized here.



Figure 1

Kids explore bioreactor panels at the Kid's and Students' University lecture on microalgae as energy resource.

Kids' and Students' University

In the third year of the Kids' and Students' University Kiel about 1,400 children visited the public lectures offered. Scientists from various departments of the Cluster of Excellence "The Future Ocean" and from two other research focuses of the CAU introduced the children to their research. Pupils experienced the excitement and fascination of science. Each lecture was complemented with a handout in order to allow the audience to review the content at home. All 18 handouts and videos are available online free of charge on the website www.ozean-der-zukunft.de, in order to enable students, parents and teachers to learn more about the marine ecosystem and marine research.

To attract attention to the lectures and to spread information about the topics in the Kiel region the media partnership with the local daily newspaper Kieler Nachrichten (print run

~100.000) and the national magazine Geolino established in 2008 was continued. The Kids' and Students' University Kiel is also listed on the German Children's University website www.die-kinder-uni.de and is a member of the European Children's Universities Network (<http://eucu.net/>).

The Kids' and Students' University has now been established as a permanent, recurring event at the University of Kiel with yearly changing topics.

360° Media Production Project

A concept for a modern planetarium presentation on the consequences of global change

was developed for preschools and elementary schools as a 360° full dome presentation. The production is based on the picture book story "The Little Polar Bear and the Whales" by Hans de Beer featuring the famous character Lars the little polar bear. The project was produced in cooperation with the Mediendom at the technical college, Kiel, targeting children aged 5 to 8. In this adventure Lars saves the whales from whale hunters and from a dangerous situation created by a glacier melting. The planetarium show uses Lars as an ambassador for the threats to the Arctic. The show is subdivided into three major parts: 1. an astronomy section, introducing the constellation of the



Figure 2

Students and Scientists contact real scientific experiments on board research Vessel Littorina.



Figure 3

Children actively participate in lectures given by Future Ocean researchers on actual research topics.

Great Bear (Big Dipper) in the Arctic, 2. the story of Lars adapted from the picture book and 3. as a contribution of "The Future Ocean", information about the nature of the Arctic and global change.

The 360° production was launched in January 2011 and has been extremely successful. So far in 2011 shows have been planned in eleven planetariums throughout Germany and in other German-speaking countries in Europe. An English language version is under development.

Kiel is the German City of Young Researchers 2011 (Stadt der jungen Forscher)

The City of Kiel, in cooperation with the Future Ocean, participated in a nationwide competition for funding to support education and cooperation between schools and extracurricular facilities. The competition is sponsored jointly by the Körber Foundation, the Robert Bosch Foundation and the Deutsche Telekom Foundation. The City of Kiel established a local consortium comprising the university, research institutes, schools, enterprises and other facilities including the Cluster of Excellence "Future Ocean" to develop a concept to foster pupils' interest in practical research activities in Kiel. In summer 2010 the concept was presented and was selected to be funded.

The idea behind the application was the following: a virtual research vessel is to be sent on a tour through schools in Kiel. The students run projects in cooperation with scientists or people from economic partnerships. More than 70 projects from schools in Kiel applied for project money. In the end 49 projects could be

funded, 33 in cooperation with the university. The results of the school projects will be presented at a science festival in May 2011 in the city of Kiel.

The Federal Environmental Award (BundesUmweltWettbewerb)

A nationwide environmental competition provided an opportunity for committed and talented students throughout Germany to test their abilities in the field of environmental studies. The competition was designed for young people between 13 and 21. The BUW offers a range of attractive prizes and is conducted annually by the IPN on behalf of the Federal Ministry for Education and Research (BMBF). To transfer the Future Ocean topics to schools in all of Germany, a special annual prize was awarded for the topic "Future Ocean – too high, too warm, too acidic?".

On 17th September the presentation of prizes took place in the Heinz-Sielmann-Stiftung, Duderstadt: funding of 450 Euro was awarded to Johannes Busse und Frederik Thomsen, Bremen (Mobil durch Algen).

School Book with the Cornelsen-Verlag, Berlin

Scientists of the future ocean and teachers submitted their articles about marine sciences at the Cornelsen Verlag in Berlin finally in October 2010. The publisher is currently revising the volume. Publication is planned in 2011.

Outlook

The Children's University at the University of Kiel for kids aged 8 to 16 will be continued and

additionally a concept for the implementation of a school lab at Kiel University is developed. The cooperation with Federal Environmental Award (BundesUmweltWettbewerb, coordinated by IPN) will continue. The work within the network Stadt der jungen Forscher and the festival for 2011 will be pursued. And the planetarium production Little Polar Bear Lars and the climate change will be translated to bring the show abroad.

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. The Kids' and Students' University is a collaboration of these partners and the Institute for Science and Mathematics Education, Kiel (IPN), with technical support from the computer center of Kiel University. It is actively sponsored by the Foundation "Stiftung 200 Jahre Sparkasse Kiel" and promoted through a media partnership with the major local newspaper Kieler Nachrichten and Geolino, a nationwide popular science journal for kids.

Contact

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Kiel Data Management : Collect, Describe, Share and Link Data and Publications

The Kiel Data Management Team (KDMT) started as a collaborative approach of three large-scale projects (SFB574, SFB754 and Cluster of Excellence “ The Future Ocean”) and the Leibniz Institute of Marine Sciences IFM-GEOMAR in 2009. Currently it comprises two main infrastructures: the KDMI portal with 15 communities (at the end of 2010) and the repository OceanRep. Publications and data are the very measure of successful science and an attractive meeting place for both scientists and public. The linkage of both systems has been set up now, linking data information to publications and vice versa. All members can log in to the portal and search for expedition or numerical model information, data and publication links.

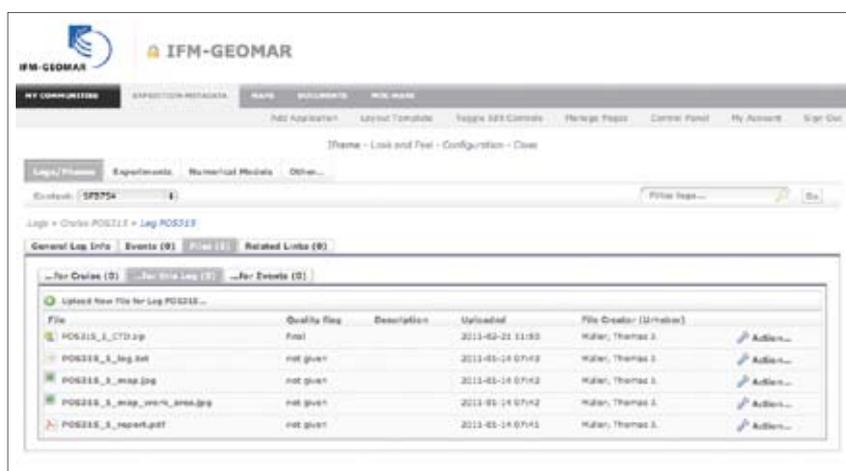


Figure 1
Screenshot of the Kiel Data Management Portal.

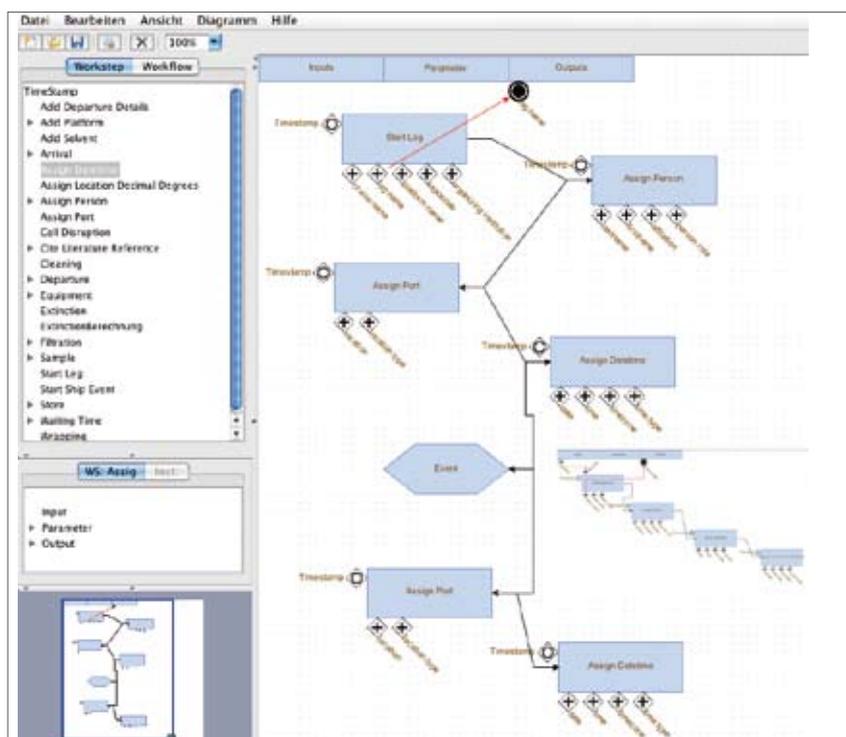


Figure 2
Workflow Systems 1. Measurement procedures can be defined through a graphical system.

Kiel Data Management Approach

The Kiel Data Management concept focuses on the identity of an individual scientist and his or her work(flow). Instead of following the classical project-based practice, the newly developed personalized data management approach avoids redundancy in data management efforts and facilitates interdisciplinary collaboration. All generated data, whether it originates from field observations, numerical simulations or experiments, is treated as a process irrespective of the discipline it comes from. This approach allows storage of the data in a single consistent data model.

Services

We offer guidance concerning formulation of a data management concept in proposals and its implementation (required staff and hardware), offer support for usage of the portal (how to log in, where to upload data), help with recommendations for portal usage in teams / research units / projects and collect ideas for the proposal of a future data policy on our web pages.

