IFM-GEOMAR

Leibniz-Institut für Meereswissenschaften
an der Universität Kiel

IFM-GEOMAR Report 2002-2004

From the Seafloor to the Atmosphere

- Marine Sciences at IFM-GEOMAR Kiel -

INSTITUT FÜR MEERESKUNDE KIEL

GEOMAR

PAX OPTIMA RERUM ACADEMIA HOLSATORUM CHILONIENSIS

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IFM-GEOMAR Report 2002-2004

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Preface

For the first time, the Leibniz Institute of Marine Sciences (IFM-GEOMAR) presents a joint report of its research activities and developments in the years 2002-2004. In January 2004 the institute was founded through a merger of the former Institute for Marine Research (IfM) and the GEOMAR Research Center for Marine Geosciences. This report addresses friends and partners in science, politics and private enterprises. It gives an insight into the scientific achievements of IFM-GEOMAR and its predecessor institutes during the last three years.

The Institute

"From the Seafloor to the Atmosphere above the Ocean ..."

IFM-GEOMAR covers the entire spectrum of marine research ranging from seafloor geology to the atmosphere above the sea. Problems such as global warming, the ocean in a changing environment, over-exploitation of marine resources and an increasing global population in coastal areas with growing sensitivity to natural hazards demand for a comprehensive approach in marine sciences as an integral part of Earth's system research. These topics illustrate the integrated research approach of IFM-GEOMAR that is to investigate the chemical, physical, biological and geological processes in the ocean and their interaction with the seafloor and the atmosphere.

Your Partner in Marine Science

IFM-GEOMAR is a partner in national and international marine research networking, which is a prerequisite for a comprehensive approach to Earth's system research. In this context, the merger of the predecessor institutes to form the Leibniz Institute of Marine Sciences may be considered as a first step to address the challenges in marine research. In March 2004 the German Marine Research Consortium (KDM) was found as a representation of all major German institutions in the field of marine research. The French Ifremer and the British Southampton Oceanography Centre joined as associate members. It is the goal of the consortium to promote research planning, strategic research development, infrastructure management, international co-operation and public relations in all fields of marine sciences. KDM is currently chaired by IFM-GEOMAR.

Our Future

The concentration of Marine Sciences in Kiel in the newly merged institute has been a major challenge in the reporting period and is still an ongoing process. Based on its scientific scope, expertise and excellence, as well as size and budget, IFM-GEOMAR is already one of the leading institutions in Marine Sciences in Europe and worldwide.

About this Report

The major changes in the institute and its organizational structure, namely the four research divisions: Ocean Circulation and Climate Dynamics, Marine Biogeochemistry, Marine Ecology and Dynamics of the Ocean Floor are described in the first two sections followed by a selection of major scientific highlights of the past three years. Our involvement and contribution to long-term research programs on the national as well as the international level is the major focus of Section 4. Marine science requires new and innovative technology. Some of these developments invented by IFM-GEOMAR are described in Section 5. Our central facilities and services supporting and facilitating the scientific work are highlighted in Section 6. Results of IFM-GEOMAR research are documented in a impressive number of publications listed in Section 7. Information about scientific exchange and cooperation on the national and international level is given in Section 8. As an institute at the University of Kiel, IFM-GEOMAR contributes substantially to student education in marine sciences. Section 9 summarizes these activities over the past 3 years. Finally, public interest in the results of our research has grown continuously as documented in the multiple activities in the field of public relations as described in Section 10. Additional information to various sections is provided in the appendices. Please note that part of the information is only provided electronically on CD in order to reduce printing costs.

I hope that you will enjoy reading this first IFM-GEOMAR Report which, from now on, will be published annually.

Kiel, May 2005

Prof. Dr. Peter M. Herzig

1. IFM-GEOMAR Development 2002-2004

1.1 Overview

The Leibniz Institute of Marine Sciences at the University Kiel (IFM-GEOMAR) was founded January 1st, 2004 through a merger of the former Institute for Marine Research (IfM) and the GEOMAR Research Center for Marine Geosciences. This document reports on the the phase of the merger during the period 2002-2004, covering two years of the individual institutes IfM and GEOMAR (2002-2003), and one year of the merged institute (2004). A brief historic background of the individual institutes is provided in the next section.

The mission of IFM-GEOMAR is **to investigate the physical, chemical, biological, and geological processes in the ocean and their interaction with the seafloor and the atmosphere.**

The main research topics are grouped in four areas: Ocean Circulation and Climate Dynamics, Marine Biogeochemistry, Marine Ecology, and Dynamics of the Ocean Floor. In addition, there are two major interdisciplinary Collaborative Research Centers (SFBs) funded by the German Science Foundation (DFG).

The institute is an independent foundation by public law, supervised by a "Board of Governors" which consists of representatives of State and Federal Governments, the University of Kiel, a representative from another research institution, a representative from private industry and the chairman of the institute's Scientific Advisory Board (SAB) (see Appendix A). The SAB of IFM-GEOMAR is an internationally constituted advisory group with leading scientists respresenting all major research disciplines found at the institute. An overview of the organizational structure of the new institute is shown in Figure 1 (page 4). By the end of 2004, IFM-GEOMAR had about 400 employees, including 240 scientists and 160 service and technical staff. About 140 scientists and 15 service and technical staff are funded through research grants.

The Leibniz Institute of Marine Sciences is associated with the University of Kiel and contributes substantially to undergraduate and graduate teaching in the following fields: oceanography, meteorology, biological oceanography, fishery biology, marine chemistry, marine geology, geophysics and mineralogy.

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The new IFM-GEOMAR logo.

The involvement of diploma and Ph.D. students in research projects is an important element of IFM-GEOMAR research. The total number of students at IFM-GEOMAR is currently about 300. Through training of students and young scientists from foreign countries, the institute has contributed significantly to the development of infrastructures for marine science in many regions of the world. Several international study programs have been implemented in recent years (see section 9).

Much of the institute's research work contributes to international research efforts such as the World Climate Research Program (WCRP), the International Geosphere-Biosphere Program (IGBP) or the Integrated Ocean Drilling Program (IODP). Emphasis is on a better understanding of the ocean's past and present role for climate variations and air-sea interactions, the role of biogeochemical transport and transformations in global change, the response and sensitivity of marine ecosystems to external forcing, gashydrate research and risk assessment of natural hazards due to plate tectonics.

IFM-GEOMAR scientists have a long tradition of participating in national and international planning and management of large-scale interdisciplinary research programs. This includes programs such as CLIVAR (Climate Variability and Predictability), BALTEX (Baltic Sea Experiment), SOLAS (Surface Ocean Lower Atmosphere), GLOBEC (Global Ocean Ecosystems Dynamics), IODP, Interridge, and others.

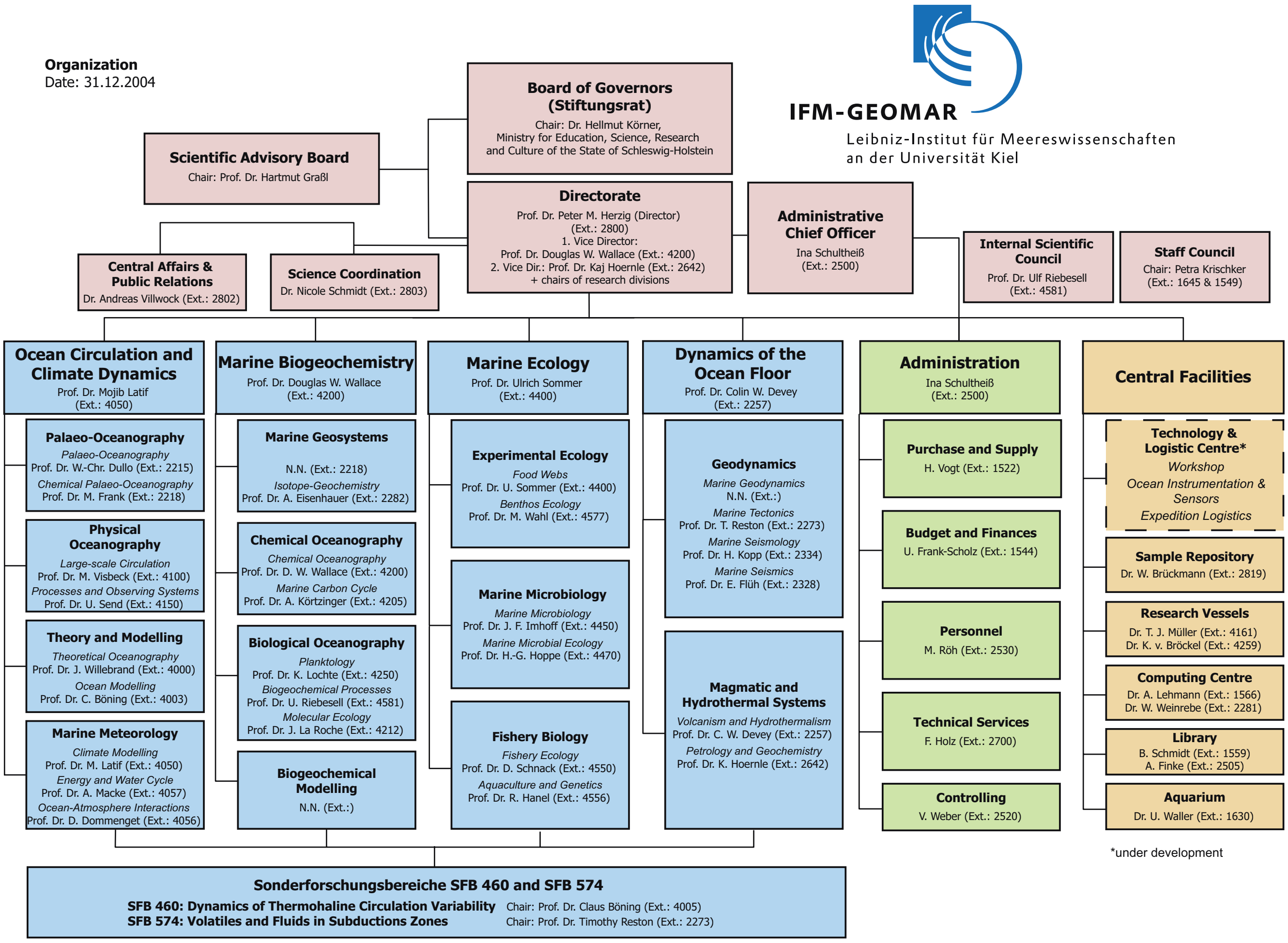


Figure 1: Organizational structure of IFM-GEOMAR by the end of 2004.

The scientific work of IfM and GEOMAR, as well as of the merged institute, could not have been maintained without funding of peer-reviewed proposals through the German Research Foundation (DFG), the Federal Ministry of Education and Research (BMBF), the directorates of the European Union (EU) as well as other funding agencies. We would like to express our gratitude to all of those who have supported our research during the past years.

Highlights in this context are the two Collaborative Research Centers (Sonderforschungsbereiche) in which IFM-GEOMAR plays a leading role. Since 1996, DFG has supported SFB 460 on "Dynamics of Thermohaline Circulation Variability" that links the physical and chemical groups at IfM with the University. SFB 574 on "Fluids and Volatiles in Subduction Zones" that started in 2000, was implemented within the groups of the former GEOMAR and investigates the "subduction factory" and its role for climate feedbacks and natural disasters (see Section 4).

The results of the institute's research work are generally made available through a wide range of publications (see Section 7). The main emphasis is on peer-reviewed international journals. Increasingly, dissemination of information in electronic form through the internet portal of IFM-GEOMAR (www.ifm-geomar.de) is used.

In particular, in the field of technology development, IFM-GEOMAR cooperates with a number of small and medium-sized companies active in marine technology and science, partly founded by former staff members of the institute.

The Leibniz Institute of Marine Sciences is a member of the Leibniz Association (Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz (WGL)) and the Konsortium Deutsche Meeresforschung (KDM).

1.2 Historical Background

1.2.1 Institute for Marine Research (IfM)

The Institute for Marine Research was founded in 1937 by the Christian-Albrechts University of Kiel (CAU), with the zoologist Adolf Remane as its first director. The second director was the chemist Hermann Wattenberg who lost his life together with nine staff members when the institute building in Kitzeberg was bombed in 1944. After the Second World War the institute, now located in the Hohenbergstraße, re-developed and grew considerably under the leadership of the oceanographers Georg Wüst (1946-1959) and Günter Dietrich (1959-1968). In 1968 the increasing importance of marine research led to an agreement between the State of Schleswig-Holstein and the Federal Government enabling the co-financing of the institute which continued to be associated with the Christian-Albrechts University. 1977 the institute became part of the so-called "Blaue Liste" characterized by the joint financing by the Federal Government, the State of Schleswig-Holstein and the community of German Federal States.

Fig. 2: West shore (IfM) campus at the "Düsternbrooker Weg" with research vessels.

In 2000, the original 10 scientific departments were restructured into three research divisions (Ocean Circulation and Climate, Marine Biogeochemistry and Marine Ecology).

The main building of IfM at Düsternbrooker Weg 20 was completed in 1972, with an extension completed in 1988 (see Fig. 2). Other locations include the old institute building at the Hohenbergstraße, and office/storage space at the Seefischmarkt and the Technical Faculty (on the east shore).

1.2.2 GEOMAR Research Center

The GEOMAR Research Center for Marine Geosciences at the Christian-Albrechts University of Kiel was founded in 1987, with Jörn Thiede as founding director. The GEOMAR mission was to pursue basic geo-marine environmental research in the broadest sense. The research objectives included past and present natural and anthropogenic processes which determine the origin, composition, and structure of sediments and magmatic rocks of the seafloor. The research focus, which united the four departments of Marine Geodynamics, Volcanology and Petrology, Paleoceanology, and Marine Environmental Geology, was characterized by its global perspective and integrated approach towards a better understanding of geomarine processes.

Fig. 3: East shore (GEOMAR) campus on the "Seefischmarkt".

The institute was located on the Seefischmarkt on the eastern shore of the Bay of Kiel. In 1996, the institute moved to a new building which was able to accommodate most of the scientific groups (see Fig. 3). The GEOMAR Research Center was originally financed by the State of Schleswig-Holstein but applied for admission into the "Blaue Liste" (see previous section) which was finally granted in 2002 in response to a positive evaluation by the Wissenschaftsrat.

1.3 Highlights 2002-2004

Although both institutes, IfM and GEOMAR, were still independent throughout the years 2002 and 2003, intensive preparations for the merger of both institutes were made during this period. The directors of IfM, Jürgen Willebrand, and GEOMAR, Wolf-Christian Dullo, prepared in cooperation with the Scientific Advisory Boards, the IfM "Kuratorium" and the GEOMAR Board of Governors the merger of both institutes.

For the new institute a new full-time director position was opened that was filled with Peter Herzig who joined the institute beginning of 2004. Mojib Latif, Douglas Wallace, Ulrich Sommer and Colin Devey assumed the lead of the four research divisions of the new institute which Douglas Wallace and Kaj Hoernle as assistant directors.

It was recognized that the merger of both institutions would only be efficient and successful, when the entire institute can be united in one location. Pre-planning for a relocation of the IfM part of the institute to the east shore campus on the "Seefischmarkt" started in 2004. First results of the merging process are the relocation of the entire administration in Building 4 and the preparation for a new Technology and Logistics Center in Building 14 on the East Shore Campus (see figure 4). The latter will be implemented in 2005. In addition, the development of a concept for the old IfM building as an international facility for teaching and education in Marine Sciences is under way.

The last three years have seen several important changes in the leading personnel of the institute: Eberhard Ruprecht, Friedrich Schott, Erwin Suess, Hans-Ulrich Schmicke and William Hay retired after many years of excellent service for IfM and GEOMAR, respectively. The institute is indebted to them.

Throughout the reporting period, excellent scientists of IFM-GEOMAR received calls on attractive positions at other universities. Most notable are Uwe Send (Scripps Institution for Oceanography) and Jason Morgan (Cornell University). A full list is provided in Appendix 1.

Fortunately, a number of open positions could successfully be filled with new staff. To note are the appointments of Mojib Latif (Meteorology), Colin Devey (Magmatic and Hydrothermal Systems), Martin Visbeck (Physical Oceanography), Ulf Riebesell (Biological Oceanography), Martin Wahl (Experimental Ecology), and Andreas Macke (Marine Meteorology). Most recently, Martin Frank joined the group on Chemical Paleo-Oceanography.

The institute hopes that in the near future appointments can be made for vacant professorships in the fields of i) bio-geochemical modeling, ii) marine geosystems, iii) marine geodynamics.

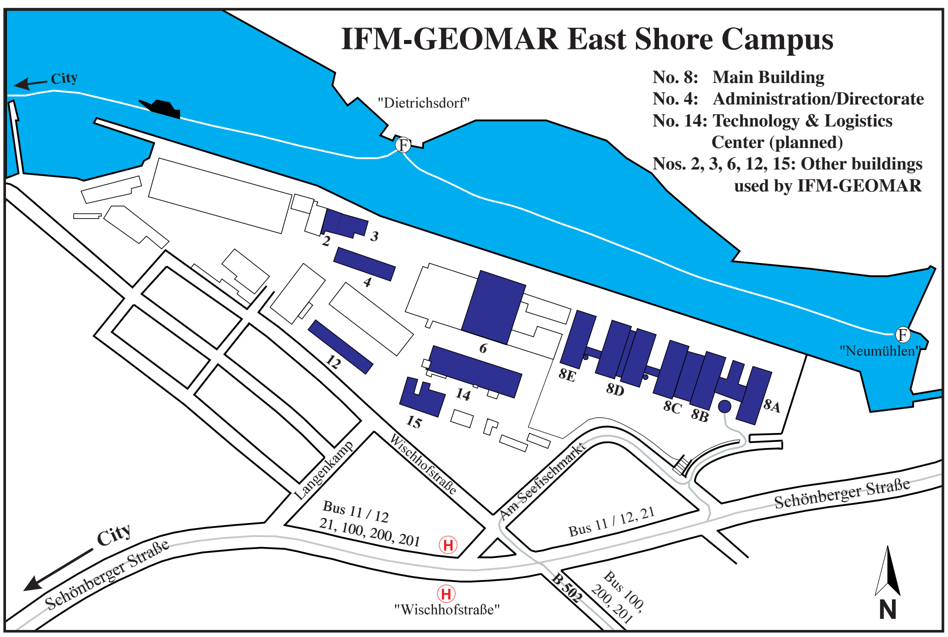


Figure 4: The IFM-GEOMAR eastshore campus on the "Seefischfarkt".

On the scientific side, there have been a number of successful proposals for new research projects or successful extensions of ongoing activities. Most notable are the successful extensions of both SFB's (SFB 460 to 2006, SFB 574 to 2008) but also the two new DFG priority programs "AQUASHIFT" and "From the Mantle to the Ocean" that will be important research foci for the next few years. In addition, a number of proposals for large projects funded by BMBF or EU with coordination by IFM-GEOMAR were granted in the reporting period. Overall, the total project funding of about 15 Mio € in 2004 (13 Mio. € in 2003), in comparison to 26 Mio. € institutional funds, highlights the success and excellent reputation of IFM-GEOMAR scientists.

The number of major seagoing expeditions with chief scientists and PI's from IFM-GEOMAR is another indicator of the research activities in the institute. During the reporting period, more than 30 of these cruises were performed every year on different research vessels (see Appendix 4). Working areas are virtually all ocean basins from high latitudes to the Tropics.

A highlight of public outreach at IfM and GEOMAR was an exhibition on marine research in Kiel during the "Volvo Ocean Race" and "Kieler Woche 2002" which attracted about 60,000 visitors in six weeks. IfM and GEOMAR also contributed to exhibitions on a coaster to the year of Geosciences in 2002, the year of Chemistry in 2003, and the year of Technology in 2004. The visit by the Prime Minister of Schleswig-Holstein, Mrs. Heide Simonis, in Spring 2004 was an important event. Details of the public relations work are reported in Section 10 of this document.

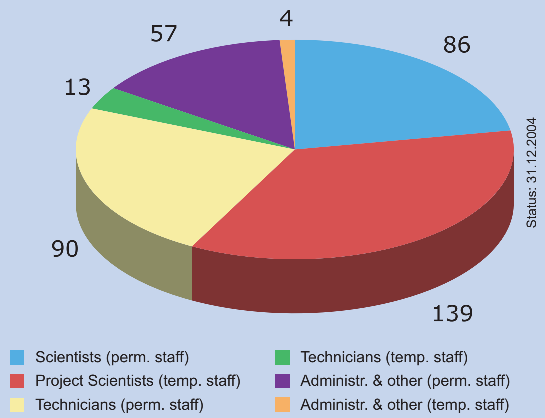
In November 2004, Peter Herzig was appointed "Maritime Coordinator" of the State of Schleswig-Holstein by the Prime Minister.

Along with so much positive news, it is our sad duty to report the death of four highly respected colleagues who had contributed to the establishment of GEOMAR, and later to maintaining the institute's continuity, almost from the beginning on: Gabriele Ippach died on 6 May 2002. She worked in the management of third-party funds. Peter Sachs died on 9 July 2002. He had been in charge of the EMS laboratory right from its very establishment. Sonja Klauke, member of SFB 574 died on 12 October 2002 and Dirk Reese on 25 Feburary 2004. Due to a tragic accident Moritz Hammes, student in experimental ecology died on 25. September 2004.
We gratefully acknowledge their contribution to the institut and hold fond memories of them. Our sympathy is with their families.

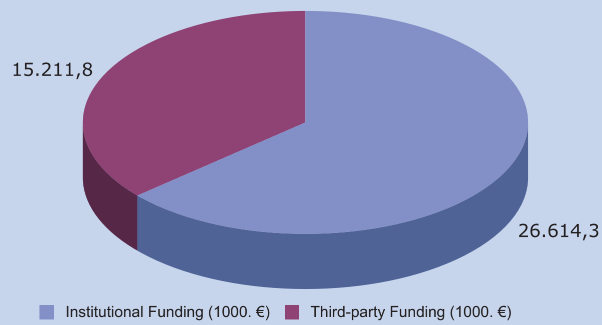
IFM-GEOMAR Fact-Sheet
(Status: 31.12.2004)

Basic facts of IFM-GEOMAR staff and funding. More details can be found in Appendices 2 & 3, respectively.

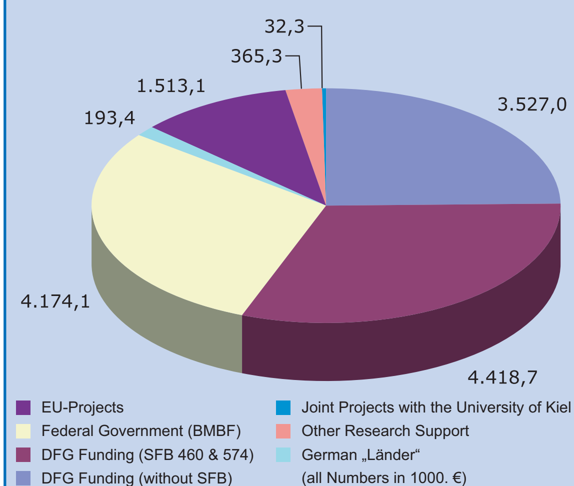
IFM-GEOMAR Staff



IFM-GEOMAR Funding 2004



Research Funding 2004



2. Reports of the Research Divisions

2.1 Research Division 1: Ocean Circulation and Climate Dynamics

Research

The ocean´s role in climate is the overarching theme for Research Division 1 (RD1). A particular strength of the Research Division is the simulataneous expertise in large-scale and process-oriented modelling, observational and sea-going capabalities able to address the dynamics governing the present-day system, and paleo-oceanographic expertise to improve our understanding of past climate conditions and variations. With the merger of IfM and GEOMAR the newly formed Research Division 1 includes the fields of meteorology, physical oceanography, and paleo-oceanography, so that the full spectrum of climate variability from seasonal to millenial timescales can be studied within the Research Division using jointly observations, numerical models, and theoretical concepts.

A major venue for the research of Research Division 1 is the "Sonderforschungsbereich" (SFB) 460 "Dynamics of thermohaline circulation variability", which has a focus on the subpolar North Atlantic. The SFB was reviewed by the "Deutsche Forschungsgemeinschaft" (DFG) in 2002 and a third extension was granted until the end of 2006, at which time the SFB will finish. An international workshop on "North Atlantic thermohaline circulation variability" was organized in September 2004 under the auspices of the Climate Variability and Predictability (CLIVAR) program of the World Climate Research Program (WCRP) in Kiel with strong participation of the SFB. Workshop participants discussed the mechanisms of North Atlantic climate variability analyzing both, observations and results from numerical models, and the potential for abrupt climate change in the North Atlantic in response to greenhouse warming.

Personnel

There have been quite some changes in the staff of the Research Division. Peter Lemke left the IfM in 2001 and was replaced as head of the unit "Maritime Meteorology" by Mojib Latif in 2003. Prof. Latif´s expertise is in the field of global climate modelling. Eberhard Ruprecht, also from the unit "Maritime Meteorology", retired in 2004 and was replaced by Andreas Macke, who is an expert in radiative transfer and cloud physics. Also in 2004, Friedrich Schott, of "Physical Oceanography-Large-Scale Circulation", retired. He was replaced by Martin Visbeck, who is strongly involved in international observational programs and the development of new observation systems.

Martin Frank was hired in 2004 in the unit "Paleo-Oceanography". He is specialized in "Chemical Paleo-Oceanography" and thus provides an important contact to Research Division 2. Dietmar Dommenget was hired as a Junior Professor in 2003 in the unit "Maritime Meteorology". His focus is on large-scale air-sea interactions in the mid-latitudes. Two professors are currently on leave: Uwe Send from the unit "Physical Oceanography - Processes and Observing Systems" and Rolf Käse from the unit "Theory and Modelling". Two young research group leaders accepted professorships elsewhere: Axel Timmermann left to the University of Hawaii and Andreas Oschlies to the Southhampton Oceanography Centre.

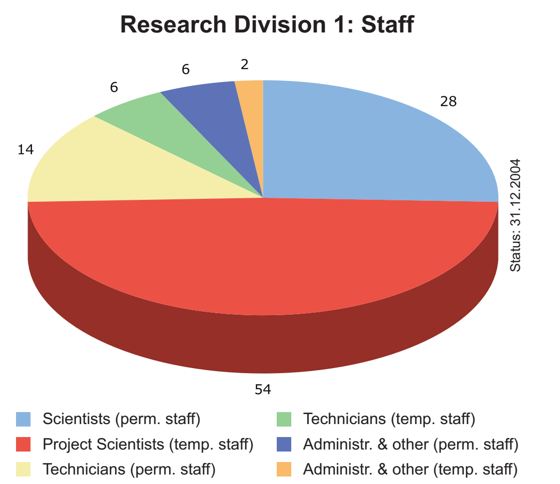
Future perspectives

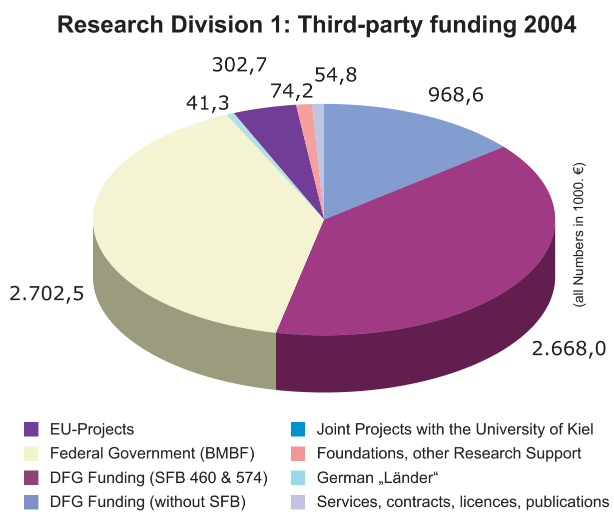
While maintaining strength in the areas of current activity, the role and the interaction of the tropical climate with ligh-latitude processes deserves more attention. In particular, for seasonal to interannual predictions the role of the tropical ocean circulation and lower atmospheric processes need better exploration and better representation in numerical models. The tropical-subtropical oceans are also believed to undergo major ecological changes under future climate scenarios. Here, the combined effects of ocean circulation variability on tropical upwelling systems and their biogeochemistry are key issues, which are to be addressed in close collaboration with Research Division 2, possibly under a new joint SFB umbrella.

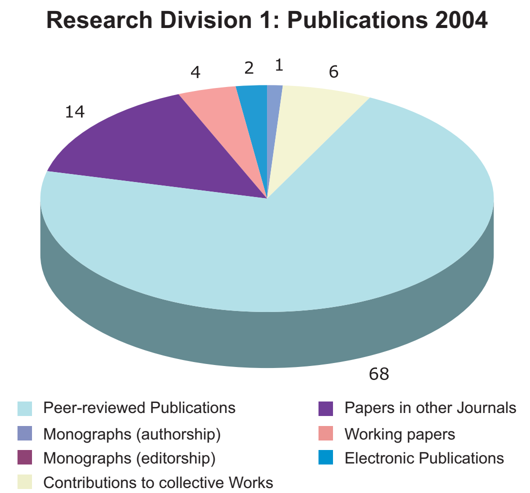
Observational methods in oceanography are rapidly expanding with the advent of remotely operating platforms such as floats and gliders.

IFM - GEOMAR will continue to play a leading role in the enhancement of these systems. Several of these developments are persued in close collaboration with Research Division 2 and possibly Research Division 3.

Understanding and modelling past climate changes is a crucial test for modern predictive climate models. The combined expertise in modern climate dynamics and the application (interpretation) of marine climate proxies of the past will be strengthened by new emphasis on paleo-climate modelling.







2.2 Research Division 2: Marine Biogeochemistry

The period covered by this report was a time of major change for Research Division 2. Most significant over the longer term will be the impact of the IFM-GEOMAR fusion in 2004: the merger is associated with a significant increase in capacity within the Division which now covers the sediment-water and atmosphere-ocean interfaces as well as the pelagic system in-between. As of January 2004, the Research Division is made up of 2 previous IfM Research Units: "Chemical Oceanography" (CH) and "Biological Oceanography" (BI) together with the former GEOMAR-department "Marine Environmental Geology" (now named "Marine Geosystems" (MG)). A fourth Research Unit "Biogeochemical Modelling" is still to be established.

Work in the Division focuses on interactions between sediment, oceanic, and atmospheric material reservoirs and the organisms (including humans) which mediate marine biogeochemical processes. Major emphasis is on the highly dynamic interfaces between atmosphere and ocean and sediment and ocean. Particular attention is paid to elements and compounds that are highly mobile and radiatively active. A closely related theme is the development of chemical, biological and isotopic diagnostic tools (proxies) that are suited to investigation of current and past oceanic conditions.

Personnel

The Research Division comprises a community of biogeochemists, geochemists, biologists, geologists and modellers with complementary skills, diverse perspectives and inter-related scientific interests. In order to establish a coherent research portfolio from such a diverse array of expertise we have developed a simple guide: the biological studies we pursue should usually be relevant to geochemical issues and our marine chemistry and geology studies should generally have some relevance and consequences for organisms.

The retirement of Erwin Suess (Head of GEOMAR's "Marine Environmental Geology" department) in October 2004 was a major personnel loss for the entire institute. Uwe Rabsch, who developed and subsequently managed the IfM's Radioisotope Laboratory, also retired in 2004. There were however also some important gains: Ulf Riebesell was recruited to the C3 Professorship in "Biological Oceanography" (August 2003) and Peter Croot joined as Assistant (C1) in "Chemical Oceanography" (April 2002). Despite these successes, the difficulties of recruitment within the area of Marine Biogeochemistry were signalled by failure to fill the C4 Position in "Biogeochemical Modelling". The position has been readvertised. In the case of the Head of the "Marine Geosystems" group (successor to Erwin Suess), the search continues into 2005.

Research

Inevitably, most research activities for the reporting period were based on proposals that had not envisioned the new possibilities arising from IFM-GEOMAR fusion. However, the impact of an earlier major reorganisation, the founding of IFM's Marine Biogeochemistry Research Division in 2000, was clearly felt. Notably, the *METEOR* 55 expedition to the tropical Atlantic Ocean in 2002 was the first expedition jointly undertaken by the "Biological Oceanography" and "Chemical Oceanography" research units. The cruise was a pilot study for the national German contribution to the new international research program SOLAS (Surface Ocean Lower Atmosphere Study). To-date this single cruise has resulted directly in 13 published peer-reviewed articles (including one in Nature) and an additional 2 submitted manuscripts. It is a clear example of the scientific benefit that can result from new, interdisciplinary organisational structures. A subsequent joint "Chemical Oceanography" and "Biological Oceanography" cruise to the sub-tropical Atlantic (*METEOR* 60/5 in 2004) was more focussed on issues relating to SFB 460, but is also producing a good return in manuscripts.

Planning is now underway for joint research programs that reflect the broader capacity arising from the IFM-GEOMAR merger. One such collaboration already exists in the joint development of paleo-proxies involving biological and isotopic studies within the ESF-supported CASIOPEIA project. However the full scientific potential of the merger must await the completion of existing projects and the development of new projects: a 3-5 year timescale is required. In the meantime, all research units were very active with their individual research programs.

In the case of "Marine Geosystems", the reporting period involved major contributions to several large BMBF-supported projects.

The **LOTUS** program (2001-2004; coordinator Peter Linke) sought new insight into the temporal variability of key physico-chemical and biogeochemical parameters in the sediment and in the water column as well as their impact on the variability of vents associated with near-surface gas hydrates. This project involved the development of new deep-sea observatories based on benthic lander technology as well as application of new technologies to the examination of the methane distribution in sediment and bottom water. Isotopic investigation was conducted into the life span and the ambient temperature of fluid and gas discharge sites.

The **OMEGA** project investigated modes and mechanisms of gas hydrate formation and dissociation in marine surface sediments. This involved sampling of hydrates under in-situ pressure conditions using autoclave technology and their structural analysis by tomography. Pore water studies and numerical modelling confirmed that hydrates are formed by ascending gas bubbles rather than fluid flow.

METRO started to operate in October 2004 as a follow-up of the OMEGA project and will continue to investigate gas hydrate formation processes, as well as mud volcanism in the Black Sea and asphalt flows in the Gulf of Mexico. Within the KOMEX project, the largest modern barite deposit was discovered in the Sea of Okhotsk and was shown to be formed by the ascent of barium-charged fluids. At the same time, the "Marine Geosystems" group played a major role in the development of SFB 574 (Speaker: Erwin Suess) and in the conduct of the SFB's first phase. In particular, MG scientists were involved in 4 sub-projects investigating fluid flow and volatile cycling in the fore-arc of Central America. The field studies showed that most of the volatiles bound in the incoming sediments are recycled into the ocean via fore-arc venting. The second phase of SFB 574 started in July 2004 and will include further studies in the Central American but also the Chilean subduction zone.

In addition to conducting a range of work into trace metal and trace gas dynamics during the previously mentioned Meteor expeditions, the Chemical Oceanography Unit made a major contribution to the EU project CAVASSOO through the establishment of an observational program on board the Swedish Car Carrier *FALSTAFF*. A vast amount of data was collected that defined the seasonal cycle of surface pCO_2 and related biogeochemical and physical properties in the mid-latitude North Atlantic. Within the EU ANIMATE project, fixed-point, near-surface, time-series measurements of pCO_2 were collected from moorings using newly-developed sensors and data telemetry schemes. Within SFB 460, work continued on the anthropogenic CO_2 uptake by the North Atlantic. However a new sub-project was also added to develop and apply the capability of autonomous profiling floats to measure the ocean's oxygen inventory.

Within both "Biological Oceanography" and "Chemical Oceanography", a major focus has been the study of effects of iron (via dust) on phytoplankton growth and hence biological CO_2 sequestration in the ocean. Members of BI and Chemical Oceanography participated in large-scale iron fertilisation experiments in the Southern Ocean (EISENEX and SOIREE). The limitation of primary production and, especially, nitrogen fixation by macronutrients or iron was assessed in the tropical and mid-latitude Atlantic (*METEOR* cruises M55, M60). This work was complemented by molecular biological investigations into the diversity of nitrogen-fixing organisms. The effects of high concentrations of CO_2 on plankton development were studied in mesocosm experiments to analyse potential future changes in marine ecosystems and biogeochemical cycling. A new line of research is the investigation of biological processes of trace gas production. All of these lines of research are to be developed and pursued under the EU's CarboOcean Integrated Project and a proposed national SOLAS contribution.

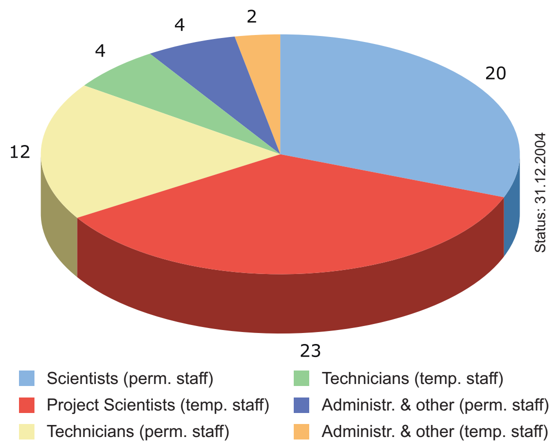
The Research Division has continued its support for scientific infrastructure. Four separate infrastructure units are managed by the Research Division on behalf of the Institute as a whole: the molecular biology laboratory, the deep-sea instrumentation group, the isotope analysis laboratory and the radio-isotope laboratory. The first three of these, in particular, have been heavily involved in supporting the scientific projects of the Research Division.

Future perspectives

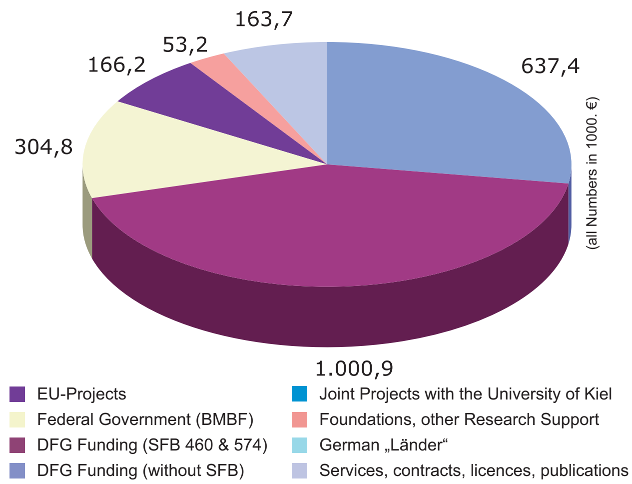
For the period that will be covered by the next report, we foresee the following major activities. The COMET program of the BMBF will carry forward the "Marine Geosystem's" research activities in the area of gas hydrates and methane research. All three research units are involved in the new EU Integrated Project CARBOOCEAN. The "Biological Oceanography" and "Chemical Oceanography" units are jointly involved in the preparation of a new BMBF program entitled SOPRAN (Surface Ocean Processes in the Anthropocene) which is a national contribution to the oceanic side of SOLAS. Scientists from both "Marine Geosystems" and "Chemical Oceanography" have worked on the development of a new DFG Priority Program proposal to study geochemical tracers (GEOTRACES). All three Research Units are playing a central role in the development of a concept for a new SFB into climate-biogeochemical interactions in the tropical oceans. Longer term, we see additional interactions developing in project areas such as: the joint study of the biogeochemical cycling of divalent cations; the effects of future CO_2 levels and climate on marine ecosystems (including anthropogenic impacts on deep sea corals); and the joint development of new ocean observing systems.

The potential for scientific interaction across the broad range of expertise and interests within the Research Division is undoubtedly very large. However there are significant barriers to interaction associated with the spatial separation of the Research Units. In the short term, there is no solution to this problem other than the scheduling of regular meetings. However barriers to scientific collaboration can be broken down if individual scientific projects share a common logistical or geographical focus. The Research Division will therefore attempt, wherever sensible, to coordinate its expedition logistics, geographical working areas and planned experiments. One possible point of contact for the Research Division and the Institute as a whole is a shared interest in the tropical oceans. In this context, efforts of the Research Division to establish a time-series program and logistics centre in the Cape Verde Islands, which were initiated with a Volkswagen Foundation-supported workshop in 2004, will be pursued further with proposals to the Foundation and the EU. Other aspects of future development will be critically dependent on filling the "Biogeochemical Modelling" and "Marine Geosystems" Professorships.

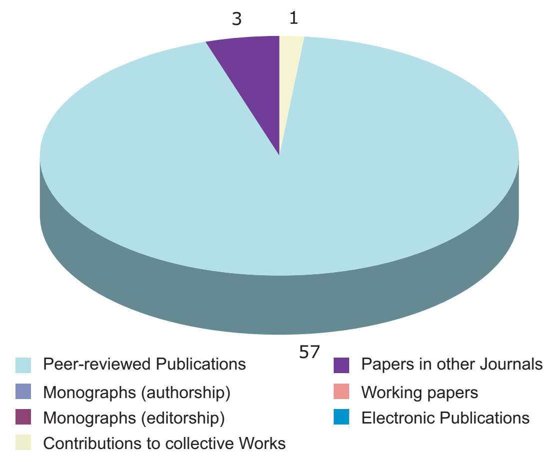
Research Division 2: Staff



Research Division 2: Third-party funding 2004



Research Division 2: Publications 2004



2.3 Research Division 3: Marine Ecology

The Research Division 3 "Marine Ecology" is focussed on the analysis of cause-and-effect relationships within marine ecosystems. Such a mechanistic analysis is required to understand the sensitivity of marine ecosystems against natural and anthropogenic changes of the physical and chemical environment and exploitation of bioresources. For a proper sustainable management of the marine environment, it is critical to understand the impact load a given local/regional ecosystem can tolerate before major structural changes occur, how such changes might affect community dynamics, and the extent to which such changes might be reversible. Such changes include outbreaks of harmful organisms, demise of commercially valuable ones, and a complete reorientation of biogeochemical cycles.

The response of ecosystems to natural and anthropogenic impacts cannot be understood by neglecting species specific differences in the response of organisms and by pooling them into broad categories (e.g. size classes, trophic levels). This is especially true for ecosystems influenced by one or a few keystone species. Therefore, the research of the RD "Marine Ecology" encompasses several hierarchical levels: ecophysiology of key species, dynamics and genetics of individual populations and of communities, interactions within and among species, structure and response of entire food webs. Single-species studies concentrate on those aspects which define the role of a species in interactions with other species or in biogeochemical cycles. This implies a strong emphasis on nutrition and growth limitation. Obviously, nutritional physiology is not only fundamental for a species' role in the natural food web and in biogeochemical cycles, but it is also of applied interest, e.g. in aquaculture and in the management of marine bioresources, including new natural substances (e.g. pharmaceuticals) from marine microoganisms.

Our research comprises all food web components from primary producers to top predators. With the appointment of Martin Wahl (C3-professorship for "Biological Oceanography – Benthos Ecology") in 2002 we could overcome the interim shortage of expertise in zoobenthos which had been mentioned in the IfM Report 1999-2001. A new Junior Professorship in "Fisheries Biology – Aquaculture" (Reinhold Hanel) has increased our capacities in aquaculture research and opened the perspective to expand ecological genetics from microorganisms to eukaryotes. An additional, new research group was established via the Emmy-Noether-fellowship for Boris Worm, whose group studies the ecosystem functions of marine biodiversity. Two new projects coordinated by RD3-scientists have intensified our international and national cooperation with other institutes: The international GAME project ("Global Approach by Modular Experiments") funded by the Mercator Stiftung and the DFG-priority program AQUASHIFT ("the impact of climate variability on aquatic ecosystems"). GAME combines teaching at the M.Sc.-candidate level and research by joint, world-wide distributed and internationally standardised experiments to answer controversially discussed issues in marine community ecology. For a more detailed description of AQUASHIFT see section 4.4 in this report.

Ecological genetics has maintained its traditional focus on marine bacteria and archaea with emphasis on the role of different genotypes in biogeochemically relevant transformations. Deep sea hot vents, phototrophic bacterial communities in the coastal zone, microbial aspects of the nitrogen cycle with focus on N_2O formation and transformation, and bacteria involved in associations with marine invertebrates and algae have been the primary study systems. In addition to this traditional focus we have initiated molecular genetic analyses of fish-stock differentiation, of the relationships between fish biogeography and speciation and on the role of intraspecific genetic diversity for the resistance of seagrass populations to environmental perturbations.

Global change research has gained momentum through the establishment of the DFG-priority program AQUASHIFT (started in November 2004). Five AQUASHIFT-projects are established at IFM-GEOMAR are funded (four at RD 3, one at RD 2). They concentrate on the impact of climate change on plankton communities and larval fish. The impacts of temperature and salinity changes on benthic interactions within the Baltic Sea are studied in additional projects. Within GAME, a series of experiments on the influence of elevated UV-radiation on the succession of littoral benthos have been accomplished.

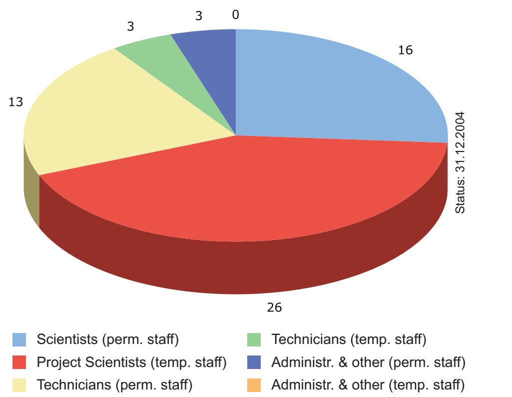
Experimental and field-centred **food web research** has been an ongoing activity during the reporting period. We have terminated successfully the experimental projects comparing marine and limnetic food webs (see IfM report 1999-2001) in 2003. Building on the scientific results and the experimental experience from those projects, we have initiated a series of experimental studies on the trophic level of marine mesozooplankton (trophic level 2 when feeding on phytoplankton, trophic level 3 when feeding on Protozoa) and its dependence on phytoplankton size structure and food supply. The experimental studies are supplemented by field surveys using the enrichment of the stable isotope 15^{o}N in animal tissue as trophic level indicator. Studies on the upper compartments of the marine food-web (primarily fish) are primarily field-centred and contribute to the scientific goals IGBP-core program GLOBEC (see section 4.5.3), either via participation in the BMBF-funded GLOBEC-Germany with its focus on the Baltic and North Sea or indirectly via GLOBEC-oriented EU-projects.

Aquaculture research is an applied spin-off of our research in feeding ecology and has been maintained through a number of projects associated to our aquarium (see section 6.1). Efforts to participate in the establishment of a large-scale aquaculture research facility in Schleswig-Holstein are on the way, the funding decision by the BMBF is, however, still pending.

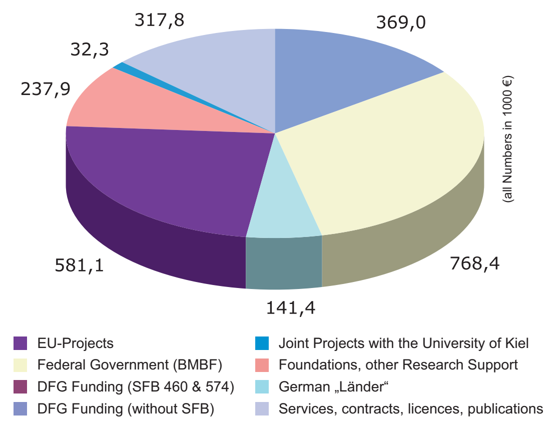
Chemical ecology has been a research focus in marine microbiology and in benthos ecology. The analysis of chemical interactions within marine communities is relatively new compared to the study of feeding relationships. Chemical interactions include the production of defence substances against predators and fouling organisms, the production and recognition of signal substances and responses to these substances. Major current topics are the chemical regulation of macroalgae-herbivore interactions and sponge-microbial interactions. The latter is part of a BMBF-funded national centre of excellence (BIOTECmarin) and has led to the foundation of a company for commercial use of natural substances for potential medical applications (see section 3.10).

Biodiversity research has comprised three components: The analysis of global patterns of biodiversity and their correlations with environmental factors (see section 3.9), the experimental analysis of the role of disturbances for maintaining diversity and preventing single-species dominance and the experimental analysis of the role of species diversity and within-species genetic diversity for ecosystem functions and recovery from environmental stress. The first and the second component are ongoing efforts, while the analysis of diversity-disturbance relationships has been accomplished during the reporting period.

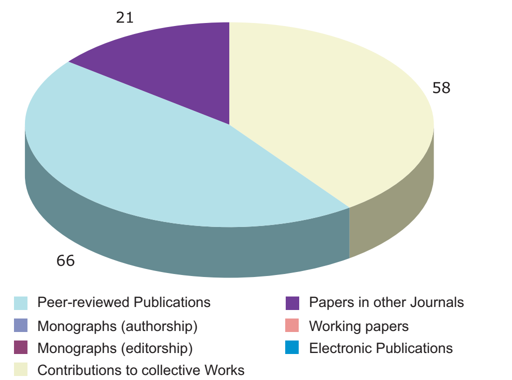
Research Division 3: Staff



Research Division 3: Third-party funding 2004



Research Division 3: Publications 2004



2.4 Research Division 4: Dynamics of the Ocean Floor

Research

The overarching theme in Research Division 4 "Dynamics of the Ocean Floor" is the origin, evolution and destruction of the ocean floor. The major current areas of investigation are: 1) Breakup of the continents and the onset of seafloor spreading, 2) Formation of the ocean floor and the ocean basins at spreading centers, 3) Composition and structure of the deeper convecting mantle based on studies of intraplate "hotspot" volcanism, 4) Destruction of the oceanic lithosphere through subduction at convergent margins and the structure of such margins, 5) Marine gateways and land-bridges, 6) Geo-hazards including earthquakes, volcanic eruptions, submarine land-slides and tsunamis, and 7) Marine resources associated with hydrothermal systems and gas hydrates.

A major change occurred with the merger of IFM and GEOMAR on January 1, 2004. Research Division 4 was formed from the former GEOMAR departments of Marine Geodynamics and Volcanology/Petrology. In 2004, the topic "Marine Hydrothermal Systems" also became a new research focus of the Division. To reflect this addition, the former group "Volcanology and Petrology" was renamed "Magmatic and Hydrothermal Systems".

Research Division 4 is heavily involved in several large-scale projects, from research programs such as the Geotechnology program. Within the Gashydrate Initiative, RD4 was involved with RD2 in the OMEGA project, contributing the developmnet of a side-scan sonar system to image the seafloor and in particular hydrate and carbonate outcrops and cold vents. The INGGAS project (2001-2004) with partners in Kiel, Hamburg and Bremen was co-ordinated within Research Division 4, leading to the development of a deep-tow streamer and positioning system, also to be used with the side-scan sonar from OMEGA. These deep-tow systems can be deployed together or separately and together with our expertise in swath-bathymetry and seismic methods provide seafloor and sub-seafloor imaging over a broad range of scales. Research Division 4 is also involved in more recent gas hydrate projects such as METRO (again with RD2: started 2004) and jointly co-ordinates the TIPTEQ project (started 2004) within the Continental Margins Initiative of the Geotechnology program (for more details, see section 4.6.2 on page 81).

Research Division 4 is very heavily involved in SFB574: *Volatiles and Fluids in Subduction Zones: Climate Feedback and Trigger Mechanisms for Natural Disasters*. Members of the division fill three of the major positions in SFB574. Prof. Tim Reston became the speaker of the SFB in 2004. Dr. Armin Freundt serves as the secretary and Prof. Ernst Flüh as the deputy speaker. Research Division 4 runs or jointly runs 8 of the 12 scientific subprojects within SFB 574 investigating fluid flow and volatile recycling in the incoming plate, in the forearc and through the arc to the atmosphere, and assessing the impact of these volatiles on the hazards associated with convergent margins. SFB 574 represents a close collaboration with Research Division 2 in particular. More details about SFB 574 can be found on page 67.

Highlights in terms of technical developments within the Research Division included the acquisition of and successful testing of a deep-tow seismic streamer and side-scan sonar (funded within the Gas Hydrate Initiative of the GeoTechnology programme), the acquisition of new high resolution seismic sources, and development of the laser step-heating Ar/Ar age dating technique, U-Th-Ra-Hf isotope analyses and volatile analyses with the Sychrotron XRF in Hamburg. The seismic processing facility and ocean bottom seismometer pool are the only German geoscience "Large-scale facility" funded by the European Union, now for a fourth term under successive framework programmes.

Personnel

Hans-Ulrich Schmincke retired on 31.03.2003 after 14 years at GEOMAR. In May 2004 he was replaced by Colin Devey who took his place as Professor for the "Dynamics of the Ocean Floor". Prof. Devey brought with him to IFM-GEOMAR the leadership of a DFG Priority Program 1144 "From mantle to ocean" studying mid-ocean ridge processes in the Atlantic (see also page 71) and the leadership of the international "InterRidge" program (page 78). Also established as a result of his appointment was the "Marine hydrothermal group"

Jason Phipps Morgan left IFM-GEOMAR in April 2004 after a stay of 5 years to take up a position at Cornell University, USA. A shortlist of candidates will be interviewed in early 2005 with a view to appointing a replacement within the year.

Ingo Grevemeyer was appointed on 15.01.2003 to a permanent staff position within the then Marine Geodynamics department of GEOMAR (now part of Research Division 4). Dr. Grevemeyer's research interests include the use of heat flow and seismic methods to study continental margins, oceanic islands and the ageing of the oceanic lithosphere.

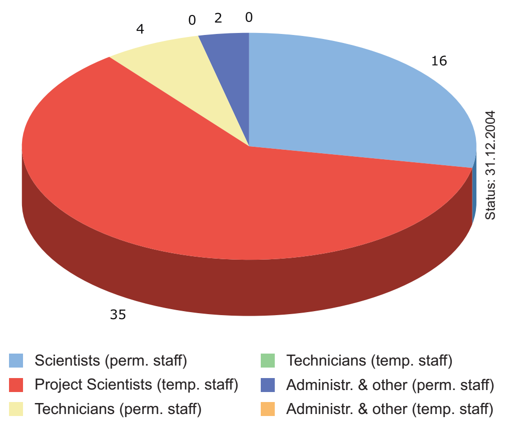
Frederik Tilmann the C1 Junior Lecturer within Geodynamics left end of March 2003 to take up a lectureship at Cambridge University. The C1 position was replaced by a Junior Professorship, which was filled by Heidrun Kopp in August 2003. Her interests are in the use of seismic and seismological methods to study active margins.

In June 2004 Klas Lackschewitz was appointed to a permanent staff position within the Magmatic and Hydrothermal Systems group. His research interests include the hydroterhmal alteration of igneous rocks. He is heavily involved in the DFG Schwerpunktprogramm 1144 "From Mantle to Ocean".

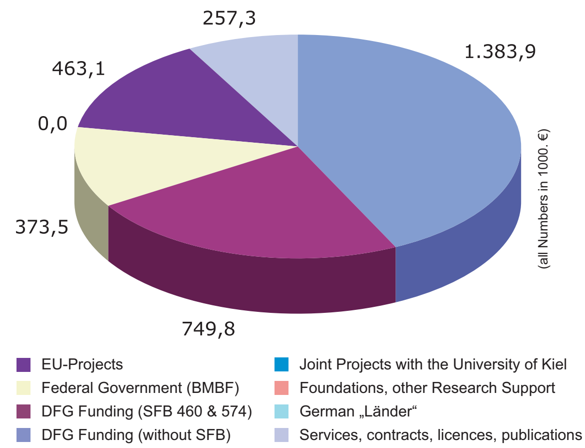
Future Perspectives

FB4 is currently in the process of appointing a new C4 to head the Geodynamics group. It is expected that the new Chair will strengthen expertise in convergent margins and the interpretation of seismic reflection data, allowing RD4 to build on its expertise in these areas. Our existing and planned expertise covers a broad spectrum in terms of both high temperature geochemistry and geophysics. The overall aim of the research division is a complete understanding of the evolution of the seafloor from its creation at mid-ocean ridges through its evolution within the plate, to its eventual destruction at convergent margins. We plan to establish a Graduate School to examine intraplate processes which will bridge the gap between our existing capacities in mid-ocean ridge and subduction zone studies in order to achieve this overall aim. An important additional perspective for Research Division 4 is to increase the work carried out on natural hazards, looking at the effects of geodynamic processes on the environment at both a local and global scale. An area of future growth with large potential is the new field of seismic oceanography in which seismic reflection methods are used to image the thermohaline fine structure of the water column: a pilot study in collaboration with Research Division 1 is underway. The Research Division will also increase its competence in deep submergence technology, with the acquisition of both remote-controlled and automous underwater vehicles and remotely-operated seafloor drilling capabilities.

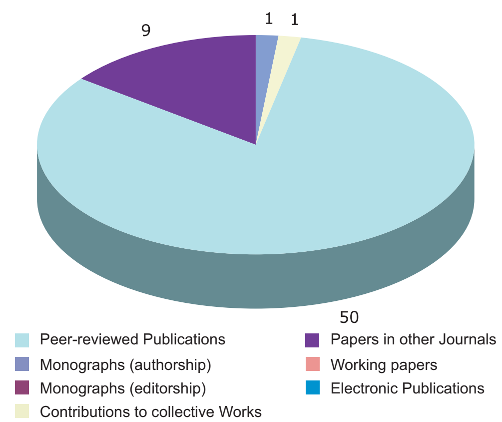
Research Division 4: Staff



Research Division 4: Third-party funding 2004



Research Division 4: Publications 2004



3. Scientific Highlights

3.1 Tropical Atlantic Variability

The Tropical Atlantic has turned out in recent years to be a key region for improved understanding of climate variability and predictability, not only for the adjacent regions of Africa and South America but for the European sector as well. And yet, present-day coupled climate models show disturbing biases for the tropical Atlantic, with anomalously warm sea surface temperatures (SSTs) instead of a minimum in the region of the eastern tropical „cold tongue". Several modes of Tropical Atlantic variability (TAV) have been identified; these include the Meridional Gradient Mode, the Atlantic Niño and the Benguela Niño and they are all strongly coupled to the seasonal cycle. Furthermore, the Pacific El Niño itself influences also the tropical Atlantic. As an example, Figure 1 shows the summer correlation between the first Empirical Orthogonal Function (EOF) of tropical rainfall with the surface winds (vectors) and SSTs (colours), indicating a strong role of the eastern tropical Atlantic in affecting precipitation of the region. In turn, droughts and related dust events and disease outbreaks in western Africa are all related to tropical Atlantic SST, making its prediction extremely important.

The gradient mode, in former times also called „dipole mode", occurs at interannual to decadal time scales and is most pronounced in boreal spring. Its SST pattern is associated with meridional wind anomalies blowing toward the warm hemisphere where it turns against the prevailing Trades, thus enhancing the effect, causing a positive feedback loop. Warm SST anomalies that occur primarily in the cold tongue region are referred to as Atlantic Niño. In some years, the warm anomalies propagate southward along the southwest African coast to beyond 20°S where they are known as Benguela Niños. The reduction in upwelling and thus nutrient supply associated with the Atlantic and Benguela Niños has large impacts on the ecosystem of the region, also including strong reduction of CO_2 outgassing into the atmosphere.

Physical Mechanisms of Tropical Atlantic Variability

The ocean can play a role in TAV through a number of mechanisms. While the intraseasonal to interannual variability in the eastern tropics and along the eastern boundary can to a large extent be explained by tropical and boundary wave processes that offer some degree of predictability, the longer-term processes in the interior are more complex. One of the yet poorly understood mechanisms is that of the shallow Subtropical Cells (STCs; Fig. 2). The STCs connect the subduction zones of the eastern subtropics (in both hemispheres) through equatorward thermocline currents with the Equatorial Undercurrent (EUC) and eastern upwelling regimes. Eastward off-equatorial undercurrents (NEUC, SEUC in Fig. 2) may also play a role in supplying the eastern upwelling domes.