We actively contact groups of potential users, e.g. meeting with Research Group leaders in order to present the portal and the metadata application in June 2010. A workshop on the proposition of a future data policy, data templates and data archives was held in fall 2010. The outcome is presented in our portal and all project members were invited to take part in the discussion.

We developed a cruise checklist for chief scientists to enhance the information flow and take over some reporting tasks (pre-filled CSR).

Current State of the system Data exchange within a project

At present we offer a web-based solution which allows scientists to upload bulk data files in the context of cruises, expeditions or models with allowance of any file format and structure of its content. Access control for a file is primarily based on the community context it was uploaded within but may be restricted by the file's owner (Fig. 1). There is currently no simple way to merge data and search for individual parameters or regions but the metadata of what, when, where and who are well documented for a file's content (i.e. data) and this aids homogenization of the metadata.

There was lively usage of the metadata solution in 2010: creation of 435 expedition entries, 36249 stations and 768 uploaded files.

Repository

A repository for full text print publications has been set up at IFM-GEOMAR in cooperation with the Future Ocean. The repository is linked with the data management portal such that authors, publications and their data can be linked. The relation between data and print publication is then available in both systems. You may find a publication in the repository and get a datalink, or you find a data collection in the database, giving references to publications (Fig. 4). Especially projects often need to provide a common publication list as their final outcome, it is possible to have a linked data list, as well. The importation of publications within the Future Ocean context is almost complete.

Future plans: Upcoming Database Solution

In advance of data collection, the measurement procedure with all parameters has to be defined by the scientist (Fig. 2) with a

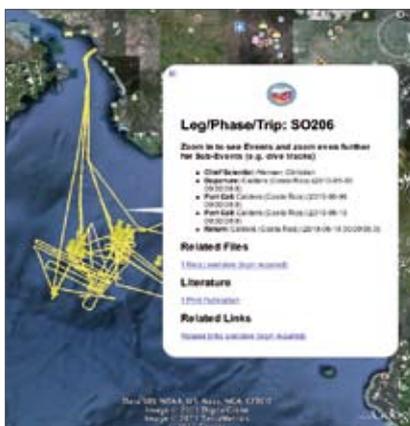


Figure 4

Data can finally be exported and displayed in Mapping Application such as Google Earth and others

Figure 3

Workflow Systems 2. Data input is organized through dedicated web forms.

graphical interface. This ensures the collection of all the necessary information during the data creation process. Data input can be a file import or entered by hand into a web form (Fig. 3) (replacing excel sheets). The underlying data model is capable of storing data from very different disciplines. New procedures can be included just by defining a corresponding workflow.

Given this workflow definition in XML the filled workflow can be validated via an XSD schema. This includes consistency and completeness of metadata, data types (geographical position, date time, number and text) and data values with ranges. The database can serve as single point of truth.

Collaborations

► GKSS (May, 2010) Gisbert Breibach from GKSS presented the COSYNA data portal.

Working Group



Carsten Schirnick, Hela Mehtens, Pina Springer, Dirk Fleischer

► BSH/DOD (June, 2010) Anne Che-Bohntengel, Friedrich Nast and Maren Fabricius visited Kiel and gave a lecture in the Meereskundliches Kolloquium. A close cooperation regarding DSHIP data and station books from German research vessels has been established.

► Computer Science Department CAU Prof. Thalheim: Development of a web application to visualize the workflow definition together with the possibility of inserting data in generic data model; Prof. Hasselbring: Pubflow (DFG-Proposal) as a possible data provider and actual use case

► ISOS: As part of the OpenAccess information day organized by the ISOS Graduate school the KDMT presented an outlook on what OpenAccess on data could mean to the scientific work of scientists

Further Reading

- 1 | <https://portal.ifm-geomar.de/group/future-ocean/metadata>
- 2 | <https://portal.ifm-geomar.de>
- 3 | <https://portal.ifm-geomar.de/web/guest/about-us>

Transfer to Application

The Transfer to Application project aims to communicate innovative knowledge and new technologies developed by the Future Ocean into industry and to non-governmental organizations. Many university and industry related organizations are already active in this field. Some aim to establish connections between scientists and industry partners, others help local companies to become internationally visible, still others 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. Some initiatives have been started in 2008, more of them in 2009. This process was still continuing in 2010 in order to evaluate where the best potentials for success lie. Whereas in 2009 the initiatives focused on PhD students and postdocs working in the cluster, in 2010 the initiatives focused on external partners outside the cluster. Common activities with both external and internal partners will start in 2011.

Science and Industry Networking

In order to foster and initiate discussion and exchange between researchers and industry the workshop series "Science meets Industry" was initiated together with the Integrated School of Ocean Sciences (ISOS). The concept of these workshops is to organize presentations by researchers and companies on certain topics, followed by discussions and open brainstorming on the future in this field. After excellent experiences in 2009 with a workshop on "Energy from the Sea" (s. Annual Report 2009) a second workshop "Science meets Industry – Algae of the Future" was organized in 2010. Algae (small, single cell microalgae and cyanobacteria as well as large, sessile macroalgae) are gaining in interest, both scientifically and economically, for biomass and bioenergy production as well as in biotechnology (see page 72). More workshops are planned for 2011.

Second Kiel Marketplace – Noise in the Sea

The event series "Kiel Marketplace" is jointly organized with the Maritime Cluster Northern Germany, an association of the local maritime industry. The event is tailored to support networking between science and industry and offers a forum for information exchange on current topics. The target audience comprises scientists from the Cluster of Excellence, representatives from companies in the Maritime Cluster Northern Germany and from politics.

The 2nd marketplace took place on the topic "Noise in the Sea". Noise is a constantly increasing type of pollution even and in particular in the ocean due to the increase in shipping activities, seismic investigations, the construction of offshore power plants, drilling platforms and other man made installations. This has consequences for any kind of life in the oceans; not only for mammals but also for fish

and other organisms. The workshop covered very diverse topics, spanning the basic physics of underwater noise origin and propagation to various technical approaches to noise reduction and prevention. This included well known procedures such as the production of air bubble curtains to limit noise from off-shore rams or special shapes and materials used to construct ship propellers to avoid cavitation. New "silent" methods to recover objects included icing of material. Special noiseless techniques for under water communication were discussed as well. The workshop attracted around 50 participants for stimulating talks and discussions in the Chamber of Commerce and Industry (IHK) in Kiel.

Third Kiel Marketplace – Submarine Energy Supply

The third Kiel Marketplace was organized on the topic of "Submarine Energy Supply". There is an increasing demand from researchers, who wish to deploy long term observatories onto the seafloor, which need to be supplied with energy, but also industrial installations would benefit from a prolonged life span and longer maintenance intervals from improved on-site energy supply. Worldwide trends can be observed, e.g. oil and gas producing platforms may be replaced by completely automatic production installations located on the seafloor.

Speakers from the Future Ocean and from industry reported on current developments and various trends. Discussions focused on demands, challenges and technical limitations in the deep sea environment. Among these were e.g. the advantages and disadvantages of various types of batteries (e.g. Li Ion) and fuel cells. The discussion impressively demonstrated that the requirements for submarine



Figure 1
More than 100 participants attended the workshop "Science meets Industry – Algae of the Future".



Figure 2
Young scientists took advantage of the opportunity to contact representatives from industry.

energy supply are constantly increasing. The Kiel Marketplace strives to create a stimulating but relaxed atmosphere for discussions to foster mutual knowledge transfer between science, politics and industry.

The recent marketplace events have become quite popular and have therefore grown significantly in attendance. As a result the Kiel Marketplace has grown from an experiment in 2009 to a firmly established event in 2010. Further Market place events will be organised in 2011, with the next one focusing on Marine Resources – Exploration and Exploitation.

Science Marketing:

The Oceanology International (OI) in London, UK, is the world's premier meeting for ocean technology and the marine sciences community.



Figure 3
Nasser Bani Hassan and Dr. Jörg Bialas attended the Oceanology International (OI) in London. They are participants of the "Industrial-Fair-Mentoring"-program, aiming to initiate contacts between maritime industry and research.

More than 6000 visitors from all over the world attended the OI in 2010, as it is both a trade fair with more than 550 exhibitors and at the same time a conference with technical and science sessions. Together with the Leibniz Institute for Marine Sciences IFM-GEOMAR, the Future Ocean set up an exhibition booth in the German pavilion organized by the Business Development and Technology Transfer Corporation of Schleswig-Holstein (WTSH).

At the OI the Future Ocean presented a novel 3-D seismic data acquisition system. Compared to conventional 3D seismic systems it features a cross cable with several hydrophones towed perpendicularly to the ship's course, fed by a single air gun close to the ship. This setup leads to greatly reduced operational costs as the system can easily be operated from mid-size vessels. A simple construction model was presented at the show to illustrate and explain the function and setup of the system (Fig. 3).

As part of the fair mentoring program conducted together with the ISOS, two Future Ocean PhD students participated in the exhibition as well, stepping out of their research labs to experience the world of industry and to look for potential working fields and topics or simply to see the future. Overall they felt that this was a good experience to learn about how the offshore industry works and to develop a feeling for the business environment. The Future Ocean also took the opportunity to present Kiel and the state of Schleswig Holstein as an important location for marine research and industry. Based on this experience we are now monitoring potential demands of cluster members for trade fairs that may be worthwhile to visit and present our project.

Other Networking activities

In 2010 networking activities with external, mainly local partners were continued and intensified. These included the Kiel Business Development Corporation, the city of Kiel and those responsible for transfer to application at various institutions like the Ministry of Economics, Science and Transportation, but also the Technical College in Kiel, the University of Lübeck the Institute for Baltic Sea Research in Rostock and the GKFZ in Geesthacht. A survey among companies was conducted, confirming that by far the most important link between science and industry are close personal contacts, leading to more than 45% of the co-operations between research institutes or universities and companies.

Outlook

In 2011 the Transfer to Application project will continue many of the successfully started projects. The demand of cluster members for certain industrial and trade fairs in 2011 is estimated, and the transfer to application is querying members and projects for potential developments suited for exhibition at such an event. The event series "Kiel Marketplace" and "Science meets Industry" will be continued. The number of participating companies will most likely increase again in 2011 as the Maritime Cluster has expanded to include our neighbor states Hamburg and Niedersachsen.

The Cluster will closely cooperate with the Chamber of Commerce and Industry in Kiel and the Christian-Albrechts-University. Managed by the Cluster of Excellence, four meetings on maritime topics will be conducted. The first one will start in January 2011 ("Researching Research – The innovation tour of the metropol region's Chambers of Commerce and Industry").

Contact

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Algae of the Future: A Workshop in the Series “Science meets Industry”

The workshop series “Science meets Industry” is a cooperative event between the Transfer to Application group and the Integrated School of Ocean Sciences. “Algae for the Future” was the title of the 2010 event, bringing together key players from academia, industry, governmental and non-governmental organizations.

Algae, an almost disregarded resource in the past, are increasingly the focus of attention in the search for new sources of energy, medical applications and health products. The potential use of algae is manifold: they are directly edible and provide extracts for dietary supplements, many are sources of natural antiviral and antibacterial agents and in pilot projects they have been shown as a potential bio energy source. Reason enough to attract academic and commercial interest.

Workshop participants discussed several aspects of their work. Professor Thomas Friedl, head of the Culture Collection of Algae (SAE) at Göttingen University spoke about their efforts to culture and conserve microalgal diversity. The SAE hosts over 2400 algal strains – one tenth of the total number that has been described to date.

Biologist and scientific co-organizer of the workshop Professor Rüdiger Schulz, a member of the “Future Ocean” cluster, specializes in microalgae: “They are outstandingly suitable for biogas plants where they can be exploited to almost 100 per cent.” Professor Schulz is convinced that “there is a huge potential in microalgae on the biotechnology and bioenergy level– it just needs to be detected”. Still, the efficiency of bio-reactors working with algae remains controversial. Scientists such as workshop participant Professor Dieter Hanelt from Hamburg University doubt whether such bioreactors will ever be energetically or economically viable.

While scientists still face a wide area for further research, others have already succeeded



Figure 1

The accompanying exhibition offered an overview on the many aspects related to the use of algae.
Picture: Gertje König

in making commercial use of algae. The Kiel company oceanBASIS markets products containing macroalgal extracts in a range of cosmetics, wines, and teas. The Bremen-based BlueBioTech offers products covering chemicals, veterinary diets, pharmaceuticals and dietary supplements. Representatives from these and several other small and larger scale industrial firms presented their projects and products and gave an outlook on future developments.

For the more than 100 workshop participants, the talks as well as the accompanying exhibition offered an overview on the many aspects related to the use of algae and a forum for networking across science and industry. For the young scientists attending it gave an opportunity to

experience the cross-over between science and application first-hand and to get in touch with professionals from both groups.

In the end, neither researchers nor manufacturers were willing to forecast which and how many algae species will be commercially successful in the long term. But on one issue there was consensus: the importance of algae will continually increase.

Contact

Annette Preikschat, Rüdiger Schulz, Avan Antia
Transfer to Application and
Integrated School of Ocean Sciences

Integrated School of Ocean Sciences: Attracting the Best Young Researchers to Kiel

About twenty percent of the 130 candidates taking part in the PhD program of the “Future Ocean” cluster are international students, reflecting the strong transnational links of Kiel marine sciences. During the last year, the Integrated School of Ocean Sciences has been involved in PhD exchange networks and seeks to present Kiel as an attractive location for early stage researchers.

A multidisciplinary environment in marine research, an excellent research infrastructure, a network of dynamic scientists and a PhD program in Marine Sciences make Kiel an attractive destination for the best young researchers. To attract international PhDs, our strategy is to put the research focus in the forefront, giving interested students the opportunity to match their own interests with interdisciplinary topics in Kiel. Through offering personal support, peer mentoring, informal language courses and training in scientific skills, the PhD programme is particularly well received by foreign students.

The ISOS supports PhD exchanges and co-operations between graduate schools of several partner institutions.

MENTOR Network

The MENTOR (Marine European Network for Training Of Researchers) Network aims at fostering the exchange of PhDs between five leading European marine science institutions in Southampton, Bergen, Brest, Bremen and Kiel. A first activity of the Network resulted in a successful Initial Training Network (ITN) project ‘Calcification of Marine Organisms’ (CalMarO), coordinated by IFM-GEOMAR with training coordination through the ISOS. Nine PhD and three postdoc researchers received trans-



Figure 1
Summer School in Qingdao, China.

European training on the topic of calcification in marine organisms.

Sino-German Cooperation in Marine Sciences

Exchange of doctoral candidates between Kiel and our cooperation partners at the Ocean University of China (OUC) in Qingdao has been pursued by profiling state-of-the-art research topics from the “Future Ocean” cluster and presenting Kiel as a premier place for research-driven doctoral education (see Figure 2). In 2010, eight doctoral candidates from the OUC were conducting research in Kiel, in topics as diverse as marine ecology, biogeochemical modeling and law of the sea.

DAAD Global Portal “PhD Germany”

To reach the best young researchers worldwide, selected cluster themes and scientists are featured on the international online portal “PhD Germany” of the German Academic Exchange Service (DAAD). This new instrument aims at making German Universities accessible on a single portal for foreign students globally. A central application procedure and administrative services by the DAAD as well as an excellent global visibility and reputation make this an attractive platform.



Figure 2
Kiel: an excellent place for PhD research.

future ocean
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At the Integrated School of Ocean Sciences (ISOS) young researchers sharpen their scientific profile and are challenged to think beyond their discipline and equip themselves for life after a Ph.D.
www.futureocean.org/isos

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OCEAN UNIVERSITÄT QINGDAO
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marthaus
KURSTHOCHSCHULE
IFM-GEOMAR

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Making Science Comprehensible

In a PhD thesis, excellence in research is a priority. But in order to stand out it takes additional skills, communication being one of them. Scientists are increasingly expected to explain their research in an understandable and even interesting manner. This is not easy to do but several ISOS doctoral candidates rose to the challenge. Guided by a science journalist, they sat down and wrote about their work. One of the results is Philipp Schubert's report on eelgrass meadows in the Baltic Sea.

Kiel Marine Scientists Listen to the Grass Grow

It grows along the entire European coastline and is, effectively, the aquarium filter of the Baltic Sea: common eelgrass *Zostera marina*. This underestimated and sometimes even unloved plant is at the center of attention of biologists from the Leibniz Institute of Marine Sciences (IFM-GEOMAR) in Kiel.

"Now all the stress and having to get up early are forgotten, aren't they?" Philipp Schubert asks his "crew" as he starts up the outboard motor of the inflatable boat. The Kiel Bight is still shrouded in early morning mist; sea gulls sit lethargically on the bollards. What for others would be the beginning of a harbor cruise is, in the life of a marine scientist, a normal work day. On board are 200 kg of diving and underwater equipment the scientists need to chart the distribution of seagrass in a predefined area.

Today the research divers are heading to the eelgrass meadows of Eckernförde Bight, about an hour's cruise from IFM-GEOMAR. Schubert explains what makes this ubiquitous seagrass so fascinating. For humans, *Zostera* provides invaluable ecosystem services, filtering contaminants and nutrients out of nearshore waters –like an oversized filter fringing the coastline. The seagrass meadows are nursery grounds for many important species of commercial and recreational fishing.

Less well publicized is that the underwater meadows offer important mechanical protection from erosion. Eelgrass is the only sea plant that can root in loose sand, forming large clumps that secure and hold the sand in place.

In addition the long leaves dampen the energy of the waves and reduce the current. In this way eelgrass prevents sand from being transported away from the coastline and contributes decisively to coastal protection on the North and Baltic Seas. "Many coastal communities forget this and are just annoyed by the unwanted flotsam after big storms" Schubert shakes his head. "I think that with some explanation every last tourist would be quickly convinced how important a functioning environment is for his or her holiday".

Getting this message across is important to Philipp Schubert; he is alarmed by the fact that the worldwide occurrence of the estimated

20 species of eelgrass has been decreasing rapidly for decades. Worldwide over 10,000 hectares of eelgrass are lost annually.

As is often the case, scientists blame human activity for the loss: over-fertilization of coastal waters through nutrient runoff from agriculture, destruction of entire eelgrass meadows through harbor building, dredging and the use of trawl nets are some causes. From an economical viewpoint this is a huge financial loss, considering that the value of eelgrass meadows for fishery alone is valued by researchers at 2,500€ per hectare.

Reason enough for the Schleswig-Holstein Department of Agriculture, Environment



Figure 1
Eelgrass in the Baltic Sea. Picture: Uli Kunz (kunzgalerie.de)



Figure 2

A GPS logger attached to a buoy tracks the exact route of the dive that can later be noted on a map. Picture: Uli Kunz (kunzgalerie.de)

and Rural Spaces (LLUR) to finance eelgrass research at the IFM-GEOMAR, including a project in which project Schubert is doing his doctoral studies. Schubert is charged with locating, estimating and mapping the occurrences of eelgrass between Flensburg and Fehmarn. In his doctoral thesis he is personally more interested in the fish populations associated with the eelgrass than the eelgrass itself. He summarizes his inquiries thus: "Do the fish prefer larger or smaller meadows; does the state of health or the genetic diversity of the meadow play a decisive role?" These are questions which can prove essential for the future development of eelgrass as well as for

the fish populations living in our backyard. In the last 20 years the decline of eelgrass populations has slowed, however the damage done is slow to recover: "The decrease in the maximum proliferation depth from 14 meters to 5 meters by the end of the 80s was dramatic." Schubert says. Now, 30 years later, Schubert and his team find eelgrass growing again at a depth of seven meters, "a first success from the decrease in nutrient load!" the biologist gladly reports.