Anomalies of the STC circulations, for example through varying wind stress and thus a change in equatorial upwelling, can result in equatorial SST anomalies that in turn affect the atmos-

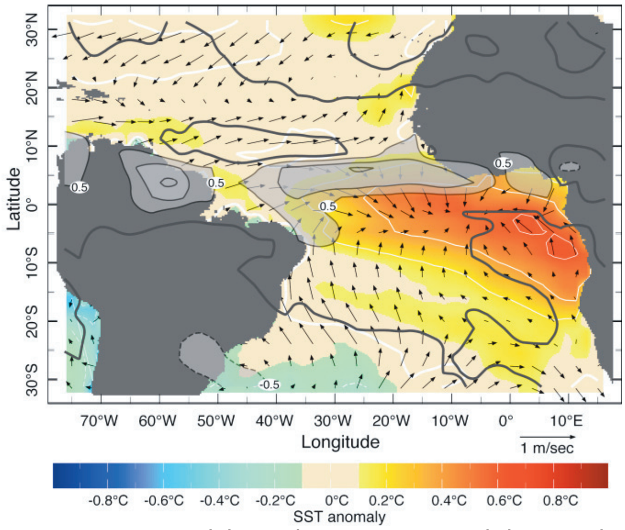


Figure 1: Typical boreal summer variability in the tropical Atlantic region presented in terms of the first EOF (explains 23% of the variance) of the June-August rainfall (contours in mm/day). The June-August SST anomaly (colours, in °C & white contours, every 0.2°) and surface wind anomaly (vector, in m/sec) are determined through regression on the time series of the rainfall EOF.

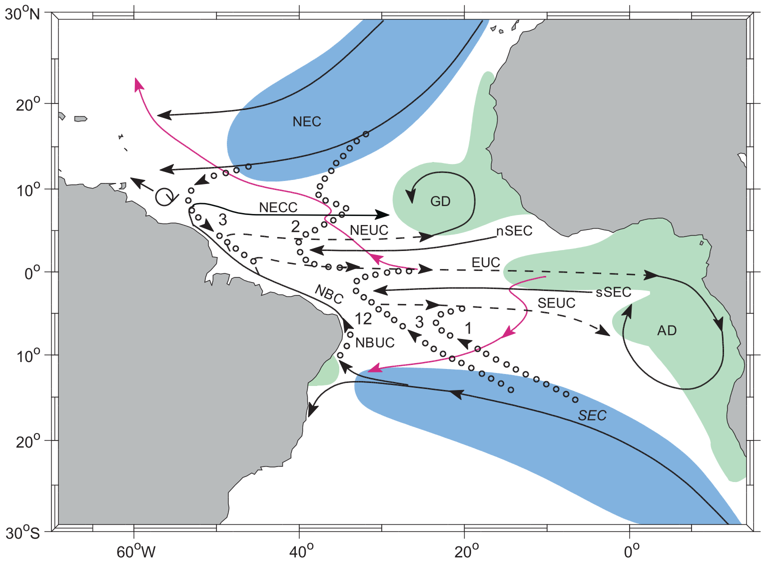


Figure 2: Schematic representation of the tropical Atlantic circulation with subduction (blue) and upwelling (green) zones. Current branches participating in the Shallow Subtropical Cell (STC) are NEC =North Equatorial Current; nSEC, sSEC = South Equatorial Current north and south of the equator; NECC = North Equatorial Countercurrent; EUC = Equatorial Undercurrent; NEUC, SEUC=North and South Equatorial Undercurrent; NBC, NBUC= North Brazil Current and Undercurrent; GD, AD=Guinea and Angola domes. Interior equatorward thermocline pathways dotted, transport estimates for the STC branches given in Sverdrups (Sv = $10^6 m^3 s^{-1}$); surface poleward pathways for the central basin (from drifter tracks marked by thin, magenta lines.

phere and climate (Fig. 1). This mechanism has just recently been proven to be a major factor in the Pacific equatorial SST variability over the past two decades. For the Atlantic, such studies have been started by IFM-GEOMAR as part of the German CLIVAR program, combing sustained observations and high-resolution modelling in the western tropics to understand the supply of the equatorial STC branches by the boundary circulation.

The thermocline in the upwelling regions (Fig. 2) rises toward the surface and one reason why coupled models work so poorly there is their lack of realistic representation of shallow-mixed-layer physics. Missing in particular is the understanding of the mutual roles of advection by the zonal equatorial currents (Fig. 2) on the one hand, and of upwelling and mixing on the other. Problems with the simulation of low-level stratus clouds in the atmosphere models increase these errors further. It is also suggested that Tropical Instability Waves (TIWs) at periods of a few weeks, generated by instabilities of the large zonal currents, play a role in the longer-term variability of the water mass distributions and SST. To answer these questions, experiments in the Atlantic cold tongue regime are planned as part of an international "Tropical Atlantic Climate Experiment" (TACE) with IFM-GEOMAR participation. These would combine moored stations, seasonal ship surveys and targeted mixing studies in the upper-thermocline and near-surface layer. The analysis of the observations would be combined with ocean-only and coupled modelling.

Why are the tropical ocean mechanisms of the Atlantic not only regionally important, but also affecting the North Atlantic and European climate? As known from observations and model studies, the North Atlantic Oscillation (NAO), which is the major atmospheric pattern of the Atlantic domain, strongly affects ocean circulation and stratification at mid- and higher latitudes. However, there is very little direct feed-back from the higher-latitude North Atlantic to the atmosphere. Instead, model simulations suggest that the variability of Labrador Sea convection and thermohaline overturning caused by NAO-related atmospheric forcing in the north is propagated toward the tropics along the western boundary and then affects tropical circulation and SST some time later. Tropical SST in turn forces the atmosphere which finally couples back to European latitudes, making the tropical Atlantic an important link in our climate system. However, these model suggestions still need confirmation by sustained observations; and plans are being proposed within CLIVAR to implement a network of stations.

Paleo-Analysis of Tropical Atlantic Variability

Analysis of the paleo records, including Caribbean corals and Sclerosponges, is an important ingredient in shedding more light on TAV. Previously, it has been difficult to obtain long, seasonally resolved proxy records from Atlantic corals because of sampling problems that severely affected the quality of the proxy data. Scienists at IFM-GEOMAR have now obtained very good results using fast growing corals from the Caribbean. The combination of stable isotope and strontium-calcium (Sr/Ca) measurements allows the reconstruction of SST and salinity changes in the Caribbean

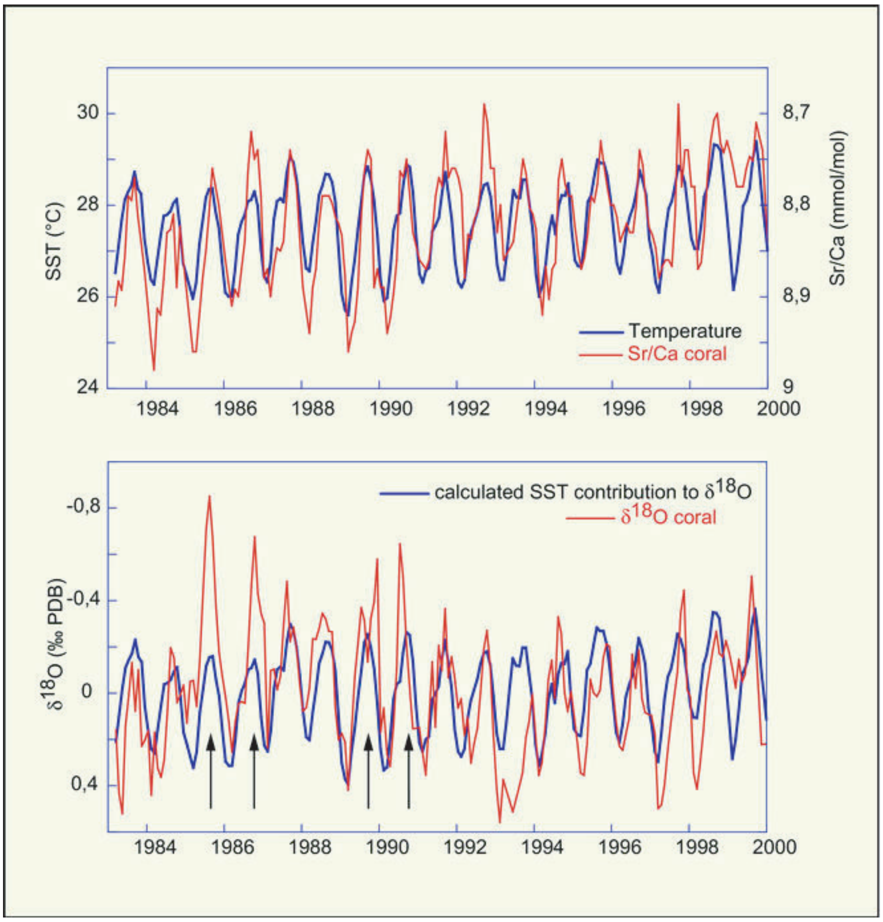


Figure 3: Monthly resolved proxy data from a Diploria coral (Guadeloupe). $\delta^{18}O$ and Sr/Ca ratios were measured from the same subsamples of coral aragonite. (a) the Sr/Ca ratios (top, red line) follow instrumental SST data (blue line). The slope of the Sr/Ca-SST relationship is -0.5mmol/mol per °C, confirming that Sr/Ca catpures the full amplitude of the seasonal SST cycle. (b) coral $\delta^{18}O$ (red line) shows much larger interannual variations, with large negative anomalies in late boreal summer (arrows), when low-salinity water from the Orinoco enters the Caribbean. The estimated SST contribution is shown by the blue line.

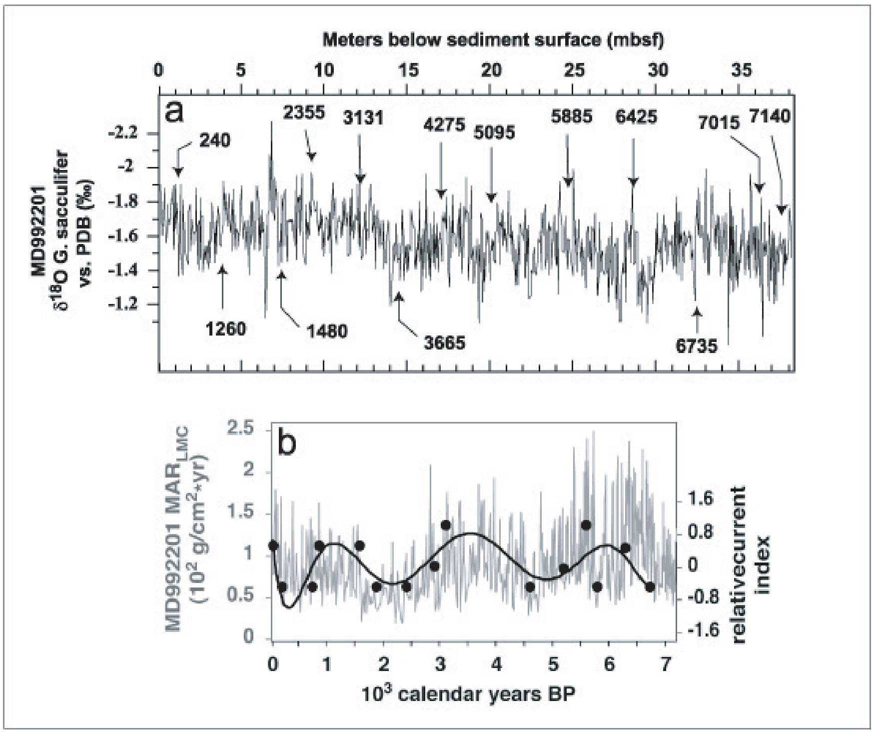


Figure 4: (a) Planktonic oxygen isotope data (G. sacculifer) for sediment record MD992201 and radiocarbon dates in calendar years BP marked by arrows. (b) Mass accumulation rates of aragonite and changes in relative current speed.

on timescales from seasonal to centennial (Fig. 3). Currently, century long, monthly resolved coral records from Guadeloupe and Venezuela are being developed. The Sr/Ca ratios of these records reflect SST variations in the tropical North Atlantic associated with the gradient mode of SST.

Sclerosponges are slow-growing marine organisms that provide climate information at least over the past 800 years. The advantage of the sponges is that they are not limited to shallow surface waters thereby recording the response to basin-wide changes in the Atlantic Ocean circulation.

IFM-GEOMAR is actively involved in European initiatives and projects aimed at the development of long, high-resolution multi-proxy records using Caribbean corals, sclerosponges and bivalve molluscs. The project aims at investigating the interaction between the tropical Atlantic Ocean and the NAO over the past millennium.

To assess tropical Atlantic climate fluctuations during the late Holocene, carbonate peri-platform sediments provide an excellent opportunity to reconstruct changes on decadal to centennial time scales. The core MD992201 from the leeward margin of the Great Bahama Bank (GBB) comprises the last 7200 years and shows sedimentation rates of up to 138 cm/100 yrs (Fig. 4). The aragonite precipitation on GBB is controlled by exchange of carbonate ions and CO_2 loss due to temperature-salinity conditions and biological activity. These factors depend on the ocean circulation and are linked to atmospheric forcing. Thus, periods with high current speeds are proposed to represent phases of strong atmospheric circulation. As the dominant proportion of surface water masses flowing over GBB is of North Atlantic origin, the deduced current strengths are suggested to be a measure of the North Atlantic subtropical gyre, and thus may provide informations about the long-term behavior of the NAO.

The strength of the currents on GBB was high during the periods 6000–5100 years BP, 3500-2700 years BP, and 1600-700 years BP. Time series analyses identified dominant, quasi-periodic oscillations on decadal to centennial timescales. Four of these signals (~200-yr, ~150-yr, ~100-yr, ~88-yr) are most likely due to solar forcing. The remaining cycles may originate from internal fluctuations of the climate system. The planktonic oxygen isotope record (Fig. 4) is indicative of high frequency variations in sea surface temperature and salinity. First planktonic foraminiferal Mg/Ca-temperature reconstructions revealed variations on the order of up to 3°C. They also indicate that the oxygen isotope record did not mainly reflect changes in sea surface temperatures. Thus, variability in sea surface salinities has to be considered. One important task for a continuation of this research is therefore to reconstruct paired records of sea surface temperatures and salinities.

IFM-GEOMAR Contributions

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Mojib Latif, Ralf Tiedemann, and Friedrich Schott

3.2 Dynamics and Predictability of North Atlantic / European Climate Variability

The climate of northern Europe is strongly controlled by the North Atlantic thermohaline circulation (THC). The THC is a global belt of ocean currents and an important component of the global climate system. Its surface branch in the North Atlantic, the North Atlantic Current which is the northeastward extension of the Gulf Stream, warms northern European temperatures by several degrees in the annual mean (Fig. 1). Strong and rapid changes in the THC have been reported from paleo-climatic records, and it is currently discussed whether greenhouse warming may have a serious impact on the stability of THC.

The North Atlantic sea surface temperature (SST) varied on a wide range of timescales during the last century. It has been pointed out that the short-term interannual variations are driven primarily by the atmosphere, while the long-term multi-decadal changes are forced by variations in ocean dynamics, specifically variations in the THC. The latter is supported by simulations with global climate models which show that variations in the THC lead to characteristic large-scale North Atlantic SST anomalies which cause climate anomalies that extend into Europe.

We have explored the dynamics and predictability of the North Atlantic/European climate variability on multi-decadal timescales initally using an extended-range integration with a global climate model from the Max-Planck-Institute for Meteorology. The model simulates the present-day climate of the North Atlantic/European region realistically. The climate model's mean thermohaline circulation is consistent with observations, with a maximum strength of about 20 Sv (1 Sv (Sverdrup) = 10^6 m^3 /s) and a northward heat transport of about 1 PW (1 PW (Petawatt = 10^{15} W/m^2) at 30ºN. The model simulates pronounced multi-decadal variability in North Atlantic SST. Its thermohaline circulation and North Atlantic SST are closely related to each other. Specifically, the strength of the meridional overturning at 30ºN, an index of the North Atlantic THC, correlates almost perfectly with the North Atlantic SST at timescales beyond several years. This suggests indeed that the multi-decadal SST fluctuations are driven by ocean dynamics and not by the atmosphere through anomalous air-sea heat exchange.

The close connection between THC strength and SST can be used to either reconstruct past changes of the THC from SST observations or to monitor the state of the THC in the future.

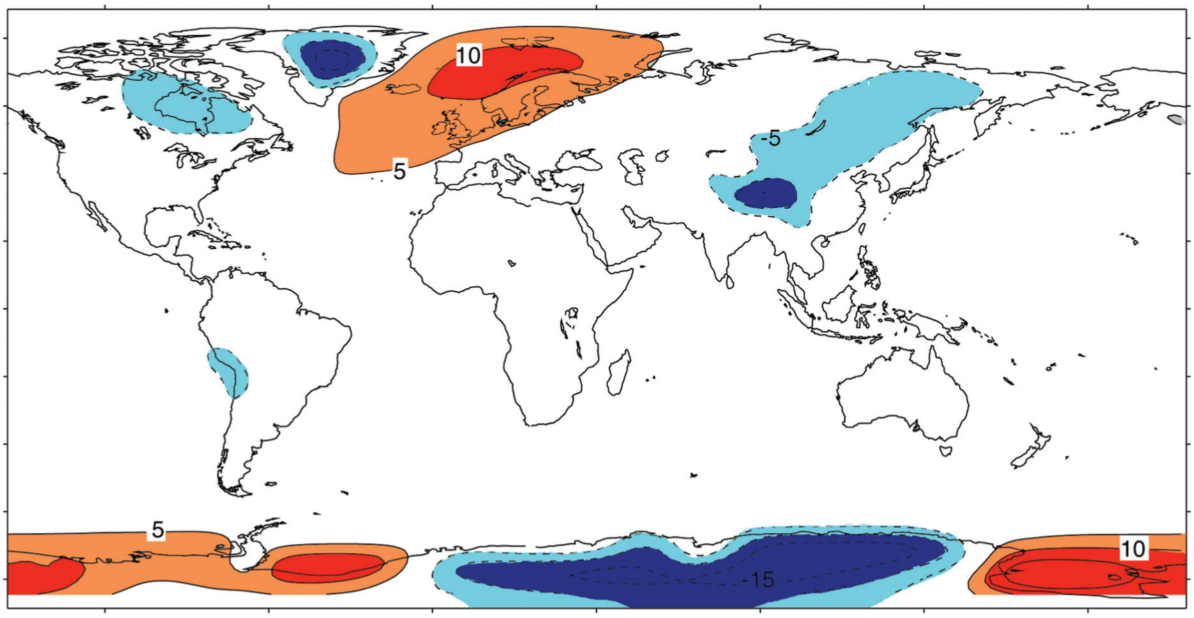

Figure 1: The deviation of annual mean surface air temperature from the latitudinal (zonal) average. Please note that northern Europe is much warmer relative to the zonal mean temperature, which demonstrates partly the impact of the THC on European climate.

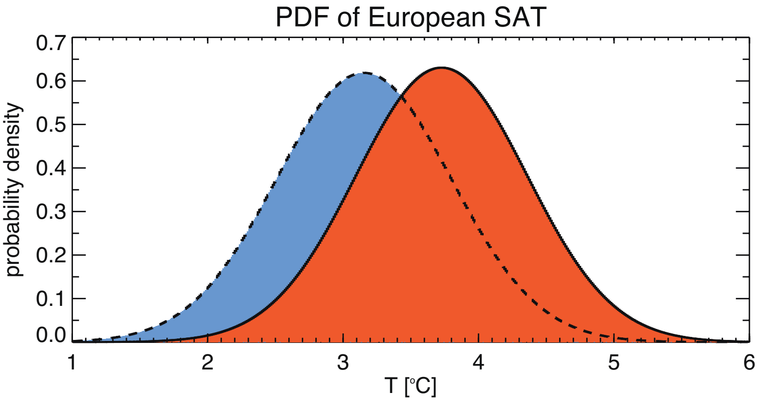

Figure 2: Fitted probability density functions (PDFs) of the European surface air temperature for years with strong (red/ solid) and weak (blue/dashed) THC. A threshold value of +/- 0.44 standard deviations has been used.

If the model mimics the real relationship between THC and SST correctly, the observed changes in North Atlantic SST during the last century can be interpreted as changes in the THC strength: Decade-long positive anomalies in the North Atlantic SST index can be regarded as indicators for an anomalously strong THC and vice versa. In particular, the strong cooling during the period 1960-1990 may just as well be related to an anomalously weak THC resulting from an internal oscillation rather than to anthropogenic factors.

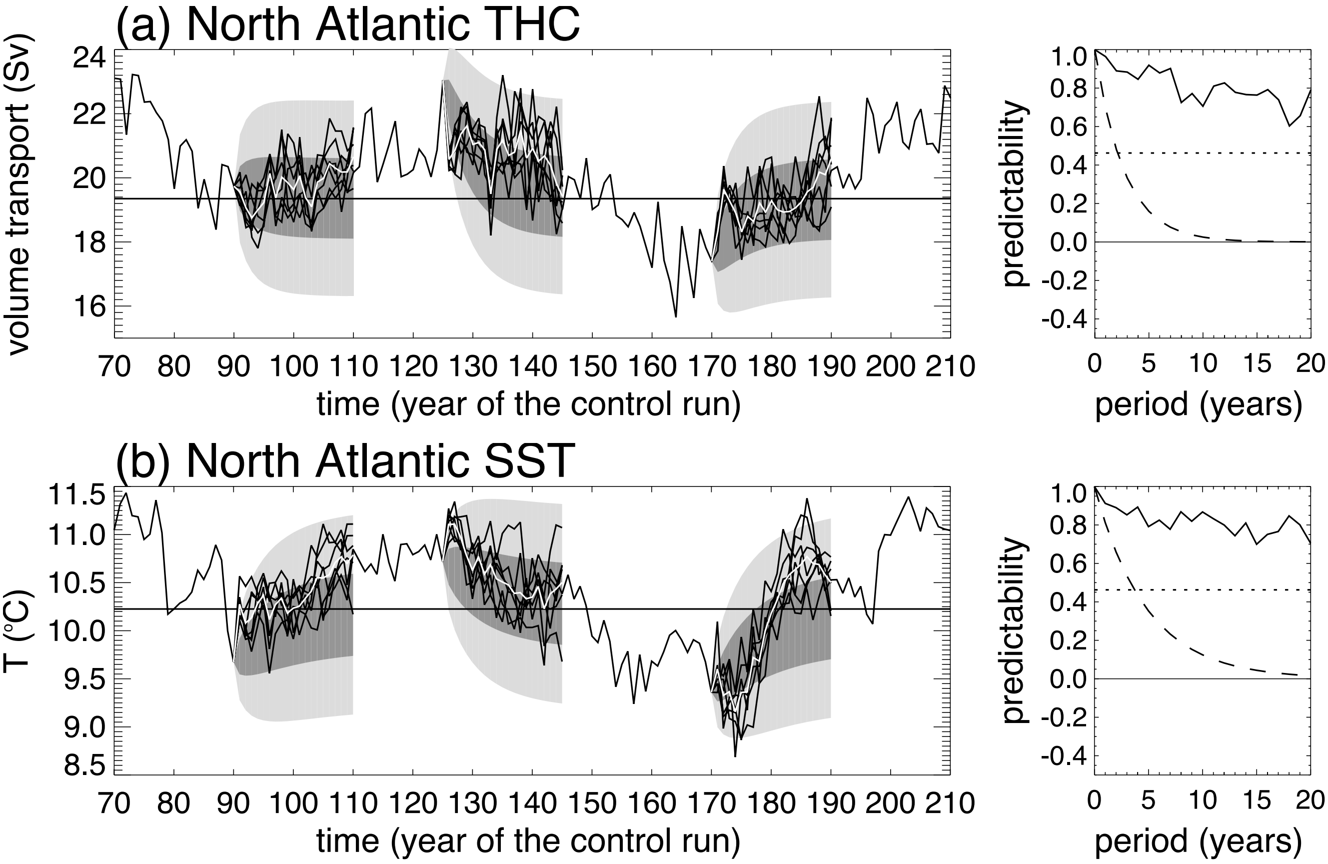

Figure 3: (a) (upper): Annual mean North Atlantic THC for years 70 to 210 of the control integration (thin black); ensemble forecast experiments initialised at the end of the years 90, 125, and 170 (thick black); and the ensemble means (white). The results of the statistical forecast method of damped persistence are shown as the range expected to contain 90% and 50% of the values from infinite size ensembles of noise driven AR-1 random processes (light and dark grey, respectively). (right) Predictability of the North Atlantic THC averaged over the three ensemble experiments (solid curve), with the damped persistence forecast (dashed) as a function of the prediction period. Additionally, the 95% significance level according to an F test is dotted. (b) (lower) As in (a), but for North Atlantic SST. Note that the changes in the North Atlantic THC and SST indices are predictable a few decades ahead.

The next question that was addressed is the impact of the multi-decadal THC variations on European climate. It is found that the probability density functions (PDFs) of surface air temperatures and precipitation over Europe are significantly affected by the multi-decadal variability of the North Atlantic THC (Fig. 2). An anomalously strong North Atlantic THC coincides with a strong northward heat transport in the North Atlantic. During such conditions the European surface air temperature is enhanced, which yields, for instance, fewer frost and more hot days. Thus some useful decadal climate predictability may exist in the Atlantic/European sector.

The close relationship between SST and THC implies that the SST variations may be predictable at decadal timescales. In order to explore the predictability of the SST, an ensemble of classical predictability experiments was conducted with the global climate model. Three states from the control integration were chosen, the atmospheric initial conditions perturbed and the model restarted. The oceanic initial conditions were not perturbed, so that the predictability estimates may be regarded as upper limits of the predictability. Each perturbation experiment has a duration of 20 years, and an ensemble of 6 perturbation experiments for each of the three initial states was conducted. This yields a total integration time of 360 years.

The results of the predictability experiments are summarised in Figure 3. A predictability measure *P* was defined as $P = 1 - (E/C)$. Here *E* is the variance between the ensemble members and *C* the variance of the control integration. If the spread between the individual ensemble members is small compared to the internal variability of the coupled system, the predictability measure is close to unity, indicating a high level of predictability. If, on the other hand, the spread is comparable to the internal variability, the predictability measure is close to zero and predictability is lost.

The time series of North Atlantic THC of the control integration and the predictability experiments are shown together with the predictability in Figure 3a. The skill in predicting the North Atlantic THC is clearly better than that of the damped persistence forecast and exceeds the 95% significance level over the whole prediction period of 20 years. The skill in predicting the North Atlantic SST is also significant at the 95% significance level over the whole prediction period of 20 years (Fig. 3b) and comparable to that of the North Atlantic THC. The predictability experiments indicate that the North Atlantic THC and SST are predictable even at multi-decadal timescales.

The SST anomaly pattern associated with the THC variability can also be used as a fingerprint to detect future changes in THC intensity. Many authors have reported a weakening of the THC in global warming simulations which may have strong impacts on the climate of the North Atlantic/European sector. However, it is unclear how such a change in THC intensity can be observed. The model results suggest that an easy means to monitor the THC strength is by observing Atlantic SSTs. However, in the presence of global warming, a differential SST index which measures the contrast between the North and South Atlantic has to be used. In order to test this hypothesis, an additional ensemble of three greenhouse warming simulations was conducted (Fig. 4). For this purpose the climate model was initialised from different states of the control integration that are 30 years apart from each other (years 30, 60 and 90), and the atmospheric CO_2 content was increased by 1% per year (compound). The results are analysed for the longest integration (110 years), initialised in year 60 in which the

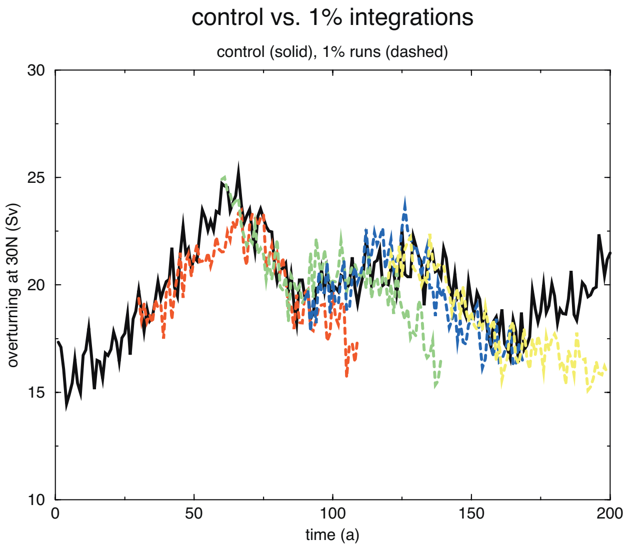

Figure 4: Time series of the annual mean anomalies of the maximum overturning (Sv) at 30ºN in the control integration (black line) and in the greenhouse warming simulations (coloured lines). Note that the evolutions in the greenhouse warming simulations closely follow those of the control integration for several decades, indicating a very high level of THC predictability.

CO_2 concentration triples, and they confirm the hypothesis that changes in THC strength can be seen in the differential Atlantic SST index.

The results also show that the THC evolution in the greenhouse warming simulations closely follows that of the control run for some decades before diverging from it (Fig. 4). This behavior is markedly different from that of global mean surface temperature which exhibits a rather monotonic increase in all members. This implies a strong sensitivity to initial conditions but also a great deal of predictability of the multi-decadal variability in the North Atlantic, provided the initial state is well known. These results are consistent with our classical predictability experiments discussed above. Furthermore, our results imply that anthropogenically forced changes in THC strength may be masked for quite a long time by the presence of the internal multidecadal variability. The next several decades may therefore be dominated by the internal multi-decadal variability, and we have to consider a joint initial/boundary value problem when assessing how the THC will evolve during this century. Greenhouse gas simulations should therefore be properly initialised using present-day ocean conditions and they should be conducted in ensemble mode to assess the uncertainty.