Finding out at what depths the plant grows is thus an important aspect of the mapping. Katharina Brundiers, the first diver, prepares her equipment during the ride. "I dive at a depth of eight meters, swim with a compass

in the direction of land and note the eelgrass coverage" she explains. She pays special attention to the plants located at the greatest depths. During her dive she pulls a cell phone-sized GPS logger attached to a buoy behind her. "That way the exact route can later be noted on a map and every observation of the diver localized" explains Schubert. As a result of his doctoral thesis he should be able to present a map of all the eelgrass meadows on the Schleswig-Holstein coast and thus contribute to its protection.

Sometimes he is struck with awe by the daunting amount of eelgrass that awaits him on the Baltic coast – "But the more eelgrass the better!" he adds, smiling, and seems to be looking forward to the task ahead.



Figure 3

Eelgrass reduces coastal erosion by dampening wave energy. Picture: Uli Kunz (kunzgalerie.de)

Contact

Philipp Schubert

is a PhD student in the working group "Evolutionary Ecology of Marine Fish" at the Leibniz Institute of Marine Sciences (IFM-GEOMAR) in Kiel.



Prepared for Social Responsibility?

Social responsibility for scientists goes beyond their role as citizens. They are increasingly called on to inform, communicate and even take a stance on scientific issues of societal relevance. Climate change is an example of an issue in which scientists play a visible role, yet often fall short of being “honest brokers” of scientific evidence. Preparing young scientists to deal with the personal and professional challenges incumbent in this challenge was the aim of a 2-day PhD retreat of the Integrated School of Ocean Sciences.

Science and decision-making are intertwined, which results in positive and negative impacts. On the one hand this may result in more informed decisions, on the other we risk sacrificing the objectivity of science if it is driven by vested interests. Using the public and scientific debate on climate change, a core competency for young scientists is to learn to understand which (scientific and non-scientific) stakeholders are involved and grasp ethical dilemmas that can arise when science is conducted in a political or commercial context.

Tom Børsen, Associate Professor at the Department of Learning and Philosophy at Aalborg University, Copenhagen, collaborated with the ISOS to develop a 2-day program for a mixed group of graduate students from backgrounds in natural sciences, law, economics and political sciences. During the retreat the group learned to apply a number of analytical tools that could help participants navigate responsibly in an environment where it



Figure 1

Professor Karin Lochte, director of the Alfred-Wegener-Institute for Polar Research, presenting her personal experiences with dilemmas in a science and policy context.

is difficult to clearly differentiate between pure science and its application in a political and social context.

Read the report by PhD candidates Mirjam Gleßmer and Jonathan Durgadoo.

Understanding and Formulating Strategies for Responsible Use of Contemporary Science

Have you ever had the feeling that an argument is completely flawed, but couldn't really pinpoint the exact reason why? A lot of us PhD students have felt that way. However, this has changed. While using gut-feeling may seem like a powerful tool to assess arguments, we are now equipped with a systematic approach to tackling arguments.

For two days in March 2010, 32 PhD students met for their annual retreat, discussing the subject of the social responsibility of scientists. The retreat was lead and taught by Associate Professor Tom Børsen and his graduate student Nicolas König of Aalborg University, Copenhagen. Everybody's attention was captivated the minute they introduced the subject.

We also had the opportunity to meet two academics who act as role models for many of us. Professor Karin Lochte, director of the Alfred-Wegener-Institute for Polar Research, joined us on the first day and presented her personal experiences with dilemmas in a science and policy context. On the second day, Professor Andreas Oschlies of IFM-GEOMAR told us about what he considered as a role model at the start

of his scientific career and how this idealized picture changed over time. Their insights gave us a perspective of the issues we are likely to face in science, and examples of how to deal with them appropriately.

During these two days, we learnt how to (de)construct arguments, check their validity and evaluate the premises they contain. In small groups, we practiced breaking down statements into ethical categories using various texts - e.g. Björn Lomborg's "We should change track on climate after Copenhagen" and climate skeptic S. Fred Singer's "Nature, Not Human Activity Rules the Climate".

We also learnt structured methods to deal with dilemmas and the so-called 'wicked problems'. We discussed in small groups, and came up with possible solutions for several dilemmas that we either feel we are in already, or that we think might face us at some point in our careers. While we certainly are not looking forward to being confronted with such dilemmas, we know they are inevitable. At least, we now feel more confident that we may be able to cope with them in an ethical way. So what we need to learn now is how to approach and confront people putting forward flawed arguments.

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PhD Miniproposals: One Step to Independent Research

Doctoral research often opens up more questions than it answers, inviting young scientists to formulate questions, research topics and follow-up projects. At the Integrated School of Ocean Sciences, PhD candidates can experience first-hand what it takes to be an independent researcher: they can apply for their own funding via a so-called “miniproposal”



Figure 1

Cruise Leader Katja Lindhorst (middle) on the Lake Ohrid. Side view of the Macedonian research vessel showing the holder construction in front as well as the sediment echosounder device along the side.

The requirements for a PhD miniproposal are that the project idea should originate from the candidate, must be supplementary to their existing project but with direct relevance to it, must be discussed with the PhD supervisors and may not be part of an existing, funding project. The first miniproposal submitted fulfilled all these criteria and exceeded several of our expectations. Katja Lindhorst, the applicant, appropriately named it BLOSSOM: Bathymetry at Lake Ohrid for Subaquatic Slide Overview Mapping.

Compared to the oceans, the dimensions of Lake Ohrid are more like a bath tub. But its small scale makes it a useful model for studying geological processes of interest in larger dimensions. Katja Lindhorst started her PhD project within the research group of Prof. Sebastian Krastel with the goal of processing and interpreting geophysical and geological data from Lake Ohrid. Her PhD aims at reconstructing the lake's sedimentary history, analyzing tectonic morphology and selecting suitable locations for an imminent drilling campaign: A well-defined PhD project.

But Katja was captivated by further questions. Her preliminary results showed that the lake exhibited additional interesting features such as large mass movement deposits. A Bachelors thesis that she co-supervised revealed that such slide deposits covering wide areas can be found everywhere within the lake. She was interested in gaining a better understanding

of such massive failure events that have been described not only in lakes but also along continental margins.

Looking at the existing echo sounder data she recognized that the lateral resolution was too limited to study the inner slide structure in more detail; she would need to take a closer look by using a multibeam device. Katja spoke to her advisor and identified an opportunity following the next project campaign, when a multibeam echosounder would be at Lake Ohrid and potentially available to her. Katja identified research questions that were outside her DFG-funded project and discussed a potential Masters Thesis project she would co-supervise with her advisor based on the data acquired. She proposed to rent the 11-m long vessel of the Hydrobiological Institute of Ohrid and map a series of tracks that she would survey.

Her supervisor Professor Krastel soon realized that Katja was on to something promising. He agreed to grant her technical help in instrument calibration, offered logistical support and scientific backing. Katjas miniproposal was submitted, reviewed and granted. She established a team of three, set up a budget and work plan and prepared the cruise.

Putting the project into practice, she dealt with all hands-on imponderabilia which can be part of scientific fieldwork including equipment transport over 2300 km by car, managing customs clearance and changes in schedule caused by delayed arrival of spares. Not surpri-

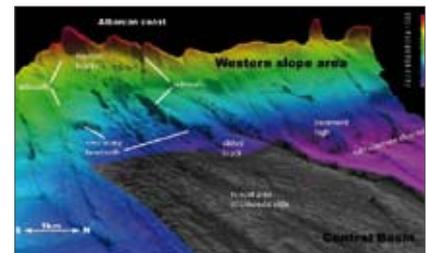


Figure 2

Bathymetric map of the southwestern part of Lake Ohrid showing the Udenisht slide.

singly, everyone involved was keen to help make the project a success.

After several problems were solved the cruise was a success and finally she obtained a dense grid of data to describe the Udenisht mass movement event, a massive mud slide named after the village where it occurred. The detailed study of the data obtained will allow quantifying the sliding event in terms of its energetic regime, trigger mechanism, and phases of sliding. Studies such as these will provide input parameters for tsunami models. Katja and “her” students are working out the results, presenting them at conferences and plan to publish. All the successes of a full proposal!

Both Katja and her advisor recognized that a self-driven miniproposal does more than generate data: it broadened her personal scientific scope and she mastered the entire range of project management, as well as being able to co-supervise students, an aspect that she sees as of essential importance for her scientific career.

In the end the miniproposal project opened yet another box of questions, but the prospects of answering them seem a little more realistic.

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Learning From Each Other

In academia (as in life), men and women work in meta-structures that are not always openly communicated. Achieving success, however, is based on the assumption that an individual's actions are rooted in an understanding of these structures. Therefore, recognizing and comprehending undisclosed patterns is a prerequisite for personal success.

Through discussions with PhD candidates and their advisors, we realize that there is often an unintentional lack of transparency in the structures and hierarchies in which the individual works. University structures are not always clear to young scientists entering the system, and it is not clear where the rulebook is. For many young scientists, trial-and-error and guess-work sometimes succeed but sometimes fail – does one understand why? Gender-specific components add a level of complexity to an already complicated system.

Learning to understand and move within the system evens the chances of success at all levels, increases diversity of individuals, supports gender equality and can stimulate a productive working environment. At the Integrated School of Ocean Sciences individuals from several levels discuss their views and share experiences.