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Mojib Latif

3.3 Millennial-scale Variability of the Global Ocean Circulation

Our recent view of Earth's climate system is influenced by the traditional perspective of long-term stable and favourable conditions. Some ten thousand years ago during the Late Pleistocene, however, rapid and profound changes in the operational mode of the combined climate - ocean system took place over the course of a few decades or centuries. The most spectacular perturbations are the Heinrich meltwater events and the Dansgaard-Oeschger (D/O) oscillations in the North Atlantic region. Transient warm climatic conditions prevailed during D/O stadials and an armada of icebergs was released into the North Atlantic during Heinrich events. The variability of these climatic events is mutually linked with changes in North Atlantic Deep Water (NADW) formation. The amplitudes of these changes are largest at high northern latitudes. In view of recent human-induced environmental changes it is important to assess the response of climates at mid latitudes where the majority of industrial centres and food-production areas are located. This appears urgent as recent oceanographic surveys have revealed that changes in oceanographic conditions can happen quickly and can spread throughout the North Atlantic basin within a few years. Studies on the late Pleistocene thermohaline circulation history in the northern North Atlantic and Nordic Seas have likewise demonstrated that rapid climatic changes affected the deep-water production „instantaneously".

We used high-resolution paleoceanographic records from two IMAGES cores from the west-

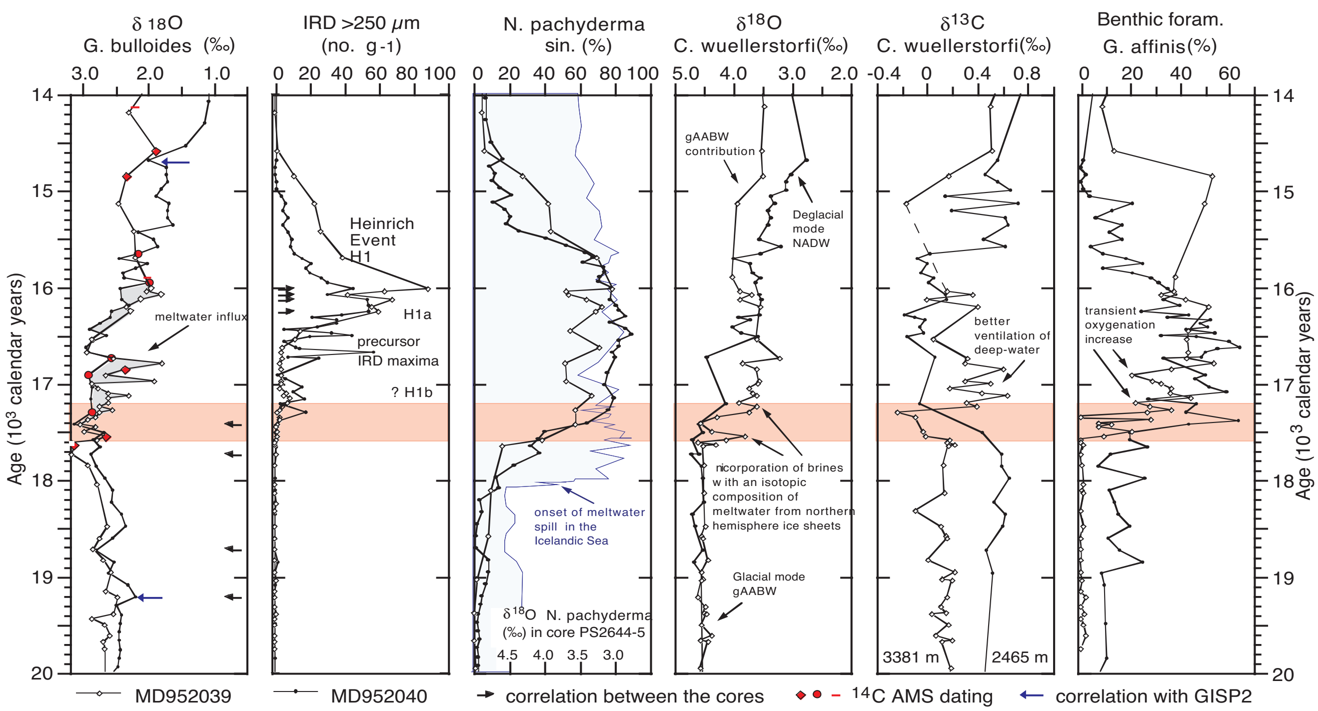

Figure 1. Oxygen isotopes of planktonic foraminifera, abundance of ice-rafted detritus (IRD), proportion of Neogloboquadrina pachyderma (sin.), oxygen and carbon isotopes of benthic foraminifera, and abundances of Uvigerina pygmea und Globobulimina affinis during the early Termination I in cores MD952039 and MD952040 off northern Portugal. The chronostratigraphy is based on ^{14}C AMS datings (red symbols), correlation with GISP2 ice core from Central Greenland (blue arrows), and correlation between the records (black arrows). The data indicate a sudden and profound environmental change (highlighted by a pink bar) that commenced 200 years before the last maximum in planktonic oxygen isotopes of Globigerina bulloides and took 670 years to affect all environments. The strongest effect is a drawdown in bottom oxygenation as indicated by a shift towards lighter benthic δ^{13}C values and increasing abundances of the suboxic benthic foraminiferal species Globobulimina affinis. The benthic environmental change is preceeded by a successively increasing influx of cold subpolar surface waters as depicted by massive abundances of Neogloboquadrina pachyderma (sin.). The planktonic δ^{18}O record from core PS2644-5 depicting the meltwater influx into the Islandic Sea (Voelker et al., 2000) is given for comparison.

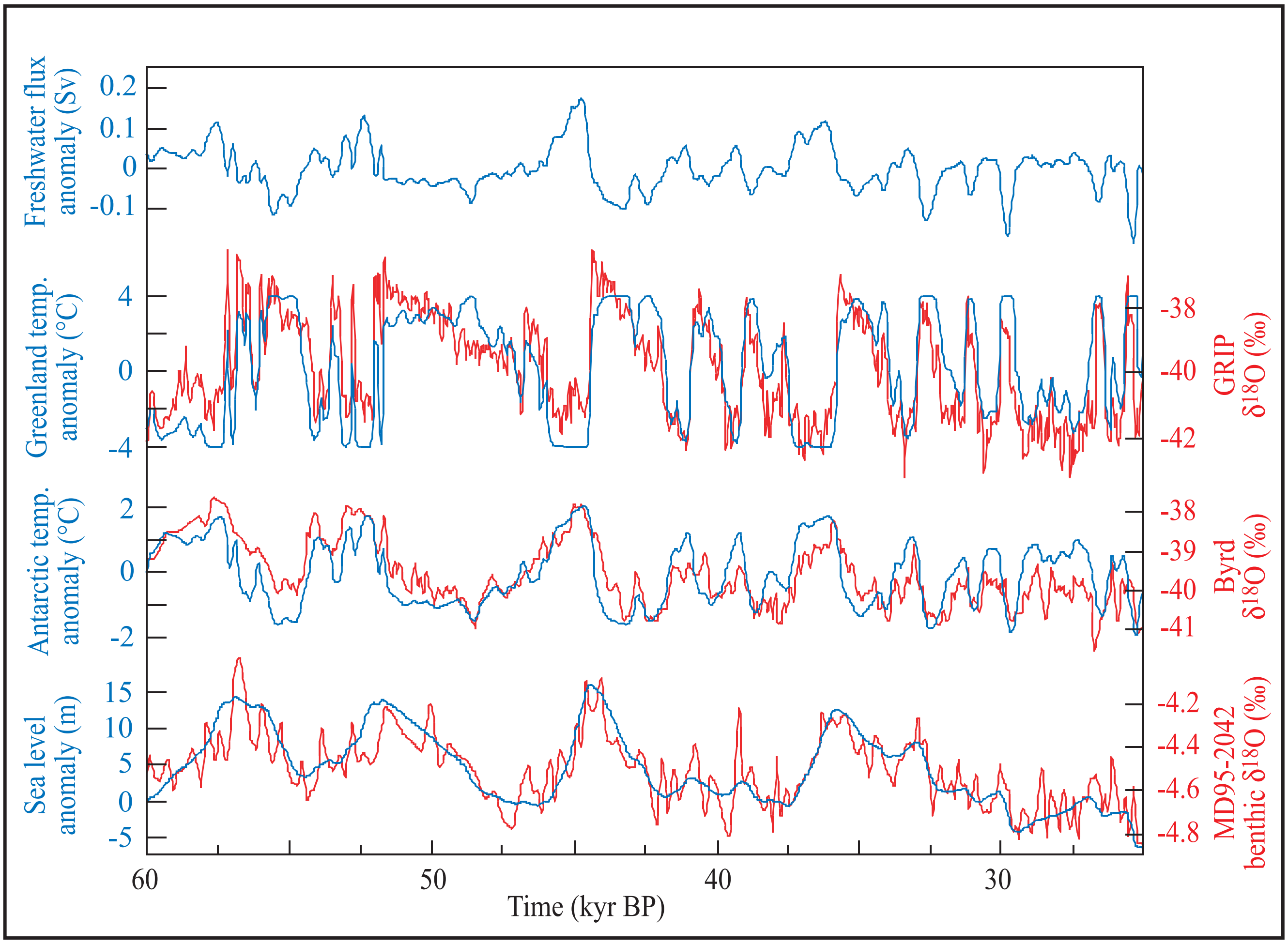

Figure 2: Variability of Greenland and Antarctic temperature and sea level derived from proxy data (red, right axes) and a conceptual model (blue, left axes). The conceptual model, which relates Greenland and Antarctic temperature, freshwater influx is applied here to show that much of the paleoclimatic evolution can be reproduced by co-varying fluctuations of nordic freshwater input and Antarctic temperatures. Climate change in polar regions and sea level were strongly coupled during Marine Isotope Stage 3. Iteratively changing the freshwater flux into the North Atlantic to maximize correlation with the proxy records yields a model solution (blue), which explains 60% (r^2) of the variability seen in the water isotopic composition of the GRIP and Byrd ice cores, and in the benthic oxygen isotope record off Portugal, which may be used as a measure for short-term sea level changes. Sv: water mass flow in Sverdrup (10^6 m^3 s^{-1}).

ern Iberian margin to assess how sea surface temperatures, deep-water production and ventilation, and benthic communities responded to rapid climatic changes during the Late Pleistocene. We linked the response patterns to marine environmental changes in high-latitude areas. A detailed chronostratigraphy allows to assess the speed of the signal transmission from high to mid latitudes.

At the onset of the last Deglaciation, a major reorganisation of surface water hydrography, benthic foraminiferal community structure, and deep water isotopic composition commenced 17,970 calendar years ago (Figure 1). Changes were initiated by glacier-derived meltwater shedding in the Nordic Seas and northern North Atlantic that commenced 100 years before concomitant changes were felt off western Iberia. The overturn affected all environments within 670 years. The intensity reduction of the thermohaline circulation, glacial NADW production, and oxygen availability in deep waters during meltwater spill and Heinrich-Events H1 and H4 is mirrored by benthic foraminiferal associations with a bloom of species which can withstand a low oxygen supply. Benthic oxygen isotopes depict the influence of brines from sea ice formation during ice-rafting pulses and meltwater spill. The brines conceivably were a source of ventilation and provided oxygen to the deeper water masses. This process has been invoked for the northern North Atlantic and Nordic Seas, and it has been discussed controversely, but our new data confirm the environmental significance of North Atlantic brine formation. For Heinrich Events H1 and H4, response times of surface water properties off western Iberia to meltwater injection to the Nordic Seas were extremely short, in the range of a few decades only. The ensuing reduction in thermohaline circulation and deep-water ventilation commenced within 500 to 600 years after the first onset of meltwater spill. These pertubations in thermohaline circulation affected the meridional heat transport and were suggested to have triggered the millennial-scale asynchrony of Greenland and Antarctic temperatures, a concept known as the 'thermal bipolar seesaw'.

Although in general agreement with the paleoceanographic record and modelling results, important issues remain unclear. The large temperature shifts of up to 16°C in Greenland, the changes of about 3°C over Antarctica, and the temporal relationships between the abrupt shifts in Greenland and the relatively slow changes over Antarcica (Figure 2) are difficult to reconcile in a physically consistant way and challenge numerical models. A coupled global ocean-atmosphere-sea ice model of intermediate complexity was used to prove that in addition to the reduction of the thermohaline circulation, sea-level changes associated with ice-sheet instabilities (Heinrich events) have a direct effect on the temperature of the Southern Ocean. Then, much heat is transported southwards in the deep Atlantic Ocean which is caused by a stronger zonal density gradient in the subtropical North Atlantic and by a fast wave adjustment process. An extended and quantitative bipolar seesaw concept is suggested to explain the timing and amplitude of Greenland and Antarctic temperature changes, the slow changes in Antarctic temperature and its similarity to sea level, as well as the time lag of sea level with respect to Antarctic temperature seen during Marine Isotope Stage 3. Figure 2 shows a comparison between our revised seesaw concept (blue) and the paleo-reconstructions (red). In addition, our analysis provides a reconstruction of meltwater discharge into the North Atlantic during Marine Isotope Stage 3. The results from our analytical work agree in their evidence that timing of the optimized freshwater discharge peaks match with the input of ice-rafted debris during Heinrich events and low values of benthic $\delta^{13}C$, indicating a reduced ventilation of the North Atlantic Deep Water. Future work will explore whether multidecadal and expected future changes of the deep-water formation in the North Atlantic have an impact on southern-hemispheric temperatures affecting living conditions in Australia, New Zealand, South Africa and South America and on sea-ice extent in the North Atlantic affecting fisheries and marine transport off northwestern Europe.

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Joachim Schönfeld and
Axel Timmermann

3.4 Physical Controls on Oceanic Biogeochemical Cycling

The ocean plays a major role in shaping the Earth's climate, not only because it covers more than 70% of the surface of our planet, but also because of the special properties of sea water and the ocean's physical and biogeochemical dynamics. Its special chemical properties allow today's ocean to contain about 50 times more carbon dioxide (CO_2) than the atmosphere. While these capacities alone already enable the ocean to passively buffer fluctuations in heat– and CO_2–content of the atmosphere, the ocean is, in fact, a more active player in the global climate system: By moving water around and depriving large water masses of direct atmospheric contact for seasons to centuries, the ocean circulation takes up heat and CO_2 from the atmosphere and releases both again later in time and elsewhere in space.

In addition to the "physical (or solubility) pump" which results from CO_2 being more soluble in colder (and denser) surface waters that may sink to form deep waters, marine biology plays a major role in redistributing carbon in the global climate system. By forming carbon-containing particles that sink through the water instead of moving with it, the "biological pump" contributes to the observed gradient in CO_2 concentration between the sea surface and the deep waters and, eventually, allows for burial of carbon in sediments at the sea floor and thus removal from the ocean. Both physical and biological pumps ensure that average CO_2 concentrations in the ocean interior are much larger than those of surface waters. Without the biological activity surface concentrations of dissolved inorganic carbon would be much higher, resulting in approximately doubled concentrations of atmospheric CO_2.

A quantitative and comprehensive understanding of what controls the air–sea carbon exchange and the fixation of organic carbon and its removal from the surface layers is essential if we aim to better understand past climate changes and predict the consequences of rising levels of anthropogenic CO_2 in the atmosphere. Physical controls of the biological pump come into play for the simultaneous requirement of both light and nutrients for phytoplankton growth, since the light-lit upper ocean would be rapidly depleted of essential nutrients without the action of physical transport processes. Vertical mixing also determines the exposure of individual phytoplankton cells to different light levels. This is particularly relevant at mid and high latitudes where deep winter mixed layers may not allow phytoplankton to remain at levels with sufficient light long enough for net growth to take place. Static stabilization of the warming surface layer in spring can then give rise to sudden algal blooms.

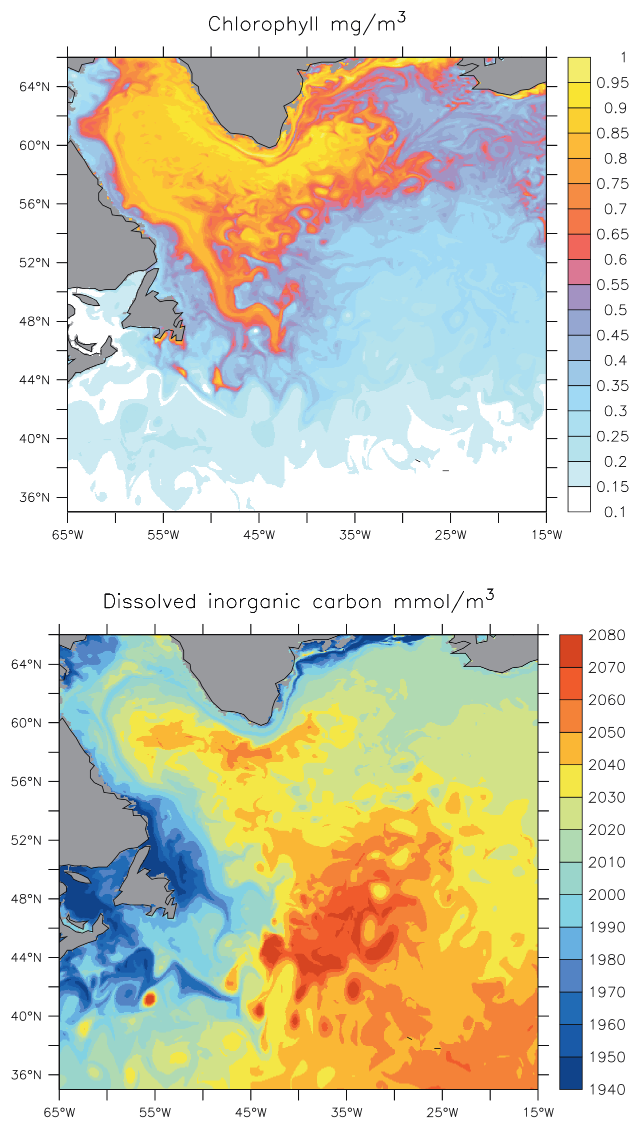

Figure 1: Instantaneous surface chlorophyll concentration (upper panel) and sea surface dissolved inorganic carbon concentration in summer in a coupled model simulation with high horizontal resolution (ca. 5km grid spacing).

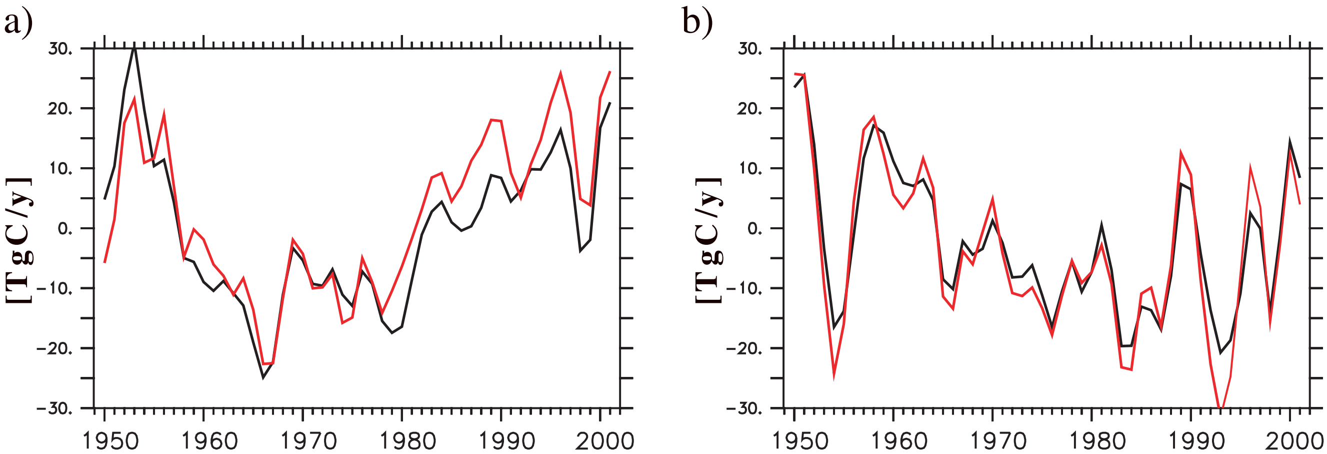

Figure 2 a): Air–sea carbon flux variability in the subpolar North Atlantic (horizontally integrated uptake between 35°N to 65°N). b): Air–sea carbon flux variability in the subtropical/tropical Atlantic (20°S to 35°N). The black line denotes in both figures results from an experiment driven by heat and wind (acting on the ocean) variability only and the red line an experiment driven by the full variability in heat, wind acting on both the ocean and the carbon surface flux formulation, sea level pressure and shortwave radiation. Positive values denote flux into the ocean.

Much of the presently observed temporal and spatial patterns of biological properties can be directly related to these underlying physical controls. For example, satellite observations reveal high concentrations of surface chlorophyll associated with deep winter mixing in subpolar regions and with upwelling off West Africa, America and along the equator, whereas chlorophyll concentrations are lowest in regions where the wind generates downwelling and winter mixing is shallow (the "subtropical gyres"). At present, it is not clear how robust this picture will be under a changing climate. As current patterns, mixing rates, and rates of water mass formation may change under natural and expected anthropogenic climate changes, physical-biological feedback mechanisms in the climate system are likely. It is one aim of the modelling studies initiated at IFM-GEOMAR to help identifying and quantifying the mechanisms by which the ocean physics can control marine biogeochemical cycles and to address their climate sensitivity and the potential participation in global feedback mechanisms.

A particular aim of the modelling activity is to better understand the physical mechanisms controlling the supply of nutrients to the upper ocean and thereby constraining biological production and associated downward carbon fluxes. Using different numerical models of the North Atlantic Ocean with moderate to very high spatial resolution coupled to a nitrate based pelagic ecosystem model, the contribution of oceanic mesoscale eddies in fueling biological production could be quantified and was found to account for up to 30% of the total biological production along the margins of the subtropical gyres. Another finding was that double diffusion, which is caused by different molecular diffusivities of salt and heat and has not been considered previously in the context of basin-scale nutrient budgets, enhances nutrient supply in the subtropics by an amount similar to that of the mesoscale eddies.

Using a constant ratio between carbon and nutrients for the buildup and disposal of organic matter in the ecosystem model, the same coupled models were used to show that the physical environment indeed strongly controls the physical and biological carbon pump of the North Atlantic. For instance, numerical models with an improved representation of the observed circulation and frontal structures, for example the Gulf Stream position and the Northwest Corner of the North Atlantic Current as shown in Figure 1, show a significant increase (up to 25%) in carbon uptake from the atmosphere compared to models with lower resolution and less realistic representation of these regions. It was demonstrated that such an improved simulation can be achieved both by increased resolution or by using simple assimilation techniques in coarser models. Similar differences can be expected for simulations of the uptake of anthropogenic CO_2 by the North Atlantic and, in turn, for the uptake of the global ocean, since the subpolar North Atlantic is one of the few locations where the deep ocean is ventilated with the increasing anthropogenic CO_2 concentrations.

On the other hand, shorter period, natural, fluctuations of the oceanic carbon uptake are also of interest and have been investigated at IFM-GEOMAR. Driven by realistic forcing for the years 1948 to 2004, the simulated North Atlantic shows natural fluctuations in carbon uptake of up to 0.1 Gigaton per year as shown in Fig. 2, which is less than the implied changes in annual global ocean uptake of several Gigaton per year estimated from atmospheric carbon inventories. The role of the different forcing components on this natural variability in oceanic carbon uptake was analyzed in a series of model experiments: Minor contributors were identified to be shortwave radiation driving primary production in the ecosystem model and input of turbulent kinetic energy (potentially) driving mixed layer depth changes. Significant contributors on the order of 10–20% of the total variability in the subpolar North Atlantic are variability in sea level pressure and the near surface wind in the air–sea carbon flux formulation. However, the most significant contributors are wind stress and heat flux driving dynamically and thermodynamically the physical ocean model (Fig. 2).

It was furthermore shown that the fast, barotropic and the delayed, baroclinic response of the North Atlantic circulation to the North Atlantic Oscillation (NAO), which is the dominant mode of atmospheric variability in the North Atlantic sector, has strong impacts on the frontal systems und related nutrient and carbon distribution in the northwest North Atlantic and consequently on changes in carbon uptake. Given a longer term prediction of the NAO, it appears possible to quantify in turn interannual changes of the uptake of atmospheric CO_2, including its anthropogenic part, by the North Atlantic.

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Andreas Oschlies and Carsten Eden

3.5 Monitoring the Ocean's Breathing

The availability of oxygen in the ocean has major implications for biogeochemical processes and therefore strongly impacts on carbon and nutrient cycling in the ocean. Dissolved oxygen concentrations in the ocean reflect a complex balance between physical and biological sources and sinks. Oxygen is produced in the surface layer by biological production (photosynthesis) whereas it is removed in sub-surface waters by the respiration of sinking organic matter. Air-sea gas-exchange rapidly equilibrates near-surface waters with the atmosphere, whereas sub-surface oxygen removal is balanced by the transport of oxygen-rich surface waters into the interior ocean. The consequence is that sub-surface oxygen concentrations, and the overall partitioning of oxygen between atmosphere and ocean, are sensitive to the rate of surface-to-deep ocean circulation and mixing, biological production, as well as temperature and salinity (the latter determine oxygen solubility).

An accurate and sensitive 'wet chemistry' method to measure dissolved oxygen was developed more than a century ago. Such manual analyses of oxygen's distribution and variability have contributed greatly to our understanding of physical and biological processes in the world ocean, through the pioneering analyses by Wüst, Riley, Jenkins and others.

Most recently, precise measurement by Ralph Keeling and others of a slight downward trend in atmospheric oxygen due to the combustion of fossil fuels has opened up new approaches to study the fate of fossil fuel CO_2. Long-term measurements of atmospheric oxygen and CO_2 allow terrestrial and oceanic net sinks for man-made carbon to be distinguished thereby addressing a long-standing problem of global carbon cycle research. The new approach rests, however, on the assumption that oceanic oxygen inventories are not changing on interannual and longer timescales.

Several recent studies have, in fact, identified a decreasing trend in the concentration of dissolved O_2 over the past decades. These trends have been attributed to decreasing 'ventilation' of sub-surface waters. Basically, less oxygen is being transported downwards with the physical circulation to balance biological respiration, implying that more oxygen is ending up in the atmosphere. Such a trend, if real, has important implications for our understanding of global change. First, the oxygen trends may be a signal of an incipient reorganization of ocean

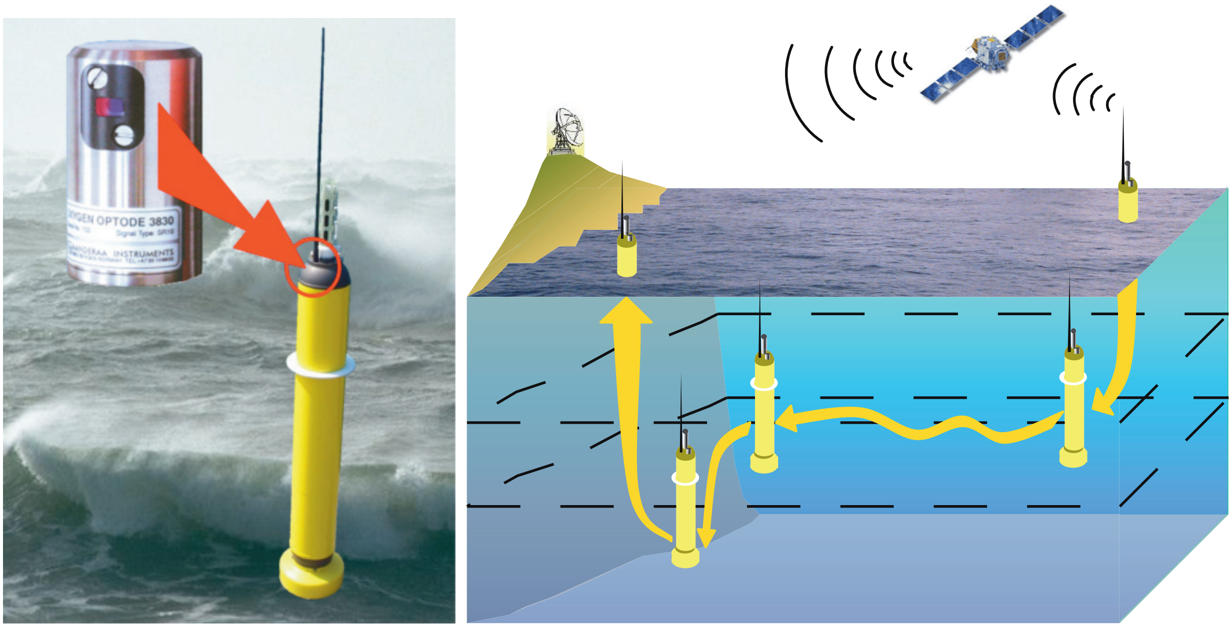

Figure 1: A global, long-term, measurement-based view of changing oceanic oxygen inventories can potentially be obtained through incorporation of accurate oxygen sensors into the next generation of profiling floats that report their data by satellite.

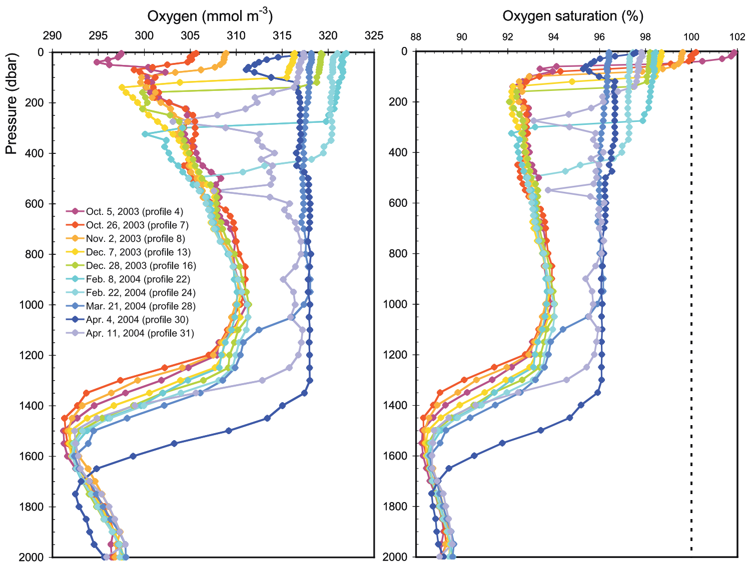

Figure 2: Selected profiles of oxygen concentration (left) and saturation (right) taken by a prototype profiling float in the central Labrador Sea. The maximum convection activity was observed in early April 2004 (profile #30). After that, the large convectively mixed water volume was sealed from contact with the atmosphere and the oxygen was exported laterally into the interior of the ocean.

circulation and mixing in response to altered climate forcing. Second, the repartitioning of oxygen between ocean and atmosphere requires a revision of the current atmospheric carbon budget and estimates of the terrestrial and oceanic carbon sinks as calculated recently by the Intergovernmental Panel on Climate Change (IPCC). Unfortunately, the database for evaluating such trends is geographically and temporally restricted, being based on shipboard measurements from occasional research cruises. The global significance of the trends, and the validity of models that reproduce the trends on a global scale, cannot be assessed with current data collection approaches.

IFM-GEOMAR scientists have been working within the SFB 460 (see section 4.1), to develop new technological approaches that are suited to global-scale monitoring of oceanic oxygen inventories. A very similar need for higher spatial and temporal resolution of ocean temperature and salinity data led the climate community to develop and deploy an array of new autonomous measurement platforms (profiling floats, gliders, moorings).

We have combined one such platform (profiling floats) with a newly-developed oxygen sensor (Fig. 1) and conducted a trial deployment of this new combination in the central Labrador Sea, which is a major region of deep convection where surface waters are mixed downwards to depths of 1-2 km during winter. The float was deployed in September, 2003 and since then measures weekly vertical profiles of temperature, salinity and dissolved oxygen in the upper 2000 m. The oxygen profiles are transmitted back to Kiel via satellite (Fig. 1) and captured a transition from late summer, well-stratified conditions (mixed layer depth <50 m) into a convectively overturning, deeply-mixed late winter situation (mixed-layer depth ~1400 m) (Fig. 2). The data are of very high quality and show no detectable sensor drift. More details about the new technology as well the data collected, and what they reveal about the 'deep breathing' of the ocean, are discussed in two recently published articles.

Based on these results, we believe that the potential to make autonomous measurements of oceanic oxygen inventories on a very large scale has been demonstrated. Currently, the international ARGO program (http://www-argo.ucsd.edu) plans to deploy 3000 profiling floats throughout the world ocean. As of early 2005, there were more than 1600 floats operating and reporting data. These floats presently measure only temperature, pressure and salinity. If these floats were equipped with O_2 sensors, our ability to measure oxygen inventories would be dramatically expanded. Dissolved oxygen may well become a key parameter for global change research during the 21st Century, perhaps even with a contribution similar in magnitude to its impact on oceanography during the 20th Century.

IFM-GEOMAR Contribtuions

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Körtzinger, A., Schimanski, J., Send, U., and Wallace, D.W.R., 2004: The Ocean Takes a Deep Breath. *Science*, **306**, 1337.

Arne Körtzinger and Douglas Wallace

3.6 Interaction of Oxygen and Marine Productivity

New data show that the modern ocean is loosing dissolved oxygen at high rates. Significant oxygen losses occur in many coastal areas and also in the open ocean at intermediate water depths. These changes may be driven by enhanced nutrient inputs causing higher rates of export production and microbial respiration and/or by global warming reducing the rates of ocean ventilation. They may be harmful to many marine biota depending on dissolved oxygen.

On geological time scales, the productivity of the global ocean is regulated by the size of the nutrient inventory residing in the vast deep water masses of the large ocean basins; the major nutrients dissolved in seawater being nitrate and phosphate. Nitrate is delivered to the oceans by rivers and by nitrogen-fixing microorganisms. It is removed from seawater by the burial of particulate organic matter in marine sediments and by microbial denitrification. The latter process occurs only in the absence of dissolved molecular oxygen. Reducing (oxygen-poor) environments serving as habitat for nitrate-consuming microorganisms can be found in poorly ventilated intermediate waters and marine sediments. Phosphate is released into the oceans via rivers and is removed by burial of phosphorus-bearing compounds in marine sediments. Oxygen-bearing (oxic) surface sediments are often rich in ferric iron and manganese phases which take up large amounts of phosphate by adsorption and mineral formation while anoxic (oxygen-free) sediments are depleted in these phases so that phosphate can only be bound in rather soluble calcium minerals formed during early diagenesis. Burial of organic phosphorus bound in the remains of marine plankton depends also on sedimentary redox conditions (abundance of oxidizing and reducing chemicals). Under reducing conditions the C/P ratio of sedimentary organic matter may be as high as 5000 while the composition of particulate organic matter in oxic deposits approaches the Redfield ratio (C/P = 106). Hence, phosphorus is buried very efficiently in oxic sediments while anoxic deposits have a diminished retaining capacity.

Positive and negative feedback loops are established by the coupling between pelagic processes (export production, ventilation of deep and intermediate water masses) and benthic turnover (Fig. 1). Under phosphate limitation, marine productivity, nutrient inventories and redox conditions may change dramatically. Thus, reducing conditions in bottom waters inhibit phosphorus burial and expand the inventory of dissolved phosphate. In response to the enhanced nutrient availability, eutrophic conditions prevail inducing oxygen consumption in the water column and underlying marine sediments. The resulting spread of anoxic environments in sediments and bottom waters induces further benthic phosphate release and eutrophication in a positive feedback loop (Fig. 1). A different picture emerges under nitrogen limitation (Fig. 1). Anoxic conditions favour the removal of dissolved nitrate via denitrification so that nutrient inventory, export production, and oxygen respiration are diminished and oxic conditions are restored in a negative feedback loop. Nitrogen limitation occurs when the rate of nitrogen-fixation is too small to compensate for denitrification and burial. Cyanobacteria, responsible for most of the nitrogen-fixation in modern and ancient oceans, are limited by iron and phosphate. They live in warm surface waters of the tropical oceans receiving iron either from dust deposition or up-welling. Anoxic sediments supply iron to up-welling bottom waters so that the rate of nitrogen-fixation may also be enhanced by the spread of anoxia. Hence, under favourable climatic conditions, the marine biogeochemical system may be unstable and subject to positive feedback amplifying external perturbations.

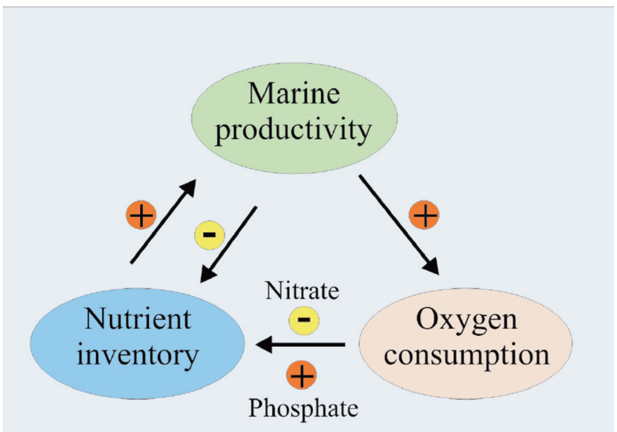

Figure 1: Feedbacks between marine productivity, oxygen consumption and nutrient inventory.

The geological record suggests that marine productivity and redox conditions changed dramatically on different time scales. Global scale anoxic events where enormous amounts of organic matter accumulated at the seafloor are documented for the mid-Cretaceous, the late Jurassic and other periods of the Earth's history. More gradual changes in the ocean's productivity occurred during late Quaternary glacial/interglacial cycles. In many productive areas of the ocean (equatorial Pacific and Atlantic, southern Arabian Sea, Subantarctic Ocean), marine surface sediments received more organic carbon and were more reducing under glacial conditions.

Field studies and sedimentary data clearly show that marginal seas dominated by anoxic bottom waters are highly productive. Usually, the anoxic conditions are ascribed to the high productivity whereas the source of nutrients is not identified even though additional phosphate supply from anoxic sediments could easily sustain and enhance eutrophic conditions in the overlying water. The role of phosphate recycling is clearly seen in the Black Sea and the Baltic Sea which are the most prominent examples of marginal seas with anoxic bottom waters. Here, the C/P ratios are high in sediments deposited after the onset of anoxia so that the enhanced productivity may be supported and maintained by benthic phosphate release from surface sediments. Moreover, the analysis of Mediterranean sapropels showed that phases of enhanced productivity were accompanied and supported by anoxic conditions in bottom waters favoring the release of benthic phosphate.

To further investigate the feedbacks between marine productivity and redox conditions, a new model for the particulate organic carbon (POC), oxygen, nitrogen, and phosphorus cycling in oceans and sediments was developed. In contrast to previous attempts, the model includes a transport-reaction model for the redox-dependent phosphorus turnover in surface sediments. Sedimentary processes are not only simulated for the deep-sea floor but also for the continental margin and shelf considering the terrigenous input of particulate P and POC. The sediment model is fully coupled to a three box model of the ocean where export production, N2-fixation, organic matter degradation and denitrification are the major processes. The coupled model reveals that the positive feedback embedded in the marine phosphorus cycle can induce large changes in the ocean's productivity and nutrient inventory. It also shows that the dissolved phosphate inventory of the ocean may have changed drastically during the Quaternary glacial/interglacial cycles.

Recent data show that eutrophication of coastal waters has been increased in many areas leading to the spread of anoxia in bottom waters, enhanced denitrification and changes in the functional groups dominating the phytoplankton community. Moreover, the stratification of the upper water column in the equatorial Pacific has been enhanced over the last decades inducing a decrease in the ventilation of intermediate waters. Finally, it has been proposed to fertilize the Southern Ocean and other areas of the ocean with iron to increase the biological CO_2 uptake and to remove anthropogenic CO_2 from the atmosphere. All of these anthropogenic perturbations are amplified by the release of dissolved phosphate from anoxic sediments and may thus ultimately push significant areas of the global ocean towards anoxia. Thus, the positive feedback rooted in the benthic phosphorus cycle has to be considered and should be more closely investigated in high-resolution models of the ocean to predict the consequences of iron-fertilization and other human impacts on the marine biogeochemical system.

IFM-GEOMAR Contributions

Körtzinger, A., Schimanski, J., Send, U., Wallace, D.W.R., 2004: The ocean takes a deep breath. *Science*, **306**, 1337.

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Klaus Wallmann

3.7 Marine Gas Hydrates

Gas hydrates are ice-like compounds in which small gas molecules are trapped inside a cage of water molecules (Fig. 1). Their formation requires low temperatures, high pressures, and enough gas to exceed saturation (Fig. 2). The trapped gas in natural gas hydrates is mostly methane, which is generated by the decay of organic matter. Gas hydrates are found in sediments with high gas productivity along continental margins and marginal seas in depths exceeding 300 – 500 and are nowadays a major focus of geo-marine research for the following reasons:

- More than 160 m^3 of gas can be stored in 1 m^3 of hydrate, i.e. the gas density is comparable to a filled compressed gas cylinder;
- The amount of energy stored in gas hydrates along the continental margins is suggested to be larger than, or at least similar to, the amount of energy stored in other known exploitable fossil energy reservoirs (i.e. coal, oil, and gas).
- The decomposition of hydrates (due to warming of bottom waters or decreasing sea level) has been suggested as a trigger or positive feedback for rapid global warming episodes in the Earth's history.
- Continental slope instability caused by hydrate decomposition is suggested as a trigger mechanism for underwater landslides and tsunami generation.

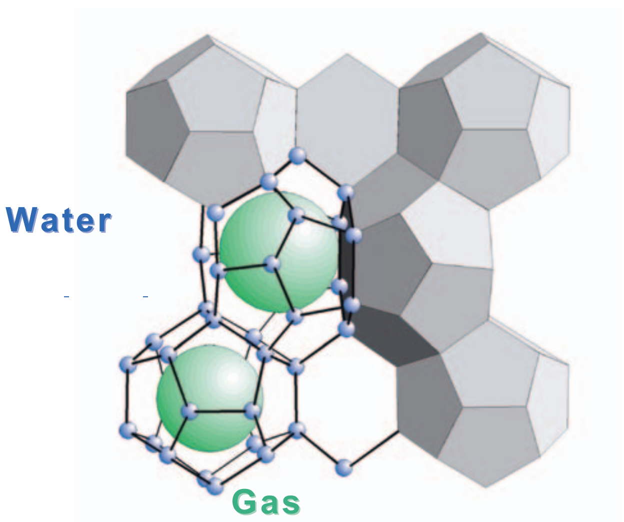

Fig. 1: Structure-1 gas hydrate. Two cage sizes are formed by a 3-dimensional network of water molecules. When all cavities are filled in a pure methane hydrate, the sum formula is approx. CH_4 5.7 H_2O.

Since the recovery of natural hydrates offshore Oregon by GEOMAR expedition *SONNE* 143 in 1996, Kiel has become one of the world's centres for research on natural gas hydrates. Two large-scale integrated projects within the Geotechnology program of BMBF have been coordinated within FB2 from 2001-2003 (LOTUS and OMEGA), with scientific expeditions to the Black Sea, the Gulf of Mexico, and the Hydrate Ridge, offshore Oregon. Former GEOMAR scientist Gerhard Bohrmann was co-chief of leg 204 of the Ocean Drilling Program, and found himself in the unusual role as a main character of the science fiction novel "Der Schwarm" by Frank Schätzing.

The following highlights, summarized here briefly, are representative of the scope of scientific knowledge gained from these projects.

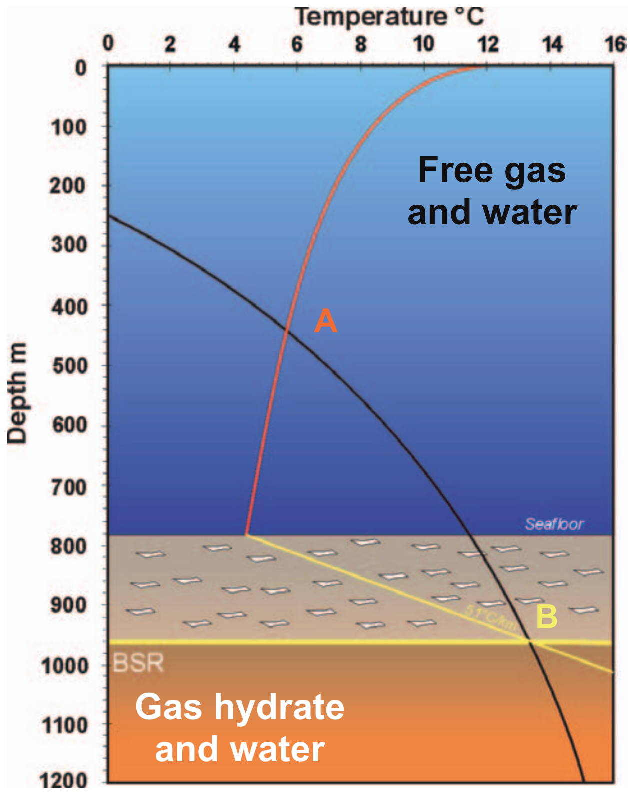

Figure 2: Stability of CH_4 hydrate in seawater. The black line is the phase boundary. Above this line, methane exceeding saturation in seawater is stable as a free gas phase; below, it will form hydrates. The red line indicates the temperature profile of seawater, the yellow line the geothermal gradient within the sediment. Hydrate is stable in the depth interval between points A and B.

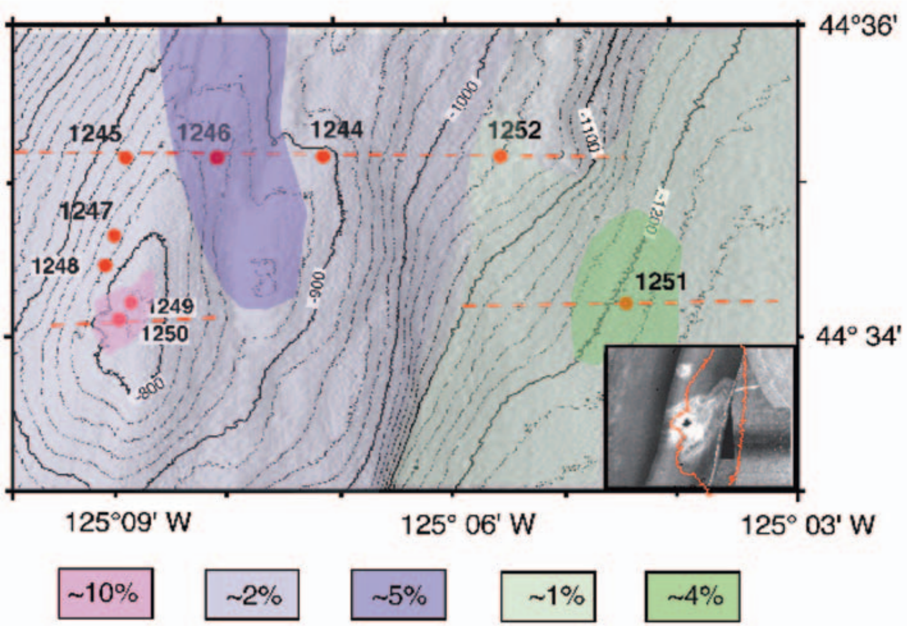

Figure 3: Fraction of the sediment occupied by gas hydrates averaged over the thickness of the gas hydrate stability field at the Southern Summit of Hydrate Ridge, Oregon. The numbers refer to the sites drilled during ODP Leg 204.

Three-dimensional Distribution of Gas Hydrates at Hydrate Ridge

Large uncertainties about the energy resource potential and the role in global climate change of gas hydrates result from uncertainty about how much hydrate is contained in marine sediments. Leg 204 of the Ocean Drilling Program (ODP) to the Southern Summit of Hydrate Ridge attempted to improve such type of estimates. The gas hydrate stability zone (GHSZ) was continuously sampled from the seafloor to its base in contrasting geological settings, which were defined by a 3D seismic survey. By integrating results from different methods, including several new techniques developed for Leg 204, it was possible to obtain a high-resolution, quantitative estimate of the total amount and spatial variability of gas hydrate in this structural system (Fig. 3).

The results unequivocally showed that high gas hydrate content (30–40% of pore space or 20–26% of total volume) is restricted to the upper tens of meters below the seafloor near the summit of the structure, where vigorous fluid venting occurs. Below that zone, the average gas hydrate content of the sediments in the GHSZ is generally <2% of the pore space. The small fraction of pore space filled by gas hydrates challenges the estimates of the global world-wide gas hydrate reservoir in the order of 1 x 10^5 GtC. A new global estimate resulting from this campaign, about an order of magnitude smaller (Fig. 4), questions the role of gas hydrates in driving global change or as an important future fossil fuel resource. High concentrations of gas hydrate, however, are present locally and may be of economic importance in the future and hence their accurate delineation needs to be pursued.

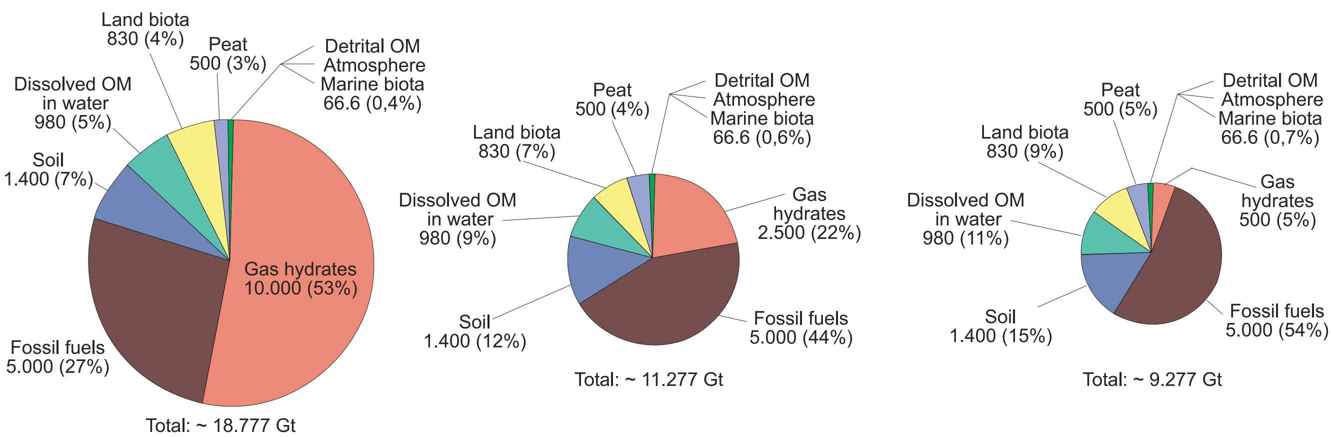

Figure 4: Diagrams of the organic carbon reservoirs on Earth with varying estimates of the gas hydrate reservoir. Values are given in GtC. The diagrams show the distribution based on gas hydrate estimates from the early 90's frequently cited, as well as the upper and lower limit of new estimates based on the new insights of filled pore space from ODP Leg 204 (modified after Milkov, 2004).

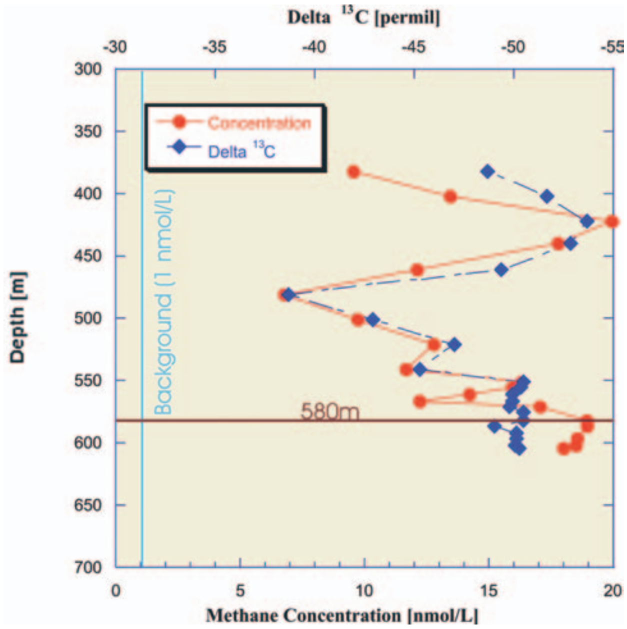

Figure 5: (a, above) Slump scars at the upper hydrate stability boundary off Costa Rica. and (b, right) methane plume above the slump scar and its stable carbon isotopic composition.

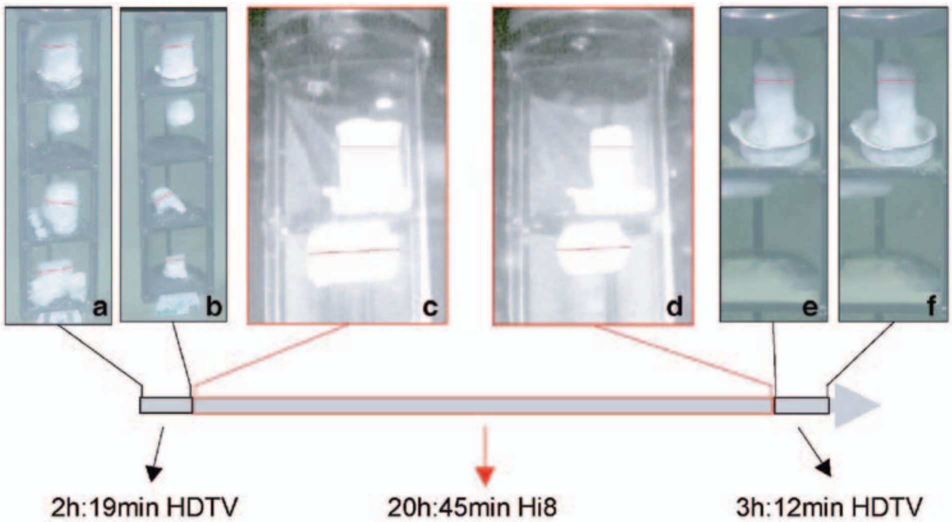

Figure 6: Overview of the evolution of the samples in the dissolution experiment. Methane hydrates are in the upper two compartments, and carbon-dioxide hydrates in the lower two. Frames are from the beginning and end of the first phase of HDTV observation (a-b), from time-lapse camera observation (c-d), and from the final HDTV observation (e-f). Only the CH_4 hydrate samples are shown in (c-f). The CO_2 hydrate samples are completely dissolved shortly after frame (c).

Relation between Gas Hydrate Occurrence and Slumping

High resolution bathymetry along the continental margin off Costa Rica revealed numerous smaller slumps at the water depths where the hydrate stability field outcrops the seafloor (Fig. 5a). At these locations, smallest changes in pressure and temperature will lead to a change from stable to unstable conditions for methane hydrates at the seafloor and vice versa. Geochemical investigation of the water column above these sites indicate active methane venting of microbial origin (Fig. 5b). The survey lead to one of the best demonstrations of enhanced abundance of slumps at the upper wedge of the hydrate stability field.

Hydrate Dissolution

Even well within the hydrate stability field, gas hydrates should be prone to dissolution in the generally highly undersaturated seawater. The kinetic of this process, which puts constraints both on the longevity of hydrate outcrops at or near the seafloor and the dynamics of the methane transport to sustain these structures, has until recently been completely unknown. In a unique deep-sea experiment, lab-grown pure methane and CO_2 hydrates were transported under pressure to the deep ocean floor (1030m) using ROV-technology and exposed to seawater with its natural CO_2 and CH_4 content and under natural current flow conditions. The dissolution caused by the contact with the undersaturated seawater was measured by monitoring the samples with HDTV-camera and a time-lapse camera system (Figs. 6,7).

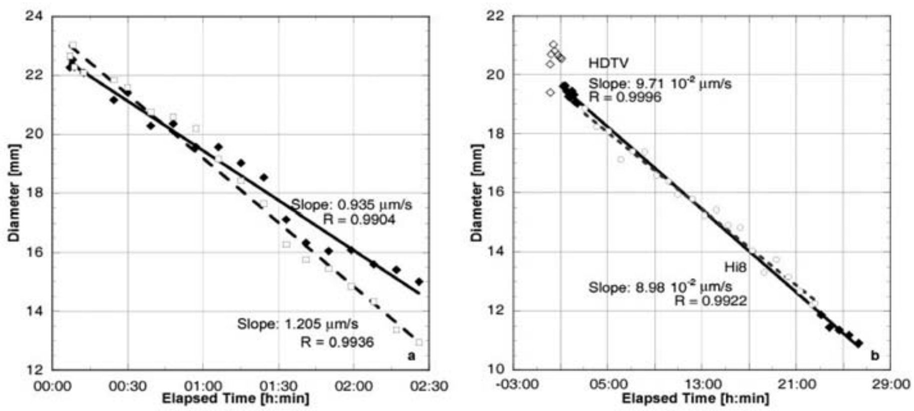

Figure 7: (a) Diameter of the CO_2 hydrate samples versus time. Upper sample: black diamonds and solid line (linear fit): Lower sample: open squares and hatched line (linear fit). (b) Diameter of the upper CH_4 hydrate sample versus time. Filled diamonds and solid line: measurements and linear fit using the HDTV observations at the beginning and the end of the experiment. Circles and hatched line: measurements and linear fit using the Hi_8 observations.

The ratio of the dissolution rates fits a diffusive boundary layer model that incorporates relative gas solubilities appropriate to the field site, which implies that the kinetics of the dissolution of both hydrates is diffusion-controlled. Dissolution of several mm methane hydrate per day in undersaturated seawater suggests that long-term survival of seafloor hydrate outcrops or hydrates close to the sediment surface observed today must be sustained by supply of sufficient CH_4 to maintain boundary layer saturation or continuous hydrate regrowth. The dissolution rate of gas hydrate might also be a key parameter controlling the supply of methane to microbial methane-oxidizing communities in hydrate bearing sediments. The rapid dissolution rate of carbon-dioxide hydrate implies that in the case of the disposal of liquid CO_2 on the sea floor, the potential to form hydrate will not significantly enhance the longevity of the released CO_2 The transformation of liquid CO_2 to hydrate on the seafloor is thus unlikely to shield bulk CO_2 from dissolution, as often suggested in CO_2 sequestration concepts.

Research on gas hydrates will remain a major focus nationally during the future phase of the Geotechnology program as well as internationally by energy-seeking interests as well as those concerned with CO_2-sequestration and climate change.

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Gregor Rehder and Erwin Suess

3.8 Dust Fertilization of the Tropical North Atlantic stimulates Nitrogen Fixation

Phytoplankton productivity is an important sink for atmospheric CO_2 and has been suggested to alter global CO_2 concentrations. Given that the nutrient availability exerts a strong control on the productivity of phytoplankton populations it is of great importance to understand which nutrients limit productivity. Alternate views exists: Biological oceanographers argue that supply of bound nitrogen (N) limits phytoplankton productivity and biomass, while geochemists assert that over geological timescales nitrogen fixation should provide the fixed N necessary for primary production and that availability of biologically utilizable phosphorus compounds (P) control primary productivity.

It has been shown that iron is a very important limiting nutrient for phytoplankton growth in the Pacific and southern ocean. There in situ iron fertilization of nutrient rich surface waters result in phytoplankton blooms. Iron has also been suggested as a potential nutrient limiting nitrogen fixation due to the iron rich nitrogen fixing enzyme nitrogenase. The oligotrophic tropical North Atlantic is considered a hot spot for nitrogen fixation. Satellite images regularly show spectacular dust clouds entering the tropical North Atlantic from the Sahara and Sahel zone that can provide iron and also P to the surface ocean (Fig. 1). This region is subjected to some of the highest mineral dust deposition rates in the world, and has high dissolved iron concentrations in surface waters relative to other oceanic basins. As such, the tropical North Atlantic is a region where the phytoplankton community is least likely to be iron limited. Therefore, surface waters have been assumed to be replete in iron with respect to nitrogen fixation.

During the *METEOR* 55 and 60 cruises (October – November 2002, and March April 2004 respectively) to the tropical North Atlantic we have attempted to determine the role of the nutrients N, P and Fe in controlling primary productivity and nitrogen fixation using a nutrient addition bioassay approach. Additions of Saharan dust were also made to investigate whether this aeolian input could provide limiting nutrients. Our results showed that at all sites phytoplankton biomass and primary production were limited by N (Fig. 2). After relief of N limitation, further stimulation was seen with the addition of P and then iron. The finding of N limitation of the phytoplankton community stresses the importance for nitrogen fixing organisms, diazotrophs, in this system. At all sites tested during *METEOR* 55 we detected nitrogen fixation, and the addition of P and Fe together stimulated nitrogen fixation (Fig. 2). Conversely, additions of inorganic N (added as NO_3^- and NH_4^+) inhibited diazotrophic activity. Saharan dust additions also resulted in enhanced primary productivity, bacterial production, and nitrogen fixation, though not at all stations tested, indicating that the dust supplies microbial populations with the nutrients that at times limit different processes.