Peer to Peer

To support first year PhD candidates especially in the initial phase of their doctorate, ISOS launched a Peer Mentoring Program in spring 2010.

It is a voluntary program where more experienced PhDs (second, third or fourth-year) who have been trained for their role support first year PhDs for 6 to 12 months.

The concept of the ISOS Peer Mentoring program is based on the idea that experienced peers have a winning margin: they have experience in learning to 'play the system' and know better what is expected of a PhD student. Since the mentors are at the same academic level as their mentees and still going through

the process of the doctorate, talking over certain issues may be easier and more relevant with a peer mentor than with a traditional mentor.

Participating in the Peer Mentoring Program may save a first year PhD candidates some of the "learning by doing" and help them to get ahead faster. Furthermore, in a mentoring team, PhDs form a network that may develop beyond the mentoring program. Finally, the program has proved to be useful not only for foreign PhDs and those new to Kiel, but mentors are also benefiting in terms of leadership skills and inspiration.

What Mentees Say

"I think it is very helpful [as a foreign PhD] to have a Peer Mentor, because there were a lot of difficulties in the beginning of PhD. A peer mentor knows how to deal with these troubles and can give good advice." (Rong Bi, biologist)

"It is a great leap forward from a diploma thesis to working on a PhD thesis – regarding the intensity of work, initiative and responsibility. Therefore, I find it extremely useful to talk to someone who has mastered this challenging phase and provides valuable tips. I got a lot out of



Figure 1
The ISOS Peer Mentoring Program.

it and can highly recommend it to every 'newbie.'"
(Bernd Hermann, evolutionary ecologist)

What Mentors Say

"During the first year of my PhD I often wished for a mentor, so when the ISOS started the peer mentoring program I volunteered. My mentee and I shared thoughts - both about the process of getting a PhD and about life in general - and it was rewarding to help her find her way through the academic system. Even though I eventually had to leave for pastures new, we are still in touch." (Mirjam Gleßmer, physical oceanographer)

"As a mentor, I enjoy being able to share my knowledge and my experiences with new PhDs because I can hand down what I have learnt from experienced PhDs when I was a novice. The exchange with my mentee can also provide ideas and inspiration for my own work." (Julia Saphörster, medical researcher)

Learning from Each Other

In an interdisciplinary research environment like the "Future Ocean" cluster, many PhDs are working on cross-disciplinary topics. For specific questions outside their core discipline or to gain a scientific overview and background information, PhDs can turn to their peers in the ISOS PhD network. For example, research on law of the sea might be more comprehensive with a basic understanding of oceanography.

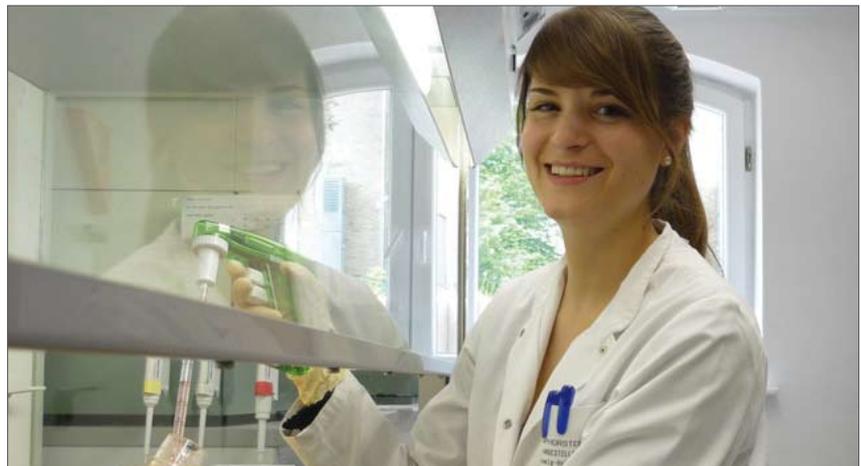


Figure 2
Prize winner and medical researcher Julia Saphörster

At ISOS, the main goal is to more intensely use the opportunities and resources of an interdisciplinary research environment for the benefit of the individual early stage researcher.

"The most important thing is that the bridge between different background people has been built which offers us the opportunity to learn from each other." (Chang Hong, lawyer).

Stepping Stones and Stumbling Blocks

Becoming a PhD means also understanding the academic system, understanding what is expected of a PhD and learning to anticipate

these expectations that are often not verbalized.

At the ISOS, senior scientists and supervisors were also involved in shedding light on underlying patterns. In an open discussion with PhDs, two scientists of the cluster disclosed expectations towards PhDs that are - although rather common across working groups and academic disciplines - rarely verbalized. Knowing these and getting answers to their own questions and concerns enables early career scientists to avoid stumbling blocks and focus on the stepping stones of their career.

Presenting Oneself

Making a mark at a scientific conference is an important step towards opening options for life after the doctorate. In 2010 the first state-wide young researchers conference was held in Kiel on "Biotechnology and Life Sciences", which offered a platform for PhD students from the programs of the Excellence Initiatives to present themselves to other scientists but also to representatives from the medical industry.

Julia Saphörster, a PhD candidate in the Cluster was awarded the first prize for her presentation on "Molecular mechanisms of cellular immune responses in marine invertebrates". She made a convincing case for her research which, combining marine biology and medical sciences, is an outstanding example for integrated marine science in Kiel.



Figure 3
ISOS offers various opportunities for PhD students to learn from each other.

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Experiencing Biodiversity and Evolutionary Research in Japan: PhD - Exchange with Kyoto University Global Center of Excellence Program

Living in Kiel you probably wouldn't choose Yakushima, the wettest place in Japan, for a tropical holiday. But this is where six young scientists from Kiel headed in July 2010, on invitation of the Kyoto University Global Center of Excellence (COE) for Biodiversity Research to participate in a field and laboratory course and an international Symposium.

The Global COE program aims to train young scientists with complementary skills in fieldwork and up-to-date molecular biological techniques, in order to communicate the fundamental methods needed to study the diversity, ecology and behavior of various wild animals, plants, and fungi. A group of German PhD candidates were invited to join the field training course on Yakushima in 2010, an exchange initiated by leading scientists Thomas Bosch and Kiyokazu Agata from Kiel and Kyoto respectively.

Coming from disciplines as diverse as Economics, Mathematics and Biology they hit the road for this unique island situated about 60 kilometres south of the Japanese mainland. Yakushima, a UNESCO World Heritage site is renowned for its cedar forest with trees dating back to over 1000 years and for its endemic flora and fauna that makes it an unrivalled place for research on biodiversity and evolution.

On arrival the group met up with their new colleagues, 18 students from the COE project and started work immediately. They were divided between three groups of Japanese and German students concentrating on different topics.

Marine biologist Alexandra Sophie Roy's team focussed on the adaptation of two *Rhododendron* species to the island's alpine environment. Most of the 46 endemic plant species of Yakushima comprise either hardy aquatic plants or alpine dwarfs. In previous courses, different mechanisms of dwarfism had been detected, depending on the species studied. The group analysed morphological

and ecological characters of these plants. As Alexandra found out, binational collaboration was effortless: "As I was the only German guest on this team, my integration was complete. We spent a great amount of time together which was always very easy." An experience shared by the Germans working in the other two groups.

Group two studied the inter-species relationship between Japanese Macaque and Sika Deer. In a commensal relationship, Sika Deer follow groups of macaques, eating leaves and fruit they drop down from the trees. The job

of this group was to estimate the density of deer and the proportion of deer foraging with macaque groups. They collected deer feces to later analyze their diet by sequencing the plant DNA. "We were able to observe the Macaques within spitting distance. And as they descend to the streets at noon to louse each other, they are quite easy to follow." zoologist Sebastian Fraune found out.

The third group studied the effect of forest disturbance on fungal diversity in the soil. Even on Yakushima, much of the pristine forest has



Figure 1

Field work was followed up by laboratory studies.



Figure 2
Scientists from Kiel and Kyoto exploring the Yakushima rain forest. Picture: *Alexandra-Sophie Roy*

given way to artificial conifer plantations, considerably deteriorating the biodiversity. During the field course, students compared the fungal diversity in natural and secondary forest and conifer plantations by taking soil samples to later sequence fungal DNA in the lab. Collecting



Figure 4
Wataru Shinohara and Alexandra-Sophie Roy analyzing their data. Picture: *Max Brück*



Figure 3
At lunchtime, the Japanese macaques meet on the streets of Yakushima to louse each other. Picture: *Sebastian Fraune*

samples, Kiel students got in touch with the nastier aspects of fieldwork: "The damp underbrush is home to all kinds of bloodsuckers that single-mindedly find their way to every uncovered patch of skin. Sometimes you first notice them when they drop down, gorged and dripping blood on your skin", Sören Franzenburg learned from experience.

But working together was only part of the project. Living together in the traditional Tatami rooms of an old meteorological station brought the Germans into close contact with the Japanese and their culture that for all of them turned out to be "mostly effortless, relaxed and simply enjoyable."

After one week of field work all went back to Kyoto to analyze the samples in the genomic lab and discuss their results. Together with their Japanese colleagues, they learned and applied state-of-the-art techniques to purify DNA from deer and monkey faeces, fungi and the other samples they had collected. This short introduction to the concepts and implementation of DNA fingerprinting, amplification of DNA sequences and sequencing of DNA fragments was a unique experience especially for Max Stöven, who had an academic background in economics.

A highlight of the trip was an international symposium that zoologist Max Brück experienced as "the most sudden change of lifestyle one can imagine: Going from living on a sub-tropical island with pouring rain, high humidity, crawling through the underbrush, struggling with huge spiders and other kind of creepy crawlers to a modern accommodation in

a historical, sun-drenched city where we had the opportunity to dress up and present our work at an international conference."