Given the high atmospheric loading of iron to the eastern tropical North Atlantic we were surprised to find that iron addition stimulated diazotrophy. It is generally argued that iron concentrations in our study area are in excess of diazotroph iron requirements, but our findings suggest that total dissolved iron concentration is a poor index of bioavailability, perhaps due to temporal variation in the chemical speciation of dissolved iron. It is also possible that the level of iron required to saturate diazotroph growth has been underestimated. The important role of iron in our study region implies that the control of nitrogen fixation by

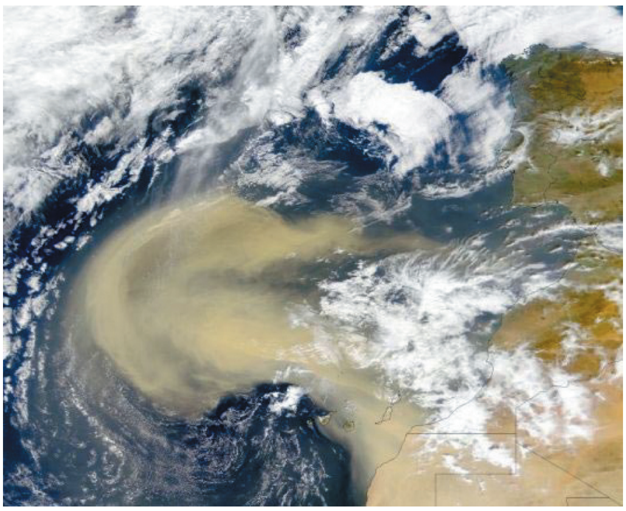

Figure 1: Dust storm over the subtropical and tropical North Atlantic from the African continent observed by SeaWiFS satellite images on February 26th, 2000.

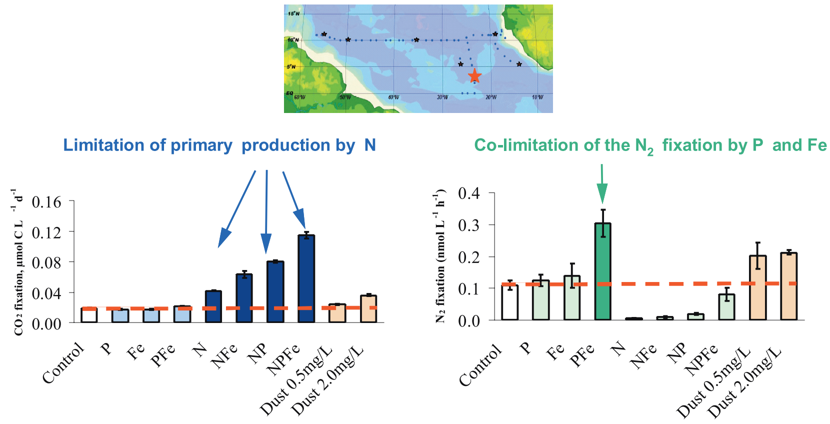

Figure 2: Effects of nutrient (N, P, Fe) additions on primary production (= CO_2 fixation) and nitrogen fixation (= N_2 fixation) in natural plankton communities of the tropical Atlantic. The map at the top shows the cruise track and the location of the bioassay experiments. Results shown are indicated by red star and red line indicates control response.

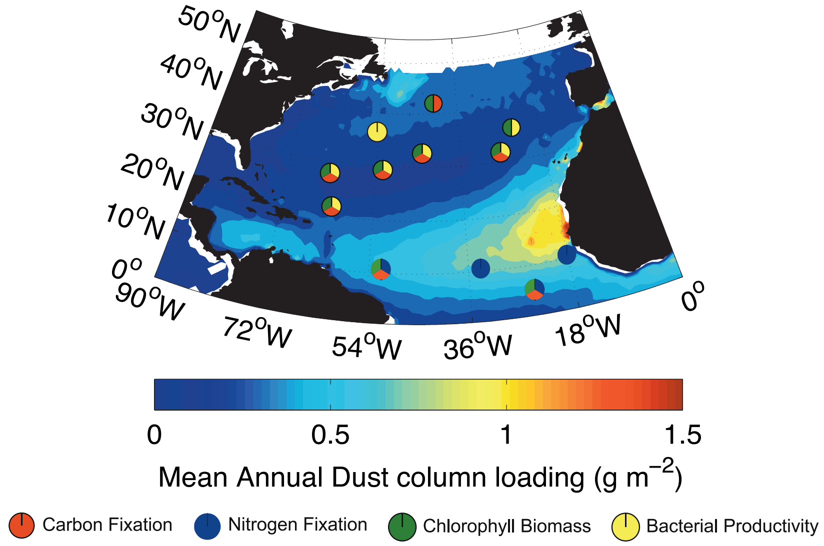

Figure 3: Mean annual dust column loading to the North Atlantic calculated using MODIS aerosol optical thickness data from April 200 – March 2004. Overlayed on the map are the sites of the nutrient enrichment bioassay experiments with colors indicating the presence of a stimulation of CO_2 fixation (red), N_2 fixation (blue), chlorophyll biomass (green), and bacterial productivity (yellow) by dust. Note: Sample analysis for N_2 fixation have been completed for sites south of 20°N.

iron should be even greater in other oceanic regions that receive less dust deposition.

Our results have important implications for understanding controls on marine microbial productivity and how it relates to CO_2 fixation in the North Atlantic. First, contrary to recent suggestions, our experiments demonstrate that the total primary productivity of the natural plankton community in the tropical/sub -tropical Atlantic is N-limited. Second, they demonstrate that nitrogen fixation is co-limited by iron and P in a region where mineral dust deposition is high and iron should be in excess. Further studies are required to determine whether this co-limitation is widespread. Finally, our results suggest that dust, when supplied at high levels locally, can relieve N limitation of primary production, iron and P co-limitation of diazotrophy, and N and P co-limitation of bacterial production.

The tropical North Atlantic is a region of high dust deposition. It is also considered one of the most important areas globally for nitrogen fixation. Dust deposition is highly episodic, and has varied widely on geological timescales. If dust deposition can to some extent relieve nutrient limitation of marine microbial communities as our results demonstrate (Fig. 3), the postulated link between changes in dust deposition as seen between glacial and interglacial periods and changes of elemental cycles in the ocean by plankton may be even stronger than initially suggested.

IFM-GEOMAR Contributions

Mills, M.M., Ridame, C., Davey, M., LaRoche, J., and Geider, R.J., 2004: Iron and phosphorus co-limit nitrogen fixation in the Eastern Tropical North Atlantic. *Nature*, **429**, 292-294.

LaRoche, J., and Breitbarth, E., 2005: The importance of Trichodesmium in the global nitrogen cycle. *Journal of Sea Research*, **53**, 67-91.

Matthew Mills and Julie LaRoche

3.9 Predator Diversity Hotspots in the Blue Ocean

Large oceanic predators such as the bluefin tuna, blue marlin, white shark, barndoor skate and leatherback sea turtle have two traits in common. First, they are fascinating creatures (Fig. 1). And second, they are threatened by extinction. Our fascination comes from their large size (leatherbacks are the largest extant reptiles, second only to dinosaurs), swimming abilities (bluefin tuna are the world's fastest fish, reaching 80 km/h), range (many species regularly migrate across entire ocean basins), and predatory power (white sharks may attack - very rarely - humans). Their endangerment comes mostly from fishing, either directed fishing (bluefin tuna may sell for over 50,000 $US a piece), or unintended bycatch in other fisheries such as longlines and gillnets (leatherbacks turtles are almost extinct in the Pacific because of this, the same goes for barndoor skates in the Atlantic).

Despite our fascination with these creatures we know surprisingly little about them. Only very recently marine scientists have begun to gain deeper insights in the biology and ecology of these fascinating animals. Considering abundance and diversity, the two most fundamental ecological metrics. Large-scale trends in abundance of large predatory fishes were analyzed for the first time on a global basis last year. Our analysis The data revealed that we have only 110% of all large fish - both open ocean species including tuna, swordfish, marlin and the large groundfish such as cod, halibut, skates and flounder - are left in the sea. Most strikingly, the study showed that industrial fisheries take only ten to twenty years to reduce any new fish community they encounter to one tenth of what it was before. This news has invigorated calls to fish more carefully, and let stocks recover to larger size to avoid collapse.

Also last year, we first gained insight into the diversity of large predators, ranging from tuna and sharks to whales and seabirds. Scientific observers on ocean-going longline fishing vessels recorded 145 species that were caught in the Atlantic, North Pacific and South Pacific. When we analyzed these data for species diversity we found some unexpected results. Oceanic predators concentrated in distinct di-

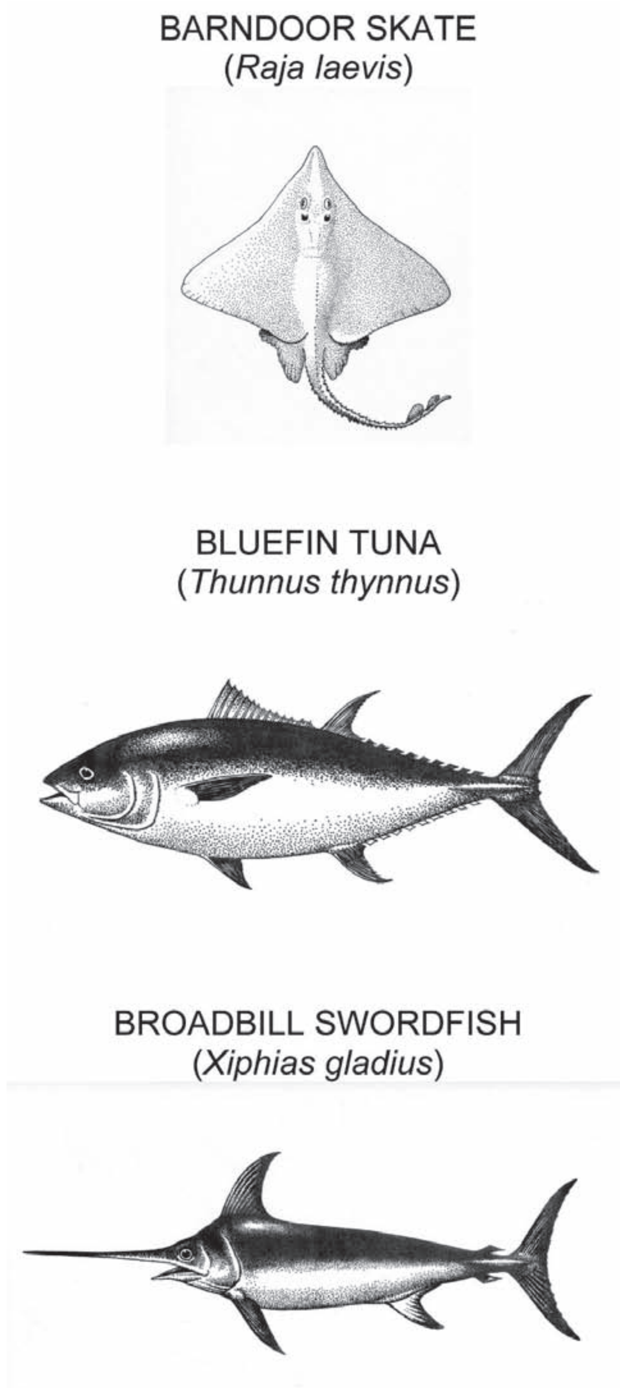

Figure 1: Large marine predators such as the barndoor skate, bluefin tuna and broadbill swordfish have become rare in the world oceans. Illustrations by Richard Ellis from "The empty ocean" (Island Press/Shearwater Books 2003). Reprinted with permission.

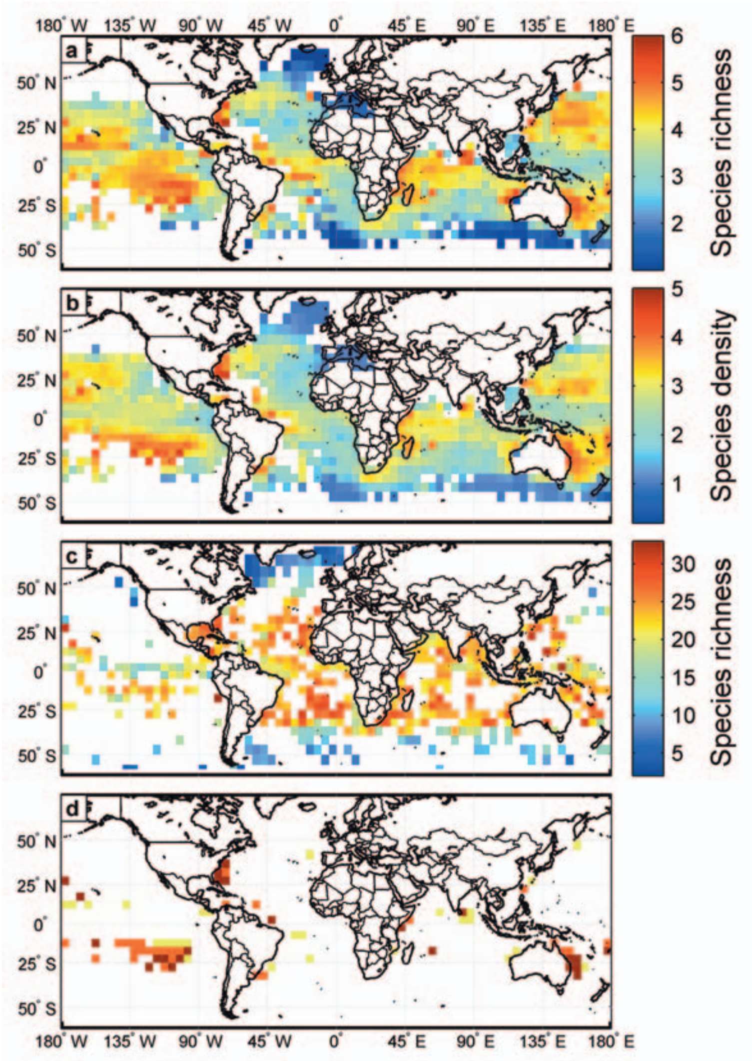

Figure 2: Global patterns of predator diversity. **a**. *Species richness of tuna and billfish expressed as the number of species per 50 individuals.* **b**. *Species density expressed as number of species per 1000 hooks.* **c**. *Patterns of foraminiferan zooplankton diversity (species richness per sample, averaged over 5ºx5º cells) for comparison.* **d**. *Top 50 cells which are hotspots of species richness (yellow), species density (orange), or both (red).*

Despite these advances worldwide patterns of predator diversity, as well as their underlying causes, have remained elusive so far. This changed when we founded a small interdisciplinary research group at the IFM-GEOMAR. In a 10-month effort Andreas Oschlies (oceanographic modeling), Marcel Sandow (bioinformatics), Heike Lotze (historical ecology), and myself in collaboration with Ransom Myers (a fishery scientist at Dalhousie University, Canada) constructed the first global maps of tuna and billfish diversity from longline fishing data (Fig. 2). Two different measures of diversity, predator species richness (Fig. 2a) and species density (Fig. 2b) both showed a consistent and surprisingly well-defined global pattern. Again peaks of diversity were found at sub-tropical latitudes and lower diversity towards the poles and at the equator. Remarkably, this general pattern closely resembles that seen for foraminiferan zooplankton, which is small single-cell plankton that accumulates in deep sea sediments (Fig. 2c). Distinct hotspots of predator diversity are seen off the U.S. and Australian east coasts, south of the Hawaiian Islands chain and most prominently in the southeastern Pacific (Fig. 2d). All these areas lie in the subtropics, as do the peaks in foraminiferan zooplankton diversity (Fig. 2c, d). Good correlation with the zooplankton data suggests that the global pattern of diversity shown here could be very valid generally for very different organisms. This would also mean that patterns of diversity in the open ocean are fundamentally different from those on land or on the sea floor which tend to peak around the equator.

versity hotspots which were found consistently at intermediate latitudes (20-30° N and S), where tropical and temperate species ranges overlap. This is very different from the land, where diversity is typically peaks around the equator, most prominently in rain forests. In the ocean, sub-tropical hotspots were often found close to prominent habitat features such as reefs, shelf breaks or seamounts. These underwater slopes and mountains are obviously special places, where many species aggregate.

Can oceanographic variables explain geographic patterns of predator diversity? Marine biologists have observed that sharp temperature fronts and whirling eddies associated with meso-scale oceanographic variability attract diverse species from plankton to whales. In contrast many oceanographers believe that large-scale patterns of temperature, productivity and climate determine the distribution of life in the ocean. We found that both were right. For example, mean temperature had a very large effect on diversity, which increased over most of the observed range (5-25°C), but declined again at high temperatures >27°C. Fronts and eddies were also important and often showed a distinct concentration of species. But also oxygen was important, as predator species are fast and active swimmers with a high metabolism. Areas with low oxygen levels (less than 2 ml per liter) clearly had fewer species than nearby regions with normal oxygen concentrations.

Finally, our analysis revealed a disturbing historic trend. We found that in the wake of industrial fisheries, predator species density has declined significantly (on average by 20%) during the last 40 years, particularly in the Atlantic and Indian Oceans. If continued, this trend may reduce the ability of communities to adapt to environmental change, and undermine the sustainability of fishing. We conclude that the seemingly monotonous landscape of the open ocean shows rich structure in species diversity, but that diversity has been declining for some time. These results could be important for the management of oceanic predators as they confirm concerns about the ecosystem-wide effects of fishing. At the same time we are offering a partial solution. Knowledge of global diversity patterns, when combined with detailed information on species biology, migration patterns, and fishing pressure, makes it possible for the first time to clearly define priority areas for open ocean conservation.

Current efforts to establish marine protected areas in the open ocean could use this information to place protected areas where most of the species are – and thereby protect many species at once.

IFM-GEOMAR Contributions

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Boris Worm

3.10 New Natural Products from Marine Microorganisms

Bacteria and other microorganisms often are living in close association with higher organisms. Associations of bacteria with sponges are among the most interesting but also the most complex objects to study the interactions between microorganisms and their host partner. In fact, the association of microorganisms with sponges is one example of numerous cases where these associations have been described. These associations gained much interest during recent years, because the production of biological active substances was reported. Though convincing evidence does exist only in a few cases, it was tempting to assume that microorganisms associated with these animals produce the active substances. They may contribute to the integrity of their hosts and their defence by the excretion of antibiotic and other biologically active substances. In particular sessile marine organisms like sponges are considered to depend on chemical defence mechanisms against predatory animals, but also against attacks of pathogenic microorganisms.

In the studies on the interaction between marine sponges and microorganisms, the Marine Microbiology group focused on selected sponge species which were analysed by microscopy, genetic studies on the associated bacteria and culture studies, which aimed at the isolation of antibiotically active bacteria. The microscopic studies revealed large differences in the association of bacteria with different sponges. Suberites domuncula e.g. showed only a small number of bacteria on its interior surfaces (Fig. 1), while the sponges Halichondria panicea (Fig. 2) and Ircinia fasciculata revealed abundant and highly diverse bacterial assemblages. This could be seen in the electron microscope but also was reflected in the high diversity of bacteria isolated from these sponges. Sponge-species specific association of bacteria was demonstrated by comparison of the bacterial community associated to different specimen of the Mediterranean sponge Chondrilla nucula from locations in the Adriatic Sea and in the Ligurian Sea. The bacterial communities of the studied sponges to a large extent contained bacteria that were genetically related to clusters found as characteristic members of sponge associated communities. Almost identical clone sequences were found in specimen from the different locations. Interestingly the sponge Thetya aurantium showed two clearly distinct morphological communities associated with exterior and interior cells, which could be shown by microscopic studies and was affirmed in denaturing gradient gel electrophoresis and 16S rDNA cloning experiments (Fig. 3). These findings support the assumption that at least part of the bacteria found in sponges are specifically associated with the animals and may have adapted during evolutionary processes to the sponge environment (in contrast to bacteria ingested as food particles).

Current studies concentrate on the role of bacteria and fungi producing antibiotic substances in association with sponges. Penicillin was the first antibiotic substance used in medical treatments. It was found by Fleming in 1928 and some years later forced into application by others. Meanwhile a whole array of different antibiotically active compounds is known. However, the strong increase of resistant bacteria causes severe problems in medical treatment and reinforces new investigations to search for compounds that are active even against multi-resistant pathogens.

Sponges are considered as one of the most important sources of natural substances with antibiotic, antitumoral or antiviral activities. This makes sponges a potentially important source of new products for medical treatment.

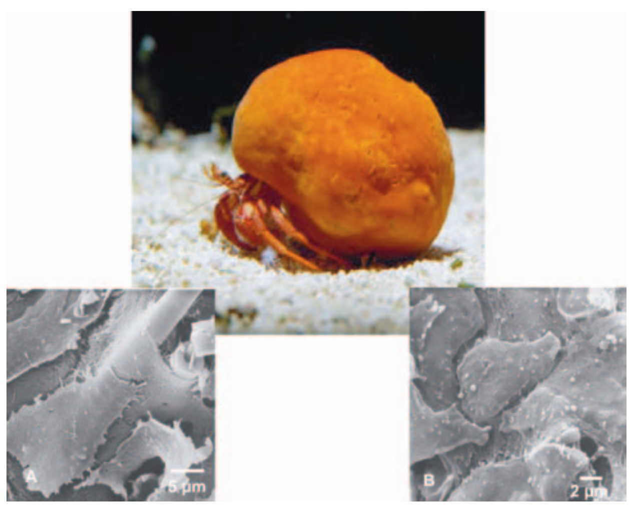

Figure 1: Suberites domuncula: (A)+(B) electron microscopic exposure of the sponge tissue with only very low numbers of bacterial cells.

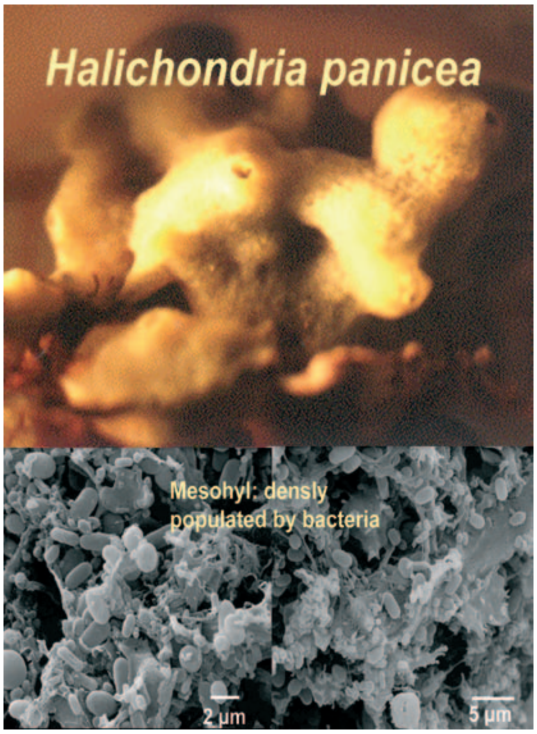

Figure 2: The breadcrumb sponge Halichondria panicea with electron microscopic pictures of its interior showing abundant bacteria.

However, in most cases it has not been demonstrated whether the sponge cells or their microbial associates produce the active substances. In fact, more and more cases become known in which it could be demonstrated that rather the associated bacteria and not the animal host produce the biological active compounds. These circumstances were an important motivation to concentrate on microorganisms associated with sponges (and other marine invertebrates) in the search for new natural substances.

At IFM-GEOMAR we have isolated and tested large numbers of bacteria and fungi for important biological activities, including antibiotic action against other microorganisms. Associated project partners have tested against multiresistant bacteria and for antitumoral and antiviral activities. Several hundred biologically active marine bacteria and fungi are currently treated in detailed biological and chemical analyses. New biologically active chemical compounds have been identified by our chemical partners. Several compounds were patented and one of these, Sorbicillacton A, is in an advanced stage of the development for medical treatment. Sorbicillacton A is produced by a fungus isolated from a marine sponge and was promoted within the "Centre of Excellence BIOTECmarin". BIOTECmarin is a national research project focusing on molecular biotechnology and bioactive compounds in marine sponges and sponge-associated microorganisms. The chemical structure was elucidated by chemists at the University of Würzburg. The biosynthetic pathway was established in joint experiments of the Marine Microbiology at IFM-GEOMAR and the chemistry group, and the important biological activities against viruses and cancer cells were established by partners at the University of Mainz.

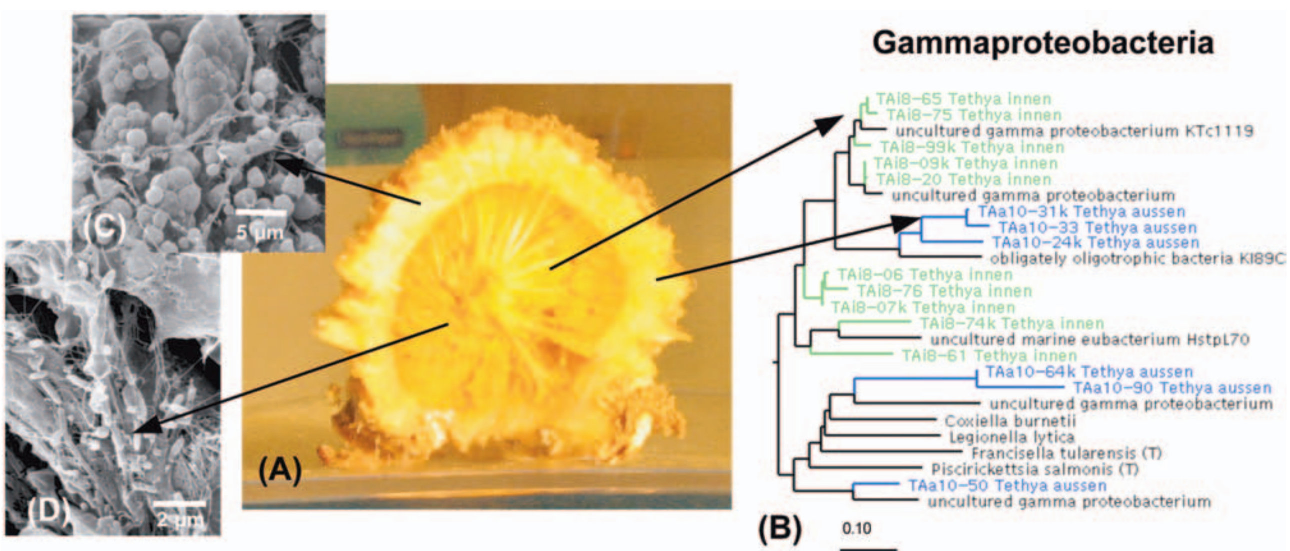

Figure 3: (A) Cross section of the marine sponge Tethya aurantium (Sea-orange), (B) The phylogenetic tree of gammaproteobacteria demonstrates specific association of different bacteria with the interior (shown in green) and the exterior (shown in blue) cell tissue of the sponge, (C) + (D) electron microscopic exposures (REM) of interior (D) and exterior (C) parts of the sponge.

Research on natural substances is a multidisciplinary task and the activities of Marine Microbiology at IFM-GEOMAR are part of an integrated network of research groups and small companies on a local and national scale. In addition, international collaborations with institutions in China and Indonesia extend these activities. Projects are funded as part of the national "Centre of Excellence BIOTECmarin" and by federal and local ministries that specifically support cooperation with companies.

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Johannes F. Imhoff

3.11 New Approaches to the Dynamics of Fish and Squid Populations

Many exploited stocks of fish and squid undergo large fluctuations or extended trends in population size on different time scales, related to environmental changes as well as to fishing pressure. Therefore, one major aim of fishery biology is to understand the mechanisms regulating these stock fluctuations and to develop methods to predict the effects of fishery on exploited stocks and ecosystems in total as well as the effects of natural environmental fluctuations and climate trends on the exploitable production. The complexity of the task is increased by the fact that natural and manmade effects are strongly interlinked and cannot be considered separately. One aspect of crucial importance is the reproductive strategy of exploited stocks which is in many species adapted to a highly variable environment, based on extremely high fecundities and diversities in stock structures, which includes the chances for population survival over periods of unfavourable conditions as well as the development of large stock sizes under favourable conditions. The regional stock structure, the size and age structure of the spawning stocks, both influenced by fishery, the nutritional condition of adults and thus the quality of gametes and the survival of the early life stages related to stock structure, abiotic environment and presence of prey and predators are the key factors determining the reproductive success of a species. One focus of the Research Unit Fishery Biology is to improve the knowledge on the most relevant factors governing the recruitment processes in fish and squid stocks by the development of new methodical approaches, which allow to elucidate the characteristics of survivors during early development and to address also behavioural patterns that provide best likelihood for survival. For this purpose the growthhistory and the chronology of important events during the early development of individual fish have to be considered. This can be supported by analysing the optical and chemical microstructures of fish otoliths or statoliths in squids, combined with new methods in survey strategies, drift modelling, biochemical identification of nutritional conditions, utilization of experimental results on physiology and behaviour for individual based modelling of survival success. Examples for corresponding activities are presented below.

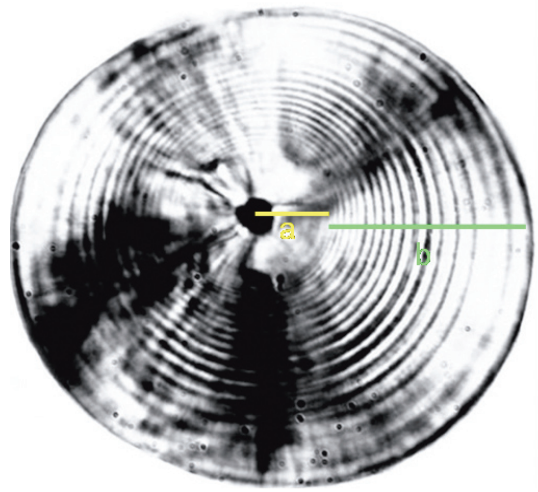

Figure 1: Sprattus sprattus otolith. (a. embryonic phase, b. larval growth zone with daily increments)

Figure 1 depicts an otolith of a larval sprat (*Sprattus sprattus*). The inner part of the otolith refers to the embryonic life phase (a.), while the part marked with "b" corresponds to the larval phase. In this part several rings are easily detectable. Each increment represents one day in a larva's life and consists of a "white" and a "dark" zone. The white zone is formed during phases of high metabolic rates and somatic growth, while the dark zone corresponds to resting periods or reduced metabolic activity. Thus, the alternation of both zones reflects typical daily activity patterns. The number of rings provide information on age, and the widths of daily as well as annual rings reflect individual growth patterns, so that individual growth histories can be obtained from otolith analysis, which is of special interest for the early larval development. In addition, the trace element composition in otoliths can be utilized to provide information on the ambient environmental conditions like water temperature and salinity, and high resolution analysis techniques allow to relate this information to age and growth based on the ring structure of the otoliths. Thus, otoliths/statoliths can be regarded as an archive recording the life history. Reading this archive, provides important information to identify characteristics of survivors and environmental conditions they were exposed to.

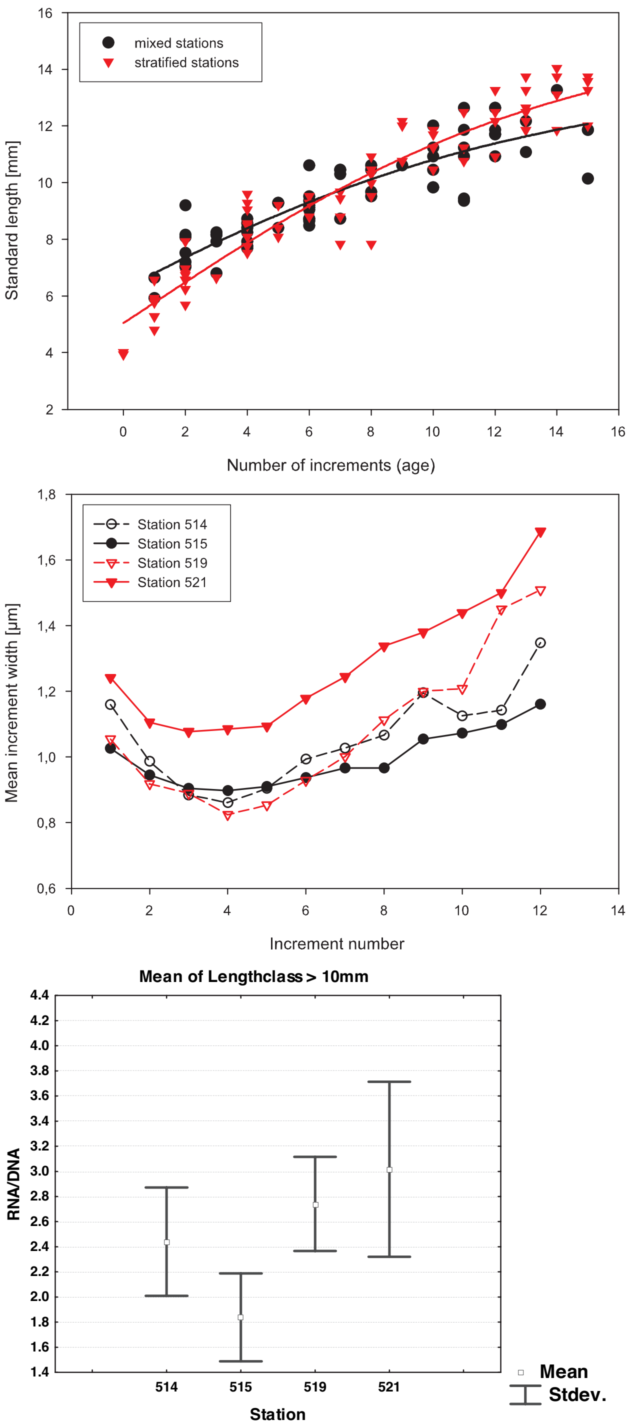

Figure 2: Comparison of size at age (apparent growth rate within the population, upper panel) and mean increment width (average and variation of individual growth rates, middle panel) of sprat and sardine larvae sampled from a tidal mixing front in the German Bight. Stations 514, 515 represent the mixed water body, stations 519, 521 the stratified water body. The lower panel indicates the mean and standard deviation of the RNA/DNA ratios reflecting protein metabolism as a measure of feeding activity determined from the same larvae caught at the different stations.

Larval Growth and Nutritional Condition in Relation to Environmental Conditions

Otolith analysis have been applied to study variations in growth and nutritional condition of fish larvae and the impact of hydrographic features like frontal systems. As an example Figure 2 presents growth rates and a biochemical measure for nutritional condition in a mixed population of sprat (*Sprattus sprattus*) and sardine (*Sardina pilchardus*) larval sampled on 4 stations across a tidal mixing front in the German Bight.

By relating size of the larvae to number of increments (age), the average growth rates within the sampled populations have been determined and compared between the mixed and stratified area (Fig. 2, upper left panel). Highest growth rates were found at the stratified water stations offshore. The results from this traditional approach may have been influenced by size selective mortality and, as it is based on a single survey and is not following the development of hatch-time cohorts, they also may have been effected by differences in the initial size of larvae. In this case some slight indication is given for a larger initial size in the mixed area.

Using increment width from otoliths provides a measure of actual daily growth rates for those individuals which have survived until the time of sampling (Fig. 2, upper right panel). These data confirm differences in growth among stations with all larvae from one station and the later larval stages from both stations of the stratified water body showing larger increment widths compared to the mixed area. These growth differences were related to higher chlorophyll concentrations and indicate higher abundance of larval food.

The assumption about food availability and consumption as basis for the observed growth differences can be verified by comparison with a biochemical index of nutritional condition measured from the same larvae. Fig. 2, lower panel presents average RNA/DNA ratios per station, reflecting protein metabolism as a measure of feeding activity. These ratios, which relate only to the conditions a short time prior to sampling, show the same ranking among stations as can be seen among the individual growth rates of the later larval stages, confirming the differences in food availability at about the time of sampling.

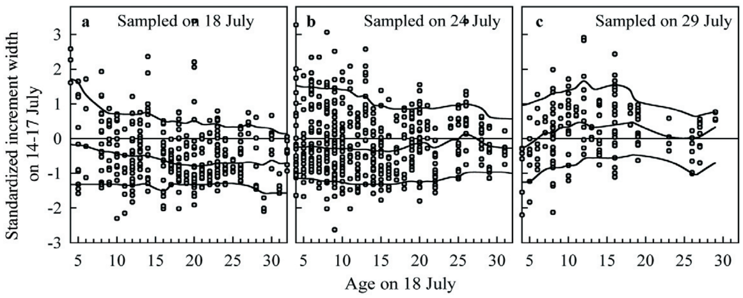

Figure 3: Standardized otolith increment widths as relative measure of individual daily growth rates, obtained for a population of radiated shanny larvae sampled at three successive dates. The lines show the 10th, 50th, and 90th percentiles of the cumulative probability distribution. Shifts between survey dates in the growth rate distribution per age group indicate size selective mortalities.

Size Selective Mortality

Differences in the average individual growth rates of larval cohorts surviving to a later stage of development may be influenced by mortality again, which complicates the interpretation of growth data, but also allows to identify size selective mortality effects, when the same population of larvae is sampled by repeated survey.

Figure 3 presents an example of results on individual growth from a comprehensive co-operative study on the development of larval radiated shanny (*Ulvaria subbifurcata*) in a large bay of Newfoundland. In order to allow a comparison of the variation and shift in daily growth rates for larval cohorts of different age, the otolith increment width data are presented in a standardized form, as deviations from the mean over time for each daily age group. The results presented in the figure indicate an obvious shift in the distribution of growth rates per age group towards higher values from one to the next survey and thus for the longer surviving part of the cohorts. It illustrates that slower growing individuals were exposed to higher mortalities during this study, which was most pronounced for the oldest larvae in the period between the first and second survey and for mid aged larvae from the second to the third survey. It could be judged from additional information that predation was the most important factor, depending in its effect on the distribution of larvae and predators combined with temperature related spatial differences in the growth characteristics.

Identification of Feeding Habitats

Simulations with a coupled biophysical model of the Baltic Sea have been performed in order to enable the reconstruction of the environmental conditions (temperature, prey) sprat larvae had been exposed to during their development. By comparing these environmental conditions with the growth histories of sprat larvae based on otolith increment width, it was possible to define areas where these larvae had encountered suitable feeding conditions. Temperature and prey ingestion have been considered as

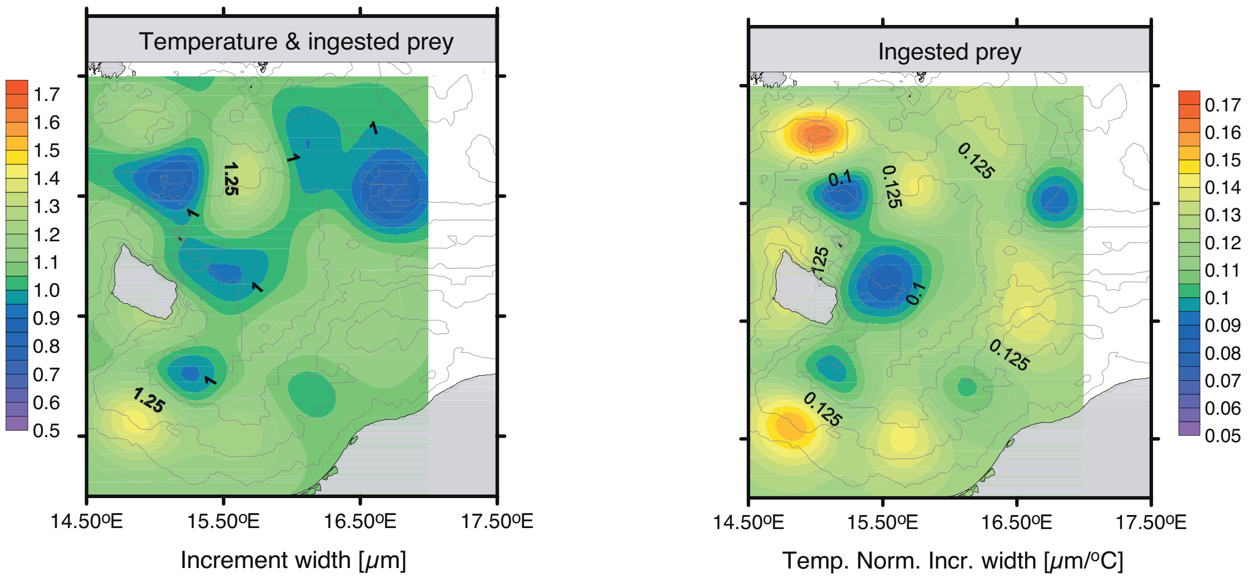

Figure 4: Horizontal distribution of otolith increment widths of sprat larvae in the Bornholm Basin in May 2001 (left panel). By separating the temperature effect on otolith growth, highest feeding success was observed especially in the eastern part of the basin, whereas less optimal feeding conditions could be related to the centre and northern area of the basin (right panel).

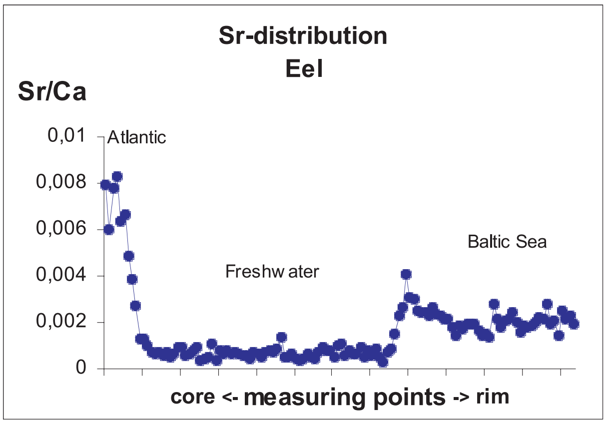

Figure 5: Strontium/Calcium ratio of an otolith of the European eel (Anguilla anguilla), caught in Kiel Bight.

driving key factors influencing otolith growth. As an example, Figure 4 displays the horizontal distribution of otolith increment widths based on the drift and growth history of sprat larvae in the Bornholm Basin in May 2001.

By separating the temperature effect on otolith growth, highest feeding success was identified for the eastern part of the basin and somewhat less for the western part, whereas less optimal feeding conditions could be related to the centre and northern area of the basin.

Detection of Migration Routes and Pathways

The trace element composition of hard structures, such as fish otoliths and statoliths of cephalopods is influenced by, e.g., ambient water temperature and salinity. Trace element composition in combination with age readings provide a powerful tool to reconstruct life history events and migration pathways of individual specimen.

Presently two different methods to determine the trace element distribution are applied by the fishery biology group in cooperation with geologists: The Synchrotron X-ray Fluorescence Analysis (SYXRF) and the use of an electron microprobe. In the marine geochemistry group at IFM-GEOMAR, electron microprobe and X-ray Flurescense analyses have frequently been applied to investigate, e.g., plate tectonic processes. The excellent micro-scale resolution and the precise analysis of elements from Calcium (Ca) to Lead (Pb) makes SYXRF a very accurate tool to gather life history information of fish and cephalopods from their otoliths and statoliths, respectively. Beam-based elemental assays can take advantage of the chronological growth sequence recorded in the otolith and are able to resolve different age or date ranges of the animal's individual history. Both methods are extremely powerful in describing fish migration routes and pathways or the identification of fish nursery areas. Taking advantage of the merger of the former IfM and the GEOMAR Institute, geologists and fishery biologists have now introduced both techniques to address questions related to fish behaviour.

As an example, in Figure 5 the strontium/calcium ratio and its spatial distribution from the inner part to the outer margins of an eel's otolith caught in the Kiel Bight are displayed. As clear Atlantic, freshwater and brackish signals were detected, this specific eel has crossed the Atlantic during its larval phase, entered freshwater afterwards and moved further on into the brackish habitat of the Baltic.

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Dietrich Schnack

3.12 The Hikurangi Oceanic Plateau: A Fragment of the Largest Volcanic Event on Earth

The Hikurangi oceanic plateau is located in the southwest Pacific off the east coast of New Zealand. The portion of the plateau exposed on the seafloor covers an area of 350,000 km^2, similar to that of New Zealand (Fig. 1a). If subducted portions beneath the North Island of New Zealand and the submarine Chatham Rise, imaged with geophysical techniques, are included, the plateau covers at least 800,000 km^2. New bathymetric, age and geochemical data obtained during the *ZEALANDIA* cruise with the German research vessel Sonne indicate that the plateau formed during the Greater Ontong Java Event (ca. 122 m.y. ago), the largest-known volcanic event on Earth. With the inclusion of the Hikurangi Plateau, this submarine event covered ~1% of the Earth's surface with volcanism possibly within a few million years and appears to have had dramatic impact on the chemistry, temperature and life of the Earth's oceans.

Large Igneous Provinces (LIPs), which represent large regions of the Earth's surface (in some cases thousands of kilometers across) covered by volcanism, include oceanic plateaus (e.g. Ontong-Java and Caribbean) and continental flood basalt events (e.g. Siberian and Deccan Traps). The formation of large igneous provinces has fundamental implications for the transfer of mass and energy from the interior of the Earth to its surface and for the growth and breakup of continents. These massive volcanic outpourings have occurred contemporaneously with all major mass biotic extinction events on Earth, suggesting a causal link. There is no doubt that they also contributed to global environmental change.

Many LIPs appear to have primarily formed over relatively short geological time intervals (several million years). The most widely accepted model to explain the large volume, wide geographic distribution, and short time interval of LIPs is that they are formed through mantle upwellings (plumes) with large mushroom-shaped heads at their initiation. Upon reaching the base of the lithosphere, these plume heads can flatten into disks with diameters exceeding 2000 km, generating widespread volcanism. Recently alternative models have been proposed to explain some LIPs. For example, it has been proposed that the Ontong Java plateau was formed as a result of a meteoritic impact and that the Caribbean Large Igneous Province formed through accumulation of intra-plate volcanism over at least 70 m.y. and terrane accretion during the subduction process.

In contrast to continental LIPs, relatively little is known about oceanic LIPs, due to their relatively inaccessable location on the seafloor. We are investigating the Hikurangi Plateau and have future plans to investigate the Manihiki Plateau, in order to gain new insights into the age, surface and internal structure, chemical composition, origin and evolution of oceanic plateaus, which form the most voluminous LIPs on Earth. Two major models have been proposed for the origin of the Hikurangi Plateau. 1: The plateau formed as part of a massive volcanic outpouring associated with a plume head that triggered the final break-up of the Gondwana super-continent (consisting of Antartica, Africa, South America, India, Australia and the New Zealand micro-continent Zealandia) ca. 100 m.y. ago). 2: The plateau formed as part of the greater Ontong Java flood basalt event ca. 122 million years ago. In accordance with the second hypothesis, the Hikurangi Plateau may have once been connected to the Manihiki oceanic plateau (now located more than 3000 km to the north) but separated in the Cretaceous by seafloor spreading at the Osbourn Trough, a paleo-spreading center (Fig. 1a). The Manihiki Plateau (ca. 122 million years) formed as a separate plateau during the greater Ontong Java volcanic event.

In order to test these hypotheses, we carried out detailed bathymetric (depth) mapping and sampling of the Hikurangi Plateau during the *ZEALANDIA* expedition. This research cruise yielded the most detailed bathymetric maps, used to evaluate the structure and volcanic evolution of the plateau, and rock collections, used for age dating and geochemical analyses, of an oceanic LIP to date. The new bathymetric maps reveal spectacular views of one of these massive volcanic outpourings on the seafloor, providing new insights into the geodynamic evolution of an oceanic plateau. The mapping for example confirmed the rifted nature of the

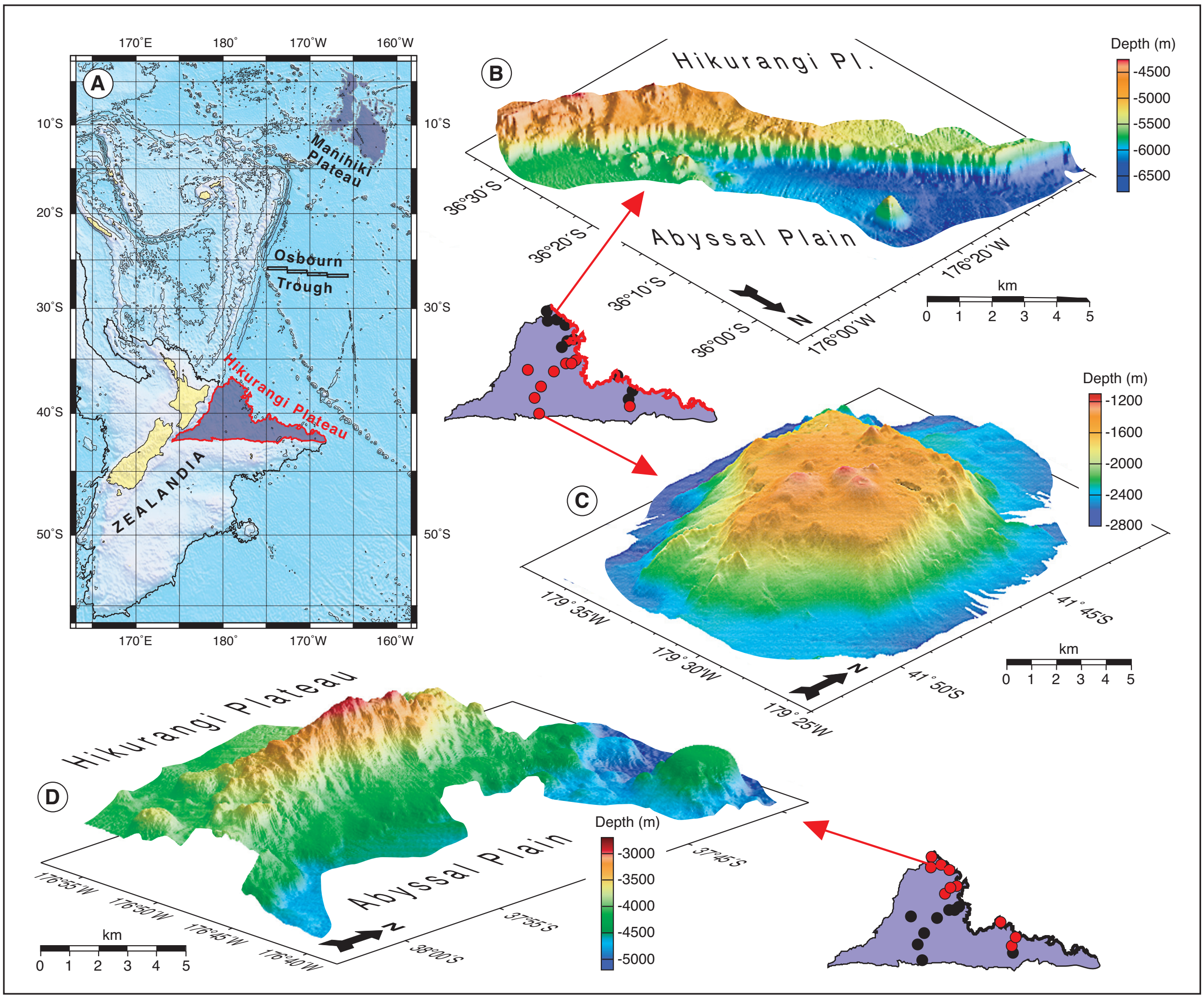

Figure 1: (a) Overview map of the SW Pacific showing the locations of Zealandia, the Hikurangi and Manihiki oceanic plateaus and the Osbourn Trough (paleo-spreading center) halfway between the two plateaus. The major morphological features of the Hikurangi Plateau comprise (b) the 1 km high northeast rifted margin, (c) interior guyot-type seamounts, and (d) marginal ridge-type seamounts.

northeast margin of the plateau, exposing sections of up to 1 km into the plateau basement (Fig. 1b).

Two major types of seamounts, representing a late stage in the evolution of the plateau, were identified: 1) large guyot-type seamounts in the interior of the plateau (Fig. 1c), and 2) ridge-type seamounts along the margin of the plateau (Fig. 1d). The most striking feature of all the interior seamounts is their guyot-like form, characterized by circular, steep-sided bases and relatively flat tops, ~1 km above the plateau basement and up to 24 km across (Fig. 1c). The mapping and recovered samples are consistent with the seamounts being former island volcanoes that were eroded to sea level. The depth of both the erosional platforms (1600-3300 m) and the base of the volcanoes (2000-4200 m) increase systematically toward the northeastern boundary of the plateau, consistent with greater subsidence near the northeast plateau margin, consistent with greater crustal thinning due tectonic rifting. The marginal ridge-type seamounts comprise elongated linear features with sharp, ridge-like tops (Fig. 1d). These seamounts occur exclusively along the northeast margin of the Hikurangi Plateau and are sub-parallel to the plateau margin. The ridge-type seamounts reach elevations of ~1.5 km above the seafloor, which exceeds the height of the erosional platforms on the guyots. Therefore at least the latest stages of volcanism on the ridge-type seamounts formed after the interior guyot-type seamounts were eroded and began to subside. The linearity of these ridge-type seamounts, their proximity to the northeast margin and

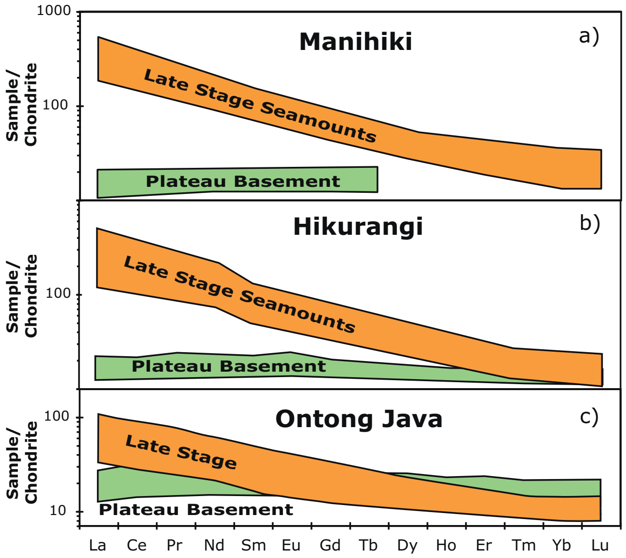

Figure 2: Chondrite-normalized Rare Earth Element (REE) patterns of volcanic rocks from the a) Manihiki, b) Hikurangi and c) Ontong Java Plateaus. The plateau basement in all three oceanic plateaus is characterized by tholeiitic volcanism and displays similar trace element characteristic, for example, flat REE patterns. A late stage of volcanism formed seamounts of alkalic composition on the Manihiki and Hikurangi plateaus. Within the Ontong Java Plateau a late alkalic phase with enriched REE patterns has also been identified (Sigana Alkali Basalts on Isabela Island). Data sources for Manihiki and Ontong-Java are from the literature and GEOROC (http://georoc.mpch-mainz.gwdg.de/).

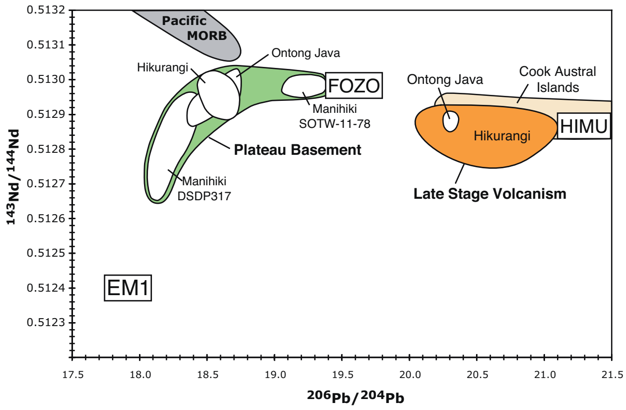

Figure 3: $^{143}Nd/^{144}Nd$ – $^{206}Pb/^{204}Pb$ isotope correlation diagram for volcanic rocks from the Hikurangi, Manihiki and Ontong Java Plateaus. The basement for all three plateaus has similar Nd and Pb isotopic compositions and overlaps the field for Pitcairn Island, characterizing enriched (EM1)-type mantle. Alkali basalts from the late magmatic stage of the Hikurangi and Ontong Java Plateaus also have similar Nd and Pb isotopes, overlapping the field for HIMU (high time-integrated $^{238}U/^{204}Pb$) type compositions from the Cook Austral Islands. The similarity in geochemistry between the three oceanic plateaus and volcanism associated with ocean island hotspot volcanoes, instead of Pacific mid-ocean-ridge basalt (MORB) which represents the composition of the upper mantle, favors an origin of the greater Ontong Java event as a result of a deep-seated mantle plume rather than through melting triggered by a meteoritic impact. Data sources are the same as in figure 2.

their orientation sub-parallel to the margin suggest that these seamounts occur in association with extensional faults, formed during the rifting event.

Igneous rocks were recovered from 77 sites on the Hikurangi Plateau, including the plateau basement and both types of seamounts. $^{40}Ar/^{39}Ar$ age dating shows that the plateau basement formed between ca. 100-120 m.y. and the guyot-type seamounts between ca. 86-99 m.y. The plateau basement rocks have tholeiitic compositions, whereas the late-stage seamount lavas have more SiO_2-undersaturated compositions, suggesting formation through lower degrees of melting during the waning stage of plateau formation. Trace element and Sr-Nd-Pb isotope data show that the plateau basement was derived from an enriched mantle (EM) source, similar in composition to the Ontong Java and Manihiki Plateaus; whereas the large alkalic guyots on the plateau were derived from a distinct high $^{238}U/^{204}Pb$ (HIMU) mantle source, similar to alkalic dikes (90 m.y.) on the Ontong Java Plateau and possibly to alkalic seamounts (ca. 75-86 m.y.) on the Manihiki Plateau (Fig. 2, 3). Therefore all three platforms appear to have had similar temporal and geochemical evolutions consistent with a common origin for all three plateaus. More work, in particular on the age and compositions of seamounts on the Manihiki Plateau, are however necessary to confirm this conclusion. A cruise with *R/V SONNE* to the Manihiki Plateau is planned for spring of 2007 to carry out detailed bathymetric mapping and sampling of the plateau basement and the late-stage seamounts.

Similar temporal and geochemical evolution and bathymetric data indicating that the NW Hikurangi margin is a rifted margin support the hypothesis that the Hikurangi and Manihiki Plateaus may have once formed a combined Hikurangi/Manihiki (HikuMani) plateau. This combined plateau could have covered an area of ≥1.3 million km^2, making it (at least) the second largest plateau (LIP) on Earth after the Ontong Java Plateau (1.5 million km^2). What is even more exceptional is that the main phase of both (or all three) of these massive volcanic events occurred at the same time! These events, combined with contemporaneous volcanism filling the Nauru and East Mariana basins, form the "greater" Ontong Java event, which covered ~1% of the Earth's surface with volcanism.

Despite the magnitude of this super event, it is not associated with a mass extinction, presumably due to this massive volcanic outpouring occurring on the seafloor instead of on land. Nevertheless, there is evidence that this event had a global impact on the chemistry, temperature and life in the Earth's oceans, since it appears for example to be closely correlated with the early Aptian "nannoconid crisis", global ocean anoxic event OAE1a ("Selli" black shale level) and global changes in seawater Sr isotopic compositions.

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Kaj Hoernle, Reinhard Werner, Folkmar Hauff and Paul van den Bogaard

3.13 Seismic Imaging of Gas Hydrates

Over the last decade, considerable attention in scientific research has been focussed on gas hydrates, i.e. gas trapped in an ice-like structure (also known as burning ice) beneath the seafloor. This interest reflects in part the large potential impact of gas hydrates on the global climate, in part the enormous amount of hydrocarbons stored in these deposits, and finally the effect of hydrates in (de-)stabilising the continental slope. The last depends on the relative importance of methane hydrates in preventing porosity loss (decreasing shear strength) and in cementing together the sediments grains (increasing shear strength). The situation is further complicated by the possibility of the dissociation of the deepest methane hydrate leading to the development of a weak zone of high porosity beneath a stronger hydrate-bearing layer, conditions ideal for the development of catastrophic landslides.