In the end all agreed that in addition to the scientific exposure, they had an enriching experience and built friendships that will last.

The PhD exchange, initiated by zoologist and vice president of the CAU Prof. Thomas Bosch is part of a larger cooperation between Kiel and Kyoto in the field of biodiversity research. In 2011 a group of Japanese PhDs will be hosted by the "Future Ocean" Cluster in Kiel.

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Internationalization of the Future Ocean Cluster

Board of the Future Ocean Cluster a position was created for coordination of internationalization of the cluster. The position was filled and work started in December 2010. One of the first activities of the coordinator was to define the goals of the cluster regarding internationalization in a concept paper. A summary of these goals and the activities to achieve them begun in 2010 follows.



The main goal of internationalization of the Cluster of Excellence "Future Ocean" is to increase the renown and visibility of the cluster in the world with the aim of attracting the best scientists to Kiel and exporting the knowledge gained in the "Future Ocean" to the international community.

The cluster will broaden its international horizons scientifically by attracting excellent scientists to work in Kiel: as PhD candidates, as postdocs and research fellows, as professors and as visiting scholars. Some instruments for

attracting young international scientists are already available: the "Future Ocean" Alexander von Humboldt Stipend and cluster funding for visiting scholars. Others will be implemented, such as targeted recruitment of these scientists at scientific conferences, by advertising and through recommendations from cluster members (for visiting scholars). First plans for a Future Ocean booth at the EGU conference in Vienna were started in 2010.

The establishment of a "Future Ocean" Postdoc Network will contribute to the attractiveness of Kiel for international postdocs and research fellows. In 2010 the footwork for such a network was begun and the network will be fully established in 2011.

The best initiatives and incentives alone cannot achieve the desired effect of attracting the best and brightest to the "Future Ocean" without an effective international outreach campaign to make them known. Thus all information about what the cluster is and what the cluster does must be available on the "Future Ocean" website in English. One of the first tasks of the internationalization coordinator in 2010 was thus to proofread all English language texts on the Future Ocean website and translate texts that were only available in German. In addition, citations in Wikipedia articles on topics relevant to cluster research were checked and updated and several press releases were translated into English.

International partnerships must necessarily form the core of any internationalization concept. The cluster therefore plans to take advantage of existing scientific good working relationships and, where possible, to formalize these in official partnerships, either on a university to university or on a cluster to cluster/institute basis. The following institutes have been selected as potential partners for the Future Ocean cluster:

- ▶ The Earth Institute, Columbia University, USA
- ▶ Halifax Marine Research Institute, Dalhousie University, Nova Scotia, Canada
- ▶ Ocean University of China, Qingdao China
- ▶ Center of Excellence "Formation of a strategic base for biodiversity and evolutionary research: From genome to ecosystem", Kyoto University, Japan
- ▶ ARC Centre of Excellence for Coral Reef Studies, James Cook University, Townsville, Australia

Sounding out of possibilities for cooperation with three of these partners, the Ocean University of China, Earth Institute and the Halifax Marine Research Institute, was begun in 2010.



Figure 1
Lamont-Doherty Earth Observatory at Columbia University, USA



Figure 2
Dalhousie University, Halifax, Canada



Figure 3
Qingdao Skyline, China

Building international partnerships



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EcoOcean

An Overfishing Simulation



Background - Overfishing

According to FAO (2007) estimates, about one quarter of all economically valuable marine fish stocks are overfished, depleted, or recovering from depletion; most of the remaining fish stocks are fully exploited and have no room for further expansion. The economic reason for the phenomenon of overfishing is the lack of appropriately defined property rights. Thus, one of the major problems of the unsustainable harvesting of fish is based on what is called the “tragedy of the commons” or a “common pool problem”. Despite the fact that most fisheries are somehow managed, individual fishers still have the incentive to take as much fish out of the water as they can.

To look at these challenges, either the control of rules has to be strengthened or, much better, the incentive for the fisher has to change. The latter is already true for a lot of small fishing communities, for example on Pacific island states, and where clear use rights have been established, e.g. territorial use rights in Chile.

The potential introduction of property rights in European fisheries is one of the major points of discussion when talking about the revision of the European Common Fisheries Policy.

Aim of the Game

The primary goal of this computer game is to demonstrate the common pool problem to the interested public. Four players have the

target to achieve as many points as possible by catching fish. All players rely on the same fish stock and therefore compete for the resource, as given in common pool resources. The game is parameterized in such a way that the fish stock will be depleted very soon, if all players catch as much as they can. Only by communicating and sticking to common rules, a sustainable, higher overall catch can be reached in the game. The next step will be to use this spatially resolving model set-up for experimental economic research and to address questions of marine protected areas.



Figure 1

Played well – The Ocean still shows plenty of fish reserves.

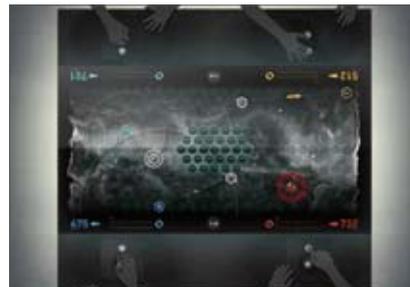


Figure 2

Bad game – Except the protected area, the fish stock is heavy depleted

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Knowledge Transfer Through Scientific Assessments

The Cluster is engaged in knowledge transfer via a structured approach including the publication of scientific assessments, where in-depth knowledge about marine issues may be of importance to stakeholders and policy makers, but also targeting outreach activities for society at large. In 2010 two publications were issued that fall into these categories, 1) an assessment paper on the oil spill incident in the Gulf of Mexico, and 2) the World Ocean Review (WOR).

The Oil Spill in the Gulf of Mexico

Many people were shocked by the March 2010 Deep Water Horizon oil spill in the Gulf of Mexico, but detailed information was released slowly, and the conclusions published were often contradictory and confusing. To overcome some of the shortcomings in the press the Future Ocean compiled a position paper in early July 2010 which was distributed for free among the interested public. In this paper Future Ocean experts wrote brief assessments related to sub-seafloor drilling technology, gas hydrate formation, decomposition of oil in the oceans,

dispersal of the oil by ocean currents, and the economic and legal impacts of the incident. The 500 printed copies and the online version quickly spread throughout ministries, NGOs, news and other organizations. In addition a podium discussion was organized in Kiel about deep-sea drilling, allowing the interested public to question scientific experts directly and discuss concerns they had about the catastrophe. It turned out that the position paper was one of the very few sound scientific statements in German and was frequently cited in public discourse.

World Ocean Review

In cooperation with the publisher Mare and the International Ocean Institute (IOI), in November the Future Ocean published an assessment on the world's oceans entitled 'World Ocean Review: Living with the Oceans' (WOR, worldoceanreview.com). The WOR summarizes key findings for 10 hot topics in marine research in a format that is scientifically correct but in a language suitable for the educated public. The production process from the initial plans to printing in October 2010 took more than two years. About 50 researchers contributed



Figure 1
Cover of the position paper on the oilspill incident in the Gulf of Mexico in March 2010.



Figure 2
Public information and discussion event was held at the Kunsthalle Kiel together with the publication of the oilspill statement paper.



Figure 3

Nikolaus Gelpke, managing director of maribus gGmbH and mare/elag publisher and Martin Visbeck, chairman Cluster of Excellence "The Future Ocean" during the press conference on the occasion of the publication of the "World Ocean Review" (WOR).

material to the 200 page volume. The WOR was published in German and English and roughly 50,000 copies each were printed and distributed globally by the IOI free of charge. The resulting media response was overwhelming with appearances in the main German TV news and talk shows. In the meantime the WOR is being used by many schools and will be presented to the European Parliament during a lunch briefing with the Commissioner for Fisheries and Maritime Affairs, Maria Damanaki, in spring 2011. Currently it is being translated into Chinese and Thai. The publication of further issues of the World Ocean Review will appear at regular intervals, shedding light on certain topical areas of interest as they arise. The next issue is planned for 2013.

These publications impressively demonstrate two important strategies of the Future Ocean: 1) the importance of knowledge transfer projects for research as a whole, as these publications bridge the communication gap between researchers and stakeholders, decision makers and the general public at the same time, making the expertise of researchers valuable for anyone addressed. 2) the importance of making the right decision on strategic partnerships. The distribution and outreach of the WOR would have never been reached without the expertise of Mare and the IOI, whereas neither of the two institutions would have been able to present such scientific expertise without the support of the Future Ocean. All in all the WOR represents a win-win-win story, which will be continued.



Figure 5

Cover of the Publication World Ocean Review, living with the oceans.

Links

<http://www.worldoceanreview.com>
http://www.ozean-der-zukunft.de/fileadmin/user_upload/pdf/oilspill.pdf

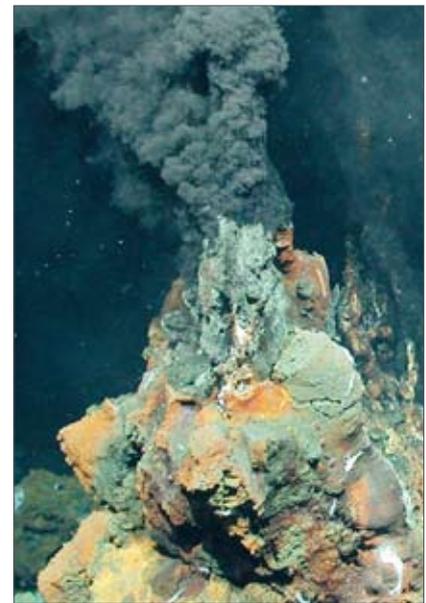


Figure 4

Massive sulphides form at black smokers – hot springs on the sea floor with temperatures approaching 400 degrees Celsius. These vents discharge minerals from the Earth's interior, forming chimneys that rise to several metres above the seabed. Black smokers are also unique habitats.

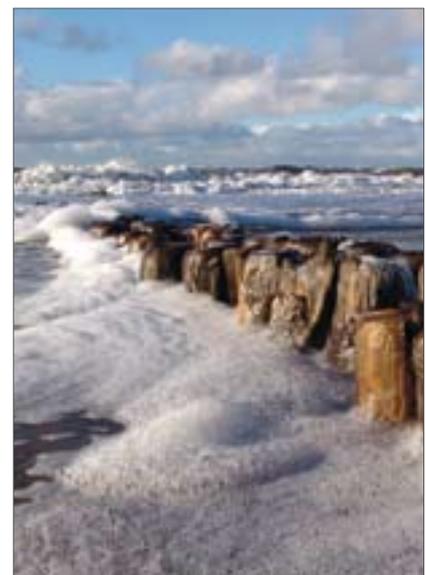


Figure 6

Eutrophication stimulates the growth of algae, which are sometimes pounded to foam in the surf, as seen here on the German North Sea coast.

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3rd Biannual Symposium of The Future Ocean 2010

For the Future Ocean symposium on September 13 – 16, 2010, experts gathered to discuss today's knowledge of the future ocean. This was reflected in seven topical sessions spanning from processes at the ocean surface to those starting at the seafloor; from river-mouths to coral-reefs, from estimating the past to future CO₂ intake capacity to valuing and managing ocean changes economically.



Figure 1
Science Advisory Board member Yoshiki Saito discusses coastal research with a colleague.



Figure 2
Colin Woodroffe elucidates Sea-Level Rise and the Vulnerability of low-lying Coasts.



Figure 3
Audience at the 3rd Biannual Symposium 2010 in Kiel.

The session on recent breakthroughs in coral research focused on comparative genomics of corals and zooxanthellae used to establish the molecular basis for symbiosis and calcification being of critical importance for growth of corals and healthy reef development. Improved understanding of the molecular relationship between symbiotic partners allows predicting responses to climate change and examining mechanisms for adaptation and acclimatization. In addition the anthropogenic and climatic drivers of coral diseases and the development of strategies for control and reduction of their economic impacts were discussed.

One of the most societal-relevant objectives of the Earth Sciences is to understand the history and impact of global sea level (eustatic) fluctuations at different time scales. The session focused on the methods to use quaternary geologic records to provide opportunities to quantify the timing, amplitudes, rates, mechanisms/controls, and effects (stratigraphic response) of millennial-scale changes in sea level. This information, in turn, provides

a baseline for predicting future global sea level rise (SLR) and assessing anthropogenic influences. SLR has increased from a few centimeters/century over recent millennia to a few tens of centimeters in recent decades. Much larger rises in sea level are possible over the next centuries, especially if the Greenland and Antarctic ice sheets disintegrate.

Global change is accompanied by rapid response of river-mouth systems at millennial or shorter time scales. The style of deposition or erosion at the end of a river course in a delta or estuary or the final locus of deposition at the sink, all influenced by rapid climate and sea level variability have emerged as key to our understanding of coasts and shallow marine sedimentary environments. During the symposium field- and modeling-based contributions were addressed. Contributions addressed the impact of abrupt changes in sedimentary dynamics on human societies, which is important as the vulnerability of the world's large, densely populated deltaic and estuary regions is increasingly recognized, yet the scientific underpinning for successful coastal management and restoration is commonly inadequate.

Tracing Tsunami Impacts On- and Offshore has been an important topic in particular since the devastating tsunami in the Indian ocean in 2004. It demonstrated that tsunamis are among the largest catastrophic events in the world. They are a major threat to coastal communities and infrastructure. Tsunamis have been recorded since historical times and investigations concerning their origin, wave distribution and energy release along coastlines have been discussed. Other contributions related to methods how to estimate the frequency and the magnitude of historic tsunamis, the

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impact of tsunamis on seafloor morphology and sediments, the triggering mechanisms, impacts on coastal buffer systems and coastal protection measures.

A session on chemistry at marine Interfaces illuminated the sea-surface microlayer consisting of mostly of organic matter, including surface-active substances such as lipids, glycans, proteinaceous compounds and hydrocarbons and influencing the ocean-atmosphere coupling as well as the surface chemistry of sea-borne aqueous aerosols by modulating the physical, chemical and biological processes at the interface. It is known that the control over air-sea gas exchange by the microlayer directly affects the climate. Moreover, intense solar irradiation induces unique heterogeneous photochemical transformations. Last but not least, bioadhesion and biofouling constitute additional marine interfacial phenomena that are of major importance for the Future Ocean. The session aimed to improve the understanding of the underlying processes. This required close interaction among experts who are exchanged latest results and developing novel concepts and ideas.

The session on the Oceanic CO₂ Sink addressed the fact, that the ocean has presently taken up roughly 50 % of anthropogenic CO₂ that has been released into the atmosphere by burning of fossil fuel, changes in land-use and cement production. On geological time scales the weathering of CaCO₃ from seafloor sediments will greatly enhance the uptake and storage capacity of the ocean with respect to CO₂ from the atmosphere. As such the ocean constitutes the ultimate CO₂ sink, having a



Figure 4

Samar Khatiwala explains the reconstruction of the Ocean sink of Anthropogenic Carbon over the Industrial Era.

strong potential of regulating climate and the global carbon cycle. Talks covered the fields of paleo-reconstruction and modern observations, forward and inverse modeling, with the aim to understand climate carbon cycle interactions, including natural fluctuations of the marine carbonate system.

Last but not least thoughts about climate engineering played an important role at the symposium. Even courageous climate policies may run the risk that catastrophic climate change takes place, although expected to happen with a low probability. If this risk increases "Climate Engineering" may become an option of last resort. Research on the risks and opportunities of some climate engineering methods should help to be prepared for such an event. These methods include both - carbon dioxide removal techniques which remove CO₂ from the atmosphere e.g. direct capture of CO₂ from the air, iron fertilization of the ocean and solar radiation

management techniques that reflect a fraction of the sun's light and heat back into space e.g. marine cloud reflectivity, shields or deflectors in space. During the session experts from climate physics, biology, oceanography, economics, ethics and law aimed to improve understanding regarding the effectiveness and environmental risks of different climate engineering methods. Developing policies to regulate the use of climate engineering methods is the particular task of experts from law, ethics and economics.

In total 250 researchers from 18 nations visited Kiel, resulting in numerous stimulating discussions. Participants were particularly impressed by the broad spectrum of topics allowing for unique opportunities to initiate the exchange of ideas across disciplines rarely experienced by others, but almost natural to cluster members. We are looking forward to the next symposium in 2012!



Figure 5

Heather Allen talks about the Molecular Organization at the Ocean Surface: Ions, Water and the Microlayer



Figure 6

Coffee Breaks offered time for chat and discussion in a relaxed atmosphere.





The Appendix

Living in the ocean
means never having
to salt your food.

Takayuki Ikkaku,
Arisa Hosaka
and Toshihiro Kawabata

Members of the Future Ocean

Name	Institution
Andersen, Nils	<i>Leibniz Labor</i>
Behrmann, Jan	<i>IFM-GEOMAR</i>
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Bleich, Markus	<i>CAU</i>
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Dullo, Christian	<i>IFM-GEOMAR</i>
Duscher, Tom	<i>MKHS</i>
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Flüh, Ernst R.	<i>IFM-GEOMAR</i>
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Frank, Martin	<i>IFM-GEOMAR</i>
Friedrichs, Gernot	<i>CAU</i>
Froese, Rainer	<i>IFM-GEOMAR</i>
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Hasselbring, Wilhelm	<i>CAU</i>
Hauff, Folkmar	<i>IFM-GEOMAR</i>
Hensen, Christian	<i>IFM-GEOMAR</i>
Herzig, Peter	<i>IFM-GEOMAR</i>
Hoeher, Peter	<i>CAU</i>
Hoernle, Kaj	<i>IFM-GEOMAR</i>
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Horn, Rainer	<i>CAU</i>
Imhoff, Johannes F.	<i>IFM-GEOMAR</i>
Jansen, Klaus	<i>CAU</i>
Jegen-Kulczar, Marion	<i>IFM-GEOMAR</i>
Jenisch, Uwe	<i>CAU</i>
Jung, Christian	<i>CAU</i>
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Karstensen, Johannes	<i>IFM-GEOMAR</i>
Keenlyside, Noel	<i>IFM-GEOMAR</i>
Kempken, Frank	<i>CAU</i>
Kläschen, Dirk	<i>IFM-GEOMAR</i>
Klepper, Gernot	<i>IFW</i>
Koch, Reinhard	<i>CAU</i>
Kopp, Heidrun	<i>IFM-GEOMAR</i>
Körtzinger, Arne	<i>IFM-GEOMAR</i>
Krastel, Sebastian	<i>IFM-GEOMAR</i>
Krawczak, Michael	<i>CAU</i>
Krüger, Kirstin	<i>IFM-GEOMAR</i>
Kuhnt, Wolfgang	<i>CAU</i>
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Institutions

CAU __ Christian-Albrechts-Universität zu Kiel

GKSS __ GKSS-Forschungszentrum Geesthacht GmbH

IFM-GEOMAR __ Leibniz-Institut für Meereswissenschaften (IFM-GEOMAR)

IFW __ Institut für Weltwirtschaft

Name	Institution
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Mayerle, Roberto	FTZ
Meier, Sebastian	CAU
Melzner, Frank	IFM-GEOMAR
Molinero, Juan Carlos	IFM-GEOMAR
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Müller, Wolf Ulrich	CAU
Nadeau, Marie-Josée	Leibniz Labor
Oschlies, Andreas	IFM-GEOMAR
Ott, Stephan	CAU
Petersen, Sven	IFM-GEOMAR
Peterson, Sonja	IfW
Pfannkuche, Olaf	IFM-GEOMAR
Piatkowski, Uwe	IFM-GEOMAR
Piepenburg, Dieter	CAU
Quaas, Martin	CAU
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Rehdanz, Katrin	IfW
Requate, Till	CAU
Reusch, Thorsten	IFM-GEOMAR
Ricklefs, Klaus	FTZ
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Rimbach, Gerald	CAU
Roeder, Thomas	CAU
Rosenstiel, Philip	CAU
Rüpke, Lars	IFM-GEOMAR
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Schäfer, Priska	CAU
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Schröder, Jens-Michael	CAU
Schrottke, Kerstin	CAU
Schulenburg, Hinrich	CAU
Schulz, Manfred	MKHS
Schulz, Rüdiger	CAU
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Slawig, Thomas	CAU
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Sommer, Ulrich	IFM-GEOMAR
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Trunk, Alexander	CAU
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
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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)

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Funded Cluster Projects

ID	Author	Titel	Duration
CP0602	Bleich	CO ₂ -induced Ocean Acidification: Biological Responses and Adaptations	24 months
CP0603	Eisenhauer <i>et al.</i>	Boron Isotopes as a Proxy for pH decrease an pCO ₂ increase	0 (Investment)
CP0605	Froese <i>et al.</i>	Managing Cod and Sprat in the Central Baltic Sea - A bio-economic multi-species approach with Stochastic regeneration functions	24 months
CP0608	Luttenberger <i>et al.</i>	dearX - XML Technology for marine Data Exchange, Archiving and Retrieval	12 months
CP0609	Macke <i>et al.</i>	The role of light fluctuations on ocean heating and photosynthesis	24 months
CP0610	Piepenburg <i>et al.</i>	Synergetic effects of temperature, pH and salinity on the metabolism of benthic organism	12 months
CP0611	Schmitz-Streit <i>et al.</i>	Complex Barriers and Microbiota in the Ocean: implications for human barrier disorders	24 months
CP0612	R Schneider <i>et al.</i>	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 <i>et al.</i>	Mathematical and Algorithmic in Modeling Marine Biogeochemical Cycles	24 months
CP0618	Zimmermann <i>et al.</i>	Beyond Mineral Resources - The International Legal Regime and Regulation of New Uses of the Deep Sea Bed	24 months
CP0619	Latif <i>et al.</i>	Development of a Coupled Climate/Ocean Biogeochemistry Model	24 months
CP0063	Körtzinger	Data Mining	6 months
CP0702	Bosch <i>et al.</i>	Transgenic <i>Aurelia</i> allow functional analysis of genes involved in control of tissue homeostasis and biological barriers	24 months
CP0704	Schulz-Friedrich <i>et al.</i>	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 <i>et al.</i>	Marine Steroid Pharmaceuticals to Control Human Diseases	24 months
CP0710	Eisenhauer <i>et al.</i>	VARAN -Variations of Trace Element Fluxes induced by Ocean Acidification at Ca ²⁺ - Channels/ Ca ²⁺ - ATPases	24 months
CP0713	Oschlies <i>et al.</i>	A new computational framework to efficiently integrate biogeochemical models from seasonal to multi-millennial time scales	24 months
CP0717	Thomsen <i>et al.</i>	Complex barriers and microbiota in the Ocean	24 months
CP0718	Klepper <i>et al.</i>	Economic valuation of the ocean's role in the carbon cycle and consequences for abatement and mitigation strategies	24 months
CP0721	Braack <i>et al.</i>	Parameterization of near surface vertical mixing processes by multiscale methods	24 months
CP0722	Sommer <i>et al.</i>	Building up the capacity for δ ³⁴ S 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 <i>et al.</i>	Changing habitats of calcareous plankton in the Greenhouse World	24 months
CP0726	Wallace <i>et al.</i>	Improved Methods for Nitrogen Isotope Studies with Specific Application at the Tropical Eastern North Atlantic Time-Series Observatory, Cape Verde	24 months

Funded Cluster Projects

ID	Author	Titel	Duration
CP0727	Rosenstiel <i>et al.</i>	Deciphering transcriptomal responses to environmental stimuli in simple aquatic model organisms by massive parallel sequencing technology	24 months
CP0730	Oschlies <i>et al.</i>	Modeling chemosensor-aided foraging in zooplankton	24 months
CP0732	Koch <i>et al.</i>	3-D Modeling of Seafloor Structures	8 months
CP0734	Oschlies <i>et al.</i>	Carbon and Nitrogen Cycle Dynamics	18 months
CP0737	Luttenberger <i>et al.</i>	An XML-based workbench for marine and biological data (XDataCollection)	6 months
CP0739	Oschlies <i>et al.</i>	Neural-network based coupling of benthic and pelagic components of biogeochemical ocean circulation models	12 months
CP0743	LaRoche <i>et al.</i>	Bioprospecting of Deep-Sea genetic resources	24 months
CP0745	Dullo <i>et al.</i>	Biogeochemical Studies on the effects of ocean acidification	6 months
CP0746	Weinberger <i>et al.</i>	A transcript profiling tool to investigate synergistic effects of non-biotoxic and biotic changes	15 months
CP0747	Karstensen <i>et al.</i>	Glider swarm Project	18 months
CP0751	Requate <i>et al.</i>	Alternative Scenarios for European Fisheries Management	12 months
CP0752	Wahl <i>et al.</i>	The neglected bottleneck: Early life stage ecology in times of global change	24 months
CP0753	Weinrebe	Iceflow activity revealed from submarine morphology - mapping glacial-morphological manifestations of a retreating ice-front	12 months
CP0754	Piepenburg <i>et al.</i>	Ecophysiological consequences of ocean warming and acidification	12 months
CP0758	Friedrichs <i>et al.</i>	The Potential of Field Measurement of Surface Water pCO ₂	24 months
CP0765	Melzner <i>et al.</i>	Gene expression patterns in sea urchin embryos: Establishing a model system for biological and marine medical research in the context of global change	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: <i>Mnemiopsis leidyi</i>	12 months
CP0805	Bosch <i>et al.</i>	Developing a novel framework for understanding evolutionary adaptation 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 <i>et al.</i>	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: adaptation to carbonate undersaturation in calcifying dinoflagellates?	15 months
CP0812	Quaas <i>et al.</i>	Tradable Fishing Grounds	8 months
CP0813	Oschlies <i>et al.</i>	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

Funded Cluster Projects

ID	Author	Titel	Duration
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 assessment of climate variability of the Baltic Sea area for the period 1970-2008	24 months
CP0820	Vafeidis <i>et al.</i>	Shipping induced sediment resuspension in the port of Venice: a case study of the effects of forced Shallow water waves	12 months
CP0822	Wallmann <i>et al.</i>	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 environmental stress research	25 months
CP0824	Wallace <i>et al.</i>	Air-sea flux measurements of trace gases with atmospheric pressure chemical ionization time of flight mass spectrometry (APCI-TOF-MS)	12 months
CP0901	Martin Wahl <i>et al.</i>	Missing Baselines and Ecological Noise	18 months
CP0906	Anna Bockelmann <i>et al.</i>	Effects of global change on Labyrinthula-infection in eelgrass <i>Zostera marina</i>	18 months
CP0910	Hermann Bange <i>et al.</i>	A novel system for continuous high-resolution measurements of atmospheric and dissolved N ₂ O	20 months
CP0911	Tina Treude <i>et al.</i>	The occurrence and relevance of nitrogen fixation in sediments of oxygen minimum zones	18 months
CP0912	Sebastian Krastel <i>et al.</i>	Submarine landslides and associated tsunami risk: Combining observations and an integrated modeling approach	18 months
CP0915	Peter Linke <i>et al.</i>	Novel, non-invasive investigation of seafloor warming on oxygen and heat fluxes from the benthic boundary layer into the water column	18 months
CP0918	Friedrich Temps <i>et al.</i>	Photolysis of Carbonyl Compounds in Seawater: Primary Products, Quantum Yields, and Loss Rates in Natural Sunlight	15 months
CP0923	Rainer Kiko <i>et al.</i>	The role of zooplankton in tropical oxygen minimum layers: physiological adaptation and contribution to fluxes of carbon and oxygen	12 months
CP0924	Priska Schäfer	The bryozoan <i>Flustra foliacea</i> - impact of ocean acidification on benthic organisms	18 months
CP0927	Andreas Oschlies <i>et al.</i>	Does the rise of slime foster an oceanic jelly carbon pump?	18 months
CP0931	Rainer Froese <i>et al.</i>	Winners and Losers in the Future Ocean	12 months
CP0932	Anton Eisenhauer <i>et al.</i>	Magnesium Isotope Fractionation in Planktic Foraminifera as a Proxy for Sea Surface pH Variations	12 months
CP0933	Till Requate <i>et al.</i>	Experimenting with marine protected areas in an ecological-economic fishery model	12 months
CP0937	Nils Andersen <i>et al.</i>	Stable isotope fingerprinting of marine organisms	18 months
CP0938	Torsten Kanzow <i>et al.</i>	A glider fleet to observe sub-mesoscale physical-biogeochemical coupling in the tropical ocean	20 months
CP0943	Kerstin Schrottke <i>et al.</i>	Response of tidal basins to sea-level rise and climate change	18 months
CP0946	Magdalena Gutowska <i>et al.</i>	Mechanisms of intracellular CaCO ₃ crystalization in hemocytes of <i>Mytilus edulis</i> : sensitivity of bivalve calcification to ocean acidification.	18 months

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