Hydrates are a natural phase of the methane-water system (and possibly other gases) in which water molecules form a cage enclosing the gas molecules. Two different types of cage formation are observed in nature: type-I is a cubic structure while type-II is of diamond shape. The second one can enclose larger molecules (e.g. Propane) but occurs less often than type-I. If completely saturated, 1 m^3 of gas hydrate would comprise of 0.8 m^3 water and 164 m^3 Methane at atmospheric pressure and temperature. Hydrates require special conditions of temperature and depth (pressure) to be stable and so only occur along the slope continental margins and permafrost regions.

Marine science first used the Bottom-Simulating-Reflector (BSR) to characterize and map out gas hydrate occurrences. During the Ocean-Drilling-Program (ODP), however, hydrate samples were taken in areas where no BSR was found. BSR represents the base of stable hydrates and is the seismic image of the interface between solid hydrate and free gas: where no free gas is present, there is no BSR even though hydrates may well be present. As the hydrate stability limit is controlled by pressure and temperature, the BSR tends to follow the shape of the seafloor, in places cutting across stratal reflections. Based on the ongoing research and results, different amounts of worldwide hydrocarbon accumulations in hydrates have been proposed. The amount postulated in the late nineties was more than twice that of the known deposits of fossil carbon ($10*10^{12}$ t), while newer estimates propose only 0.5 – 2.5 * 10^{12} t of hydrocarbon bound in the worldwide hydrate deposits. Prior to the scientific evaluation of hydrate quantify and its possible consequences, it is essential to develop methods for detailed characterization of gas hydrate deposits. Consequently, various tools have been developed and measurements taken by IFM-GEOMAR over the last few years.

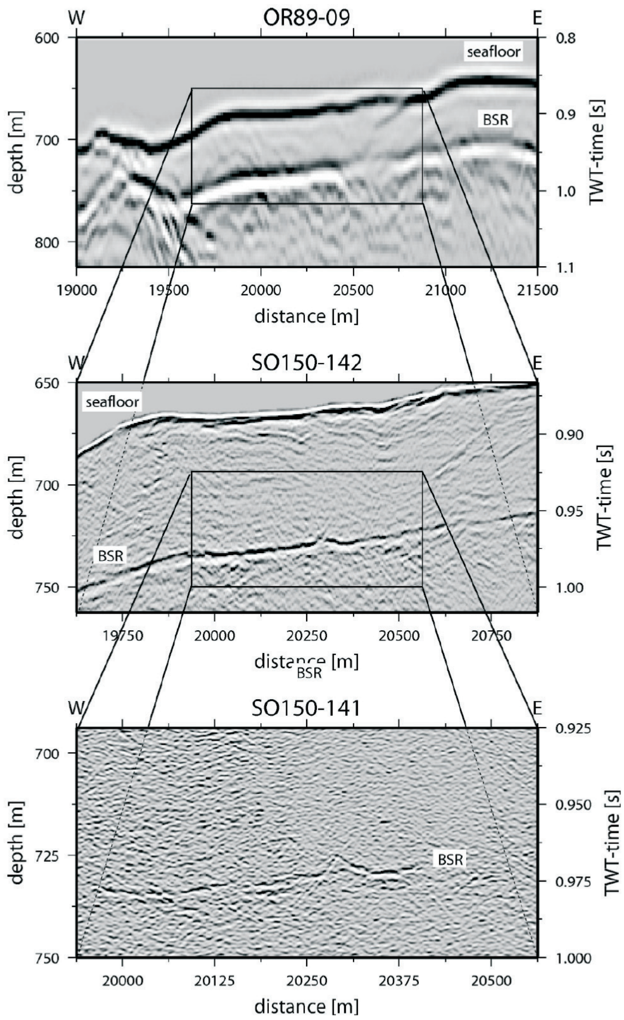

Figure 1: Multiple survey acquisition, using a surface streamer, over the same subsurface structure with different source frequencies. Main frequency: top 40 Hz, center 120 Hz, bottom 280 Hz. With increasing source frequency the image shows an increase of resolution and the BSR an increase of complexity.

Seismic image processing visualizes the subsurface structure by means of reflected acoustic signals. The seafloor signal is marked by a white/black reflection, which means that the subsurface volume is harder than the volume above (Figure 1). Expressed in acoustic terms: the acoustic impedance, the product of density and speed of sound, below the seafloor in the sediment is higher than the impedance of the water column. In contrast, the BSR is marked by a black/white reflection indicating possibly high hydrate impedance above a gas filled sediment of methane with low impedance. As the resolution of the seismic image is limited by the seismic source bandwidth and as the physical parameters describing the seismic subsurface respond are frequency-dependent, multiple surveys with different acquisition parameters are needed to get a more complete knowledge of the sediment parameters (Figure 1).

The Hydrate Ridge off Oregon is well known for its methane hydrate deposits. The seismic profile OR89-02 crosses the southern summit where ODP drilled the sites 1245 and 1244 (Figure 2). Prior to the drilling the seismic profile OR89-02 was analyzed in respect of the subsurface P-wave velocity and the BSR depth. Besides extensive high-resolution geochemical and microbiological sampling, geophysical logging tools were deployed in the drill hole to calibrate the remote sensing seismic methods. Geophysical logging confirmed that the velocities estimated from the seismic profile are quite close to in situ velocities and that the prediction of the BSR depth was accurate to a few meters (Figure 2).

Standard seismic acquisition involves towing a surface source and hydrophone behind a ship and shooting every few seconds: the energy from the source is reflected back to the surface by the different layers in the sub-surface to be detected by the streamer. However, with the continued progress in gas hydrate research the need for increased detail in investigation of such deposits and related feeder channels requires new tools and techniques. In particular, it is important to increase the resolution of the survey method, which can be achieved by lowering either the source or the receiver close to the seafloor, by using a high frequency but broad bandwidth seismic source. However such data are non-standard and require specialised and sophisticated processing techniques.

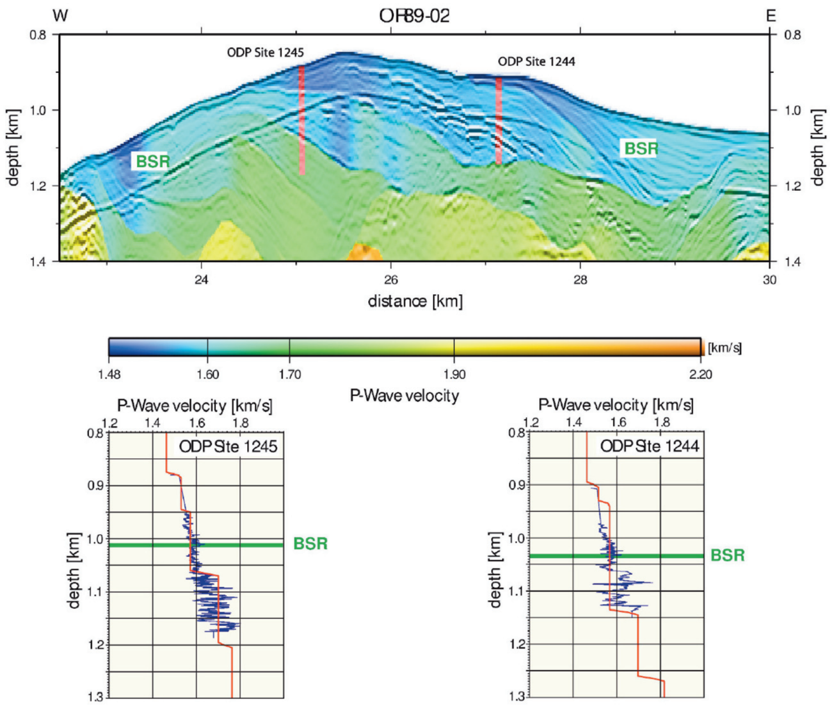

Figure 2: Seismic profile OR89-02 across the southern summit of the Hydrate Ridge. The seismic image is illuminated by the subsurface velocity determined from prestack depth migration analyses. A BSR crossing the stratigraphic sedimentary units is clearly visible. In the diagram the predicted subsurface velocity (red) and the in situ velocity (blue) at the two ODP sites 1244 and 1245 show a good agreement.

Lowering the receivers to the seafloor can be achieved through the use of ocean-bottom-seismometers (OBS). As these instruments are effectively fixed, shooting over them provides raypaths through the sub-surface over a wide range of offsets, yielding detailed information on the velocity of propagation of the seismic energy, and hence on the physical properties of the subsurface.

Using the OBS data displayed in Figure 3, estimates of the gas hydrate content were computed for these observations in the Black Sea. The hydrate content was found to be 10% – 15% of the pore volume close to the seafloor, while it increases to 35% - 40% at the BSR. These values were calculated assuming the hydrate is part of the solid phase without effecting the cementation. If it does effect the cementation, then lower values

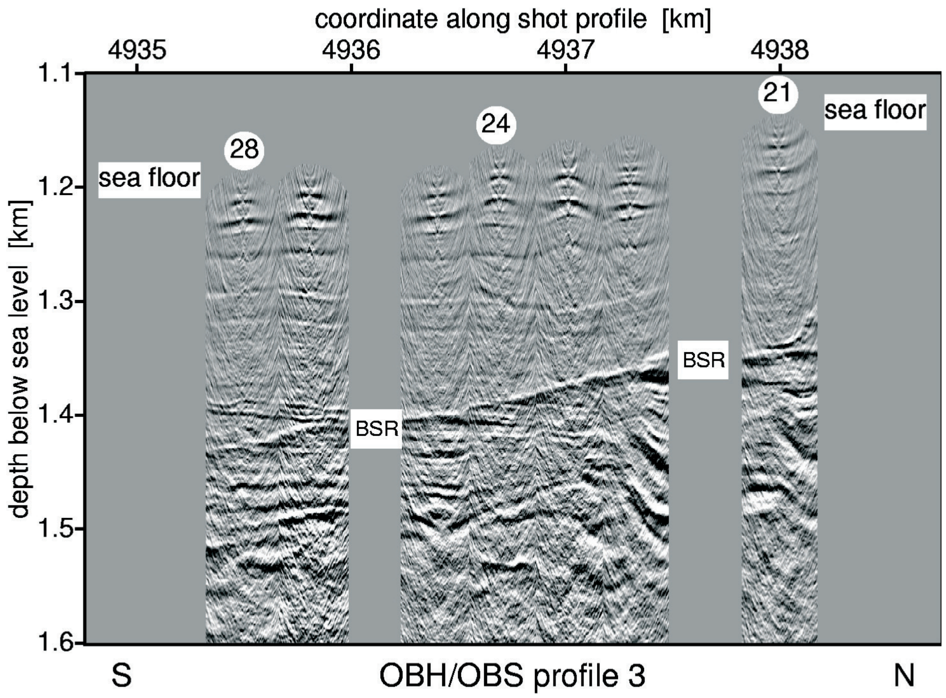

Figure 3: Kirchhoff migrated image of a BSR observed by OBS within the Dnjepr plaeo-fan, Black Sea, GHOSTDABS project 7 hydrophone channels of OBS 21 – 28 were used to image the BSR 200-230 m below seafloor.

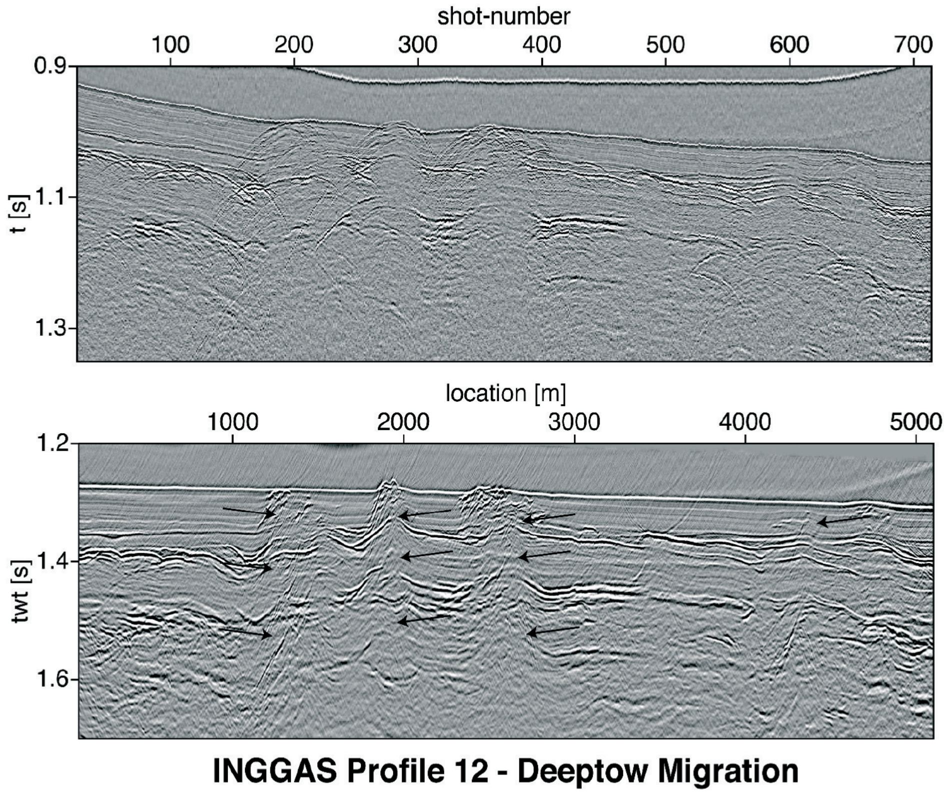

Figure 4: Pre-Stack Depth migrated seismic image of chemoherms Max & Moritz offshore Peru (display is converted to TWT). Arrows mark small scaled faults which are interpreted to represent feeder channels for upward migrating methane enriched fluids.

are obtained. In the latter case one would not expect to find hydrates down to 40 m bsf. At the BSR 25% to 30% should be expected. As well the amount of free gas underneath the BSR is calculated within a broader range of values, which varies between 1.6% - 0.1% depending on the model assumed to be applicable.

However, unless a large number of such instruments are used, the gaps between instruments results in gaps in the seismic image in the critical shallow sub-surface (Figure 3) Alternatively, it is possible to tow a hydrophone streamer close to the seafloor rather than at the sea-surface, although the necessarily limited length of such a streamer and its fixed positon relative to the source results in little information on seismic velocities and hence physical properties. As the two techniques are complementary, we have followed both strategies, developing a pool of ocean bottom seismometers for detailed determination of seismic velocity and for high resolution imaging beneath the seafloor and a deep-towed hydrophone streamer for very high resolution imaging of the shallowest sub-surface. The streamer itself is a modular design, which allows varying the offset of the single hydrophone nodes by applying different cable lengths in between. For navigational purposes the system is equipped with an ultra-short baseline acoustic navigation (USBL), which enables us to locate the front of the streamer behind the vessel in terms of azimuth and depth. Typical operation parameters are 3000 m water depth and about 6000 m length of towing cable while the streamer is towed about 100 m above the seafloor. A deep towed SideScan sonar system can be deployed simulataneously to allow back-scatter imagery of the seafloor (identifying chemoherms, fluid seeps and faults for instance).

With this receiver configuration high resolution images of gas hydrate and carbonate related structures could be investigated with resolutions not available by conventional techniques. As an example observations of the Max and Moritz chemoherms are displayed in Figure 4.

Chemoherms are carbonate precipitations that occur when Methane enriched fluids are expelled at the seafloor. With conventional seismic methods sediment layers beyond such structures cannot be resolved in detail, as seismic energy is scattered and the layers below appear as "blanking" zone. With the deep towed streamer reflecting energy could be recorded from below the structure resolving small-scaled ruptures in the sediment layers, which are continued from the sides. Such small-scale faults probably serve as feeder channel for the upward migrating fluids - this image represents the first time such conduits have been convincingly imaged beneath a chemoherm field. If such faults reach as deep as the base of the hydrate stability zone they may allow free gas from depth to pass through the hydrate stability zone, without forming gas hydrates in their vicinity. If the upward migrating fluids are heated they may cause gas hydrates deposited to the sides of the faults to dissociate again and release their methane content to the seafloor as well. The dissociation of the cementing hydrate may lead to a major destabilization of the margin as discussed above, which in turn could lead to slumping of a slope. Such high resolution imaging thus has important applications in future studies of slope stability and hazard assessment. Furthermore, the enhanced resolution of such a system also allows the BSR itself to be mapped out more thoroughly, meaning that the nature of the interface between the hydrate stability zone and underlying free gas can be constrained better.

Modern processing techniques such as prestack Kirchhoff depth migration are also necessary to make use of the close receiver spacing and compute images of the subsurface from such recordings (Figures 3 and 4). Details of the display benefit from the increased resolution due to the receiver location at or near the seafloor and the overlapped range of far offset observation along the profile (Figure 3). Using the entire wavefield information (P-wave, vertical and shear component) not only velocity-depth distributions could be achieved. Computing density, bulk and shear modulus allow to estimate further physical parameters. Computation of porosity enables to estimate the content of hydrates and free gas within the observed column of sediments, as well as the role of hydrates in cementing together the sediment.

These examples demonstrate that we now have the tools for detailed analysis of hydrate bearing sediments. Future work will include the better determination of the amount of hydrate and its distribution within the sediment (i.e. cementing or not), contributing to our understanding of these deposits and their relevance.

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Dirk Klaeschen, Matthias Zillmer and Jörg Bialas

3.14 Seafloor Hydrothermal Systems

Circulation of seawater through the oceanic crust is the principal process responsible for the formation of submarine hydrothermal systems. Seawater, which deeply penetrates into the oceanic crust at seafloor spreading centers, is modified to a hydrothermal fluid with low pH, low Eh, and high temperatures during water-rock interaction above a magmatic heat source. This hydrothermal fluid is then capable of leaching and transporting metals and other elements, which eventually precipitate as massive sulfides at and below the seafloor.

Today, more than 200 sites of hydrothermal activity and seafloor mineralization are known on the ocean floor (Fig. 1). About 100 of these are sites of high-temperature venting and related mineral deposits. They occur on fast-, intermediate-, and slow-spreading mid-ocean ridges, on axial volcanoes and off-axis seamounts, on sediment-covered ridges, in subduction-related island arc and back-arc environments, and along rifted continental margins, at water depths ranging from >4,000 m to <100 m. Different types of hydrothermal systems are hosted by different rocks including mafic to ultramafic as well as felsic volcanic rocks and sediments.

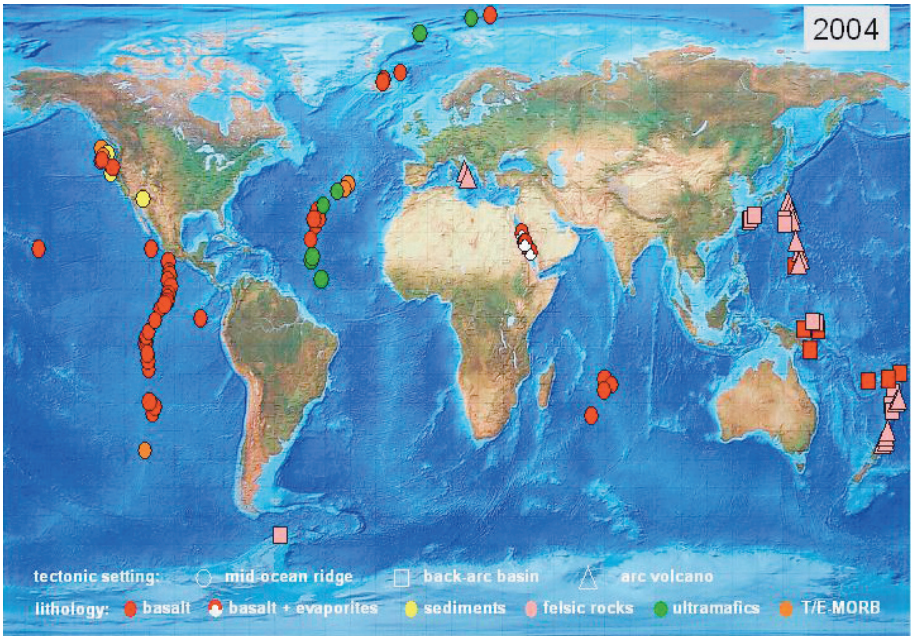

Figure 1: Map of worldwide distribution of seafloor hydrothermal systems.

Studying these modern seafloor hydrothermal systems provides important insights into the formation and development of seafloor vent sites, which in turn have a global impact on the chemical composition of seawater and the alteration of the oceanic crust. The physico-chemical properties of the hydrothermal fluids, the alteration, the sulfide textures as well as the structure and the geological setting of the deposits can be studied in these natural laboratories.

Our understanding of the hydrothermal systems forming at the seafloor, however, has been limited over the past 20 years by the fact that, until recently, only two dimensions of the hydrothermal sites have generally been accessible. Neither the subseafloor extent nor the temporal evolution of the deposits have been explored in detail. The recently set-up hydrothermal research working group at IFM-GEOMAR is aiming at documenting the variability of seafloor hydrothermal systems as well as at determining their extent, character of the subsurface, evolution through time, and evaluating the impact of the released metals on the marine environment.

Exploring the third dimension of active seafloor hydrothermal systems is necessary to fully understand these hydrothermal systems. The Ocean Drilling Program (ODP) and its successor the Integrated Ocean Drilling Program (IODP) provide one possible framework to perform these investigations. A recent ODP drilling leg was conducted at the felsic-hosted PACMANUS hydrothermal site near the crest of Pual Ridge in the eastern Manus back-arc basin (Papua New Guinea). It provided samples, which allowed us to determine the complex and multi-stage alteration history of the rocks beneath this hydrothermal site. Our data show how the physical and chemical variables in the hydrothermal fluids controlled the alteration mineral paragenesis, and how water-rock reactions affected the chemical and isotopic exchange between felsic rocks and hydrothermal fluids. A surprising picture emerged. Using the mineralogy and composition of the alteration minerals it was possible to reconstruct both the composition of the fluids, which altered the rock (especially the relative proportions of hot hydrothermal fluid and seawater) and also the temperature of alteration. Instead of the expected steady decrease in fluid temperature and increase in seawater proportion in the fluid as the seabed is approached, we found the situation shown in Figure 2. There is a clear temperature maximum just below the seafloor, probably reflecting the importance of a capping seal of either fresh lavas or alteration products in containing the hottest, most buoyant fluids.

Drilling at hydrothermal sites is technologically challenging because of the friable nature of the host rocks, their altered derivatives and the massive sulfides. Drilling from a surface ship during, for instance, ODP drilling does often not

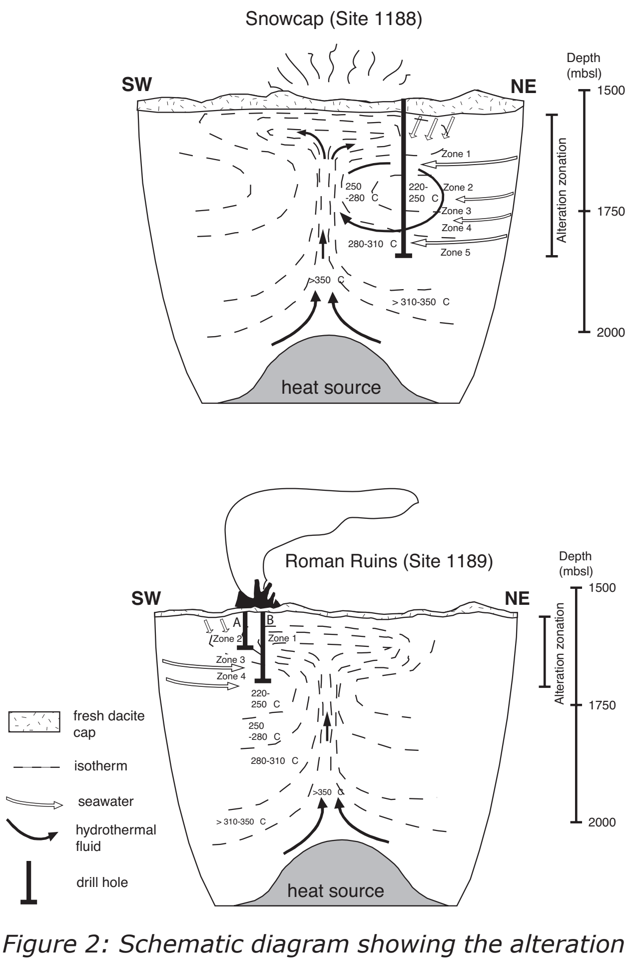

Figure 2: Schematic diagram showing the alteration zones underneath two active hydrothermal sites in the Eastern Manus Basin (Papua New Guinea).

Figure 3: The British Geological Survey Rockdrill onboard RV Sonne.

allow the controlled drilling and good core recovery necessary in these environments. A far better alternative is to place the drill rig on the seafloor using a portable drilling device such as the British Geological Survey "Rockdrill", a system capable of drilling up to 5 m holes into the seafloor (Fig. 3). This system was successfully deployed in 2002 from the German Research Vessel SONNE to conduct shallow drilling operations at the PACMANUS site. Drilling with the "Rockdrill" recovered the massive sulfide-rich sections just below the seafloor, which were not accessible by ODP drilling technology, and revealed high base- and precious metal contents at depth, similar to those in massive sulfide chimneys previously collected from the surface (Fig. 4). The shallow drilling revealed a wealth of mineralogical features which imply that seawater penetration, reworking of primary sulfide material and possibly multi-staged hydrothermal activity are important processes during the evolution of the deposit, allowing us to greatly refine our models of ore-deposit formation in the deep sea.

A completely different hydrothermal system occurs in the fore-arc region of the New Ireland arc (Papua New Guinea). Here, magmatic

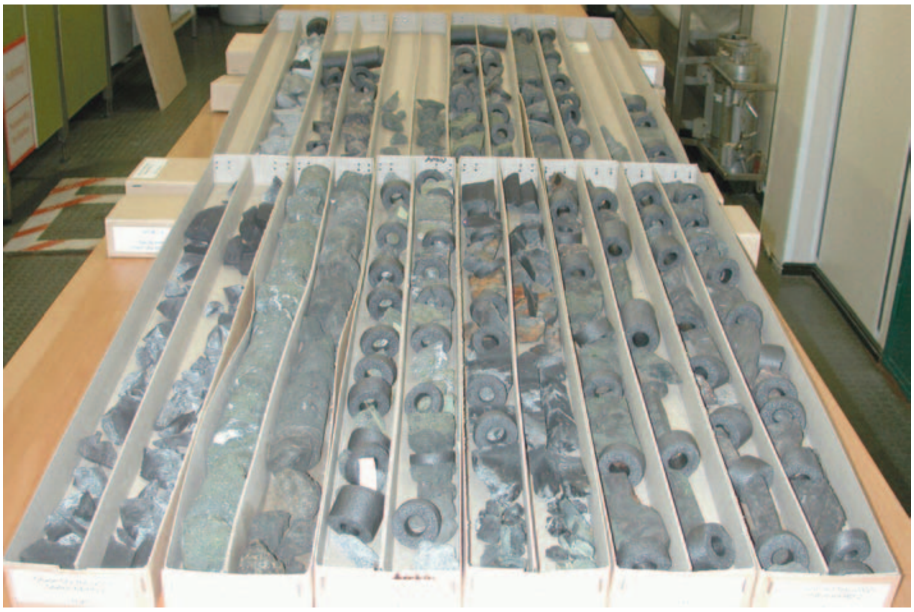

Figure 4: Massive sulfide cores drilled at the PACMANUS Hydrothermal field (Papua New Guinea).

rather than hydrothermal fluids are responsible for the development of a vein-style, gold-rich mineralization at the summit of a 600 m high submarine volcano (Conical Seamount). Drilling the upper 5 meters of this unusual system, albeit recovering only a limited amount of mineralized samples, provided evidence for a more widespread occurrence of altered and mineralized material in the subsurface. The extension of the mineralized area and the recovery of altered material below a carapace of less-altered volcanic rocks indicate the possibility of a larger gold-mineralized hydrothermal system at depth. Based on these results an application for deep drilling with the Integrated Ocean Drilling Program (IODP) has been put forward.

Plate growth at slow- and ultra-slow spreading centers, which account for 20 – 40% of the total length of the global mid-ocean ridges, appears to involve the exposure of significant amounts of mantle (ultramafic) rocks on the seafloor. So far, only four out of more than 200 known submarine hydrothermal sites are hosted by ultramafic rocks, and our understanding of these sites is limited. During the recent *R/V METEOR* cruise M60/3 the ultramafic-hosted Logatchev site on the Mid-Atlantic Ridge was investigated in detail using the remotely operated vehicle QUEST. Geological mapping and sampling of this field revealed that about 25% mafic rocks and 75% ultramafic rocks are present at the seafloor in this region. Visual observation and structural interpretation imply that the area surrounding the hydrothermal field is covered by ultramafic debris flows originating higher up on the rift valley walls. The geochemistry of the hydrothermal fluids and the massive sulfides suggest reactions between ultramafic and mafic rocks underneath the Logatchev hydrothermal field.

Outlook

The temporal evolution of seafloor hydrothermal systems and its effects on the hydrosphere can only be studied through long-term monitoring. For this purpose IFM-GEOMAR is planning to actively participate in the NEPTUNE program, a multi-year, multi-million dollar effort to study plate-scale hydrothermal processes along the Juan de Fuca Ridge using instrumentation linked to a fiber-optic cable network. Future studies in the framework of SPP1144 will include drilling of the Logatchev hydrothermal field using the lander-type Rockdrill II of the British Geological Survey and exploring and investigating new hydrothermal sites in the southern Atlantic, south of the Romanche Fracture Zone (see chapter SPP1144). Access to new underwater technology such as remotely operated vehicles (ROV's) and autonomous underwater vehicles (AUV's) will be necessary to conduct our future work on hydrothermal systems.

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Thomas Kuhn, Klas Lackschewitz, and Sven Petersen

4. Contributions to Long-Term Research Programs

4.1 SFB 460: Variability of Deep Water Formation and Circulation in the Subpolar North Atlantic

The formation of deep water in the subpolar North Atlantic comprises a suite of phenomena of prime importance for climate (Figure 1). The conversion of the temperate, northward flowing upper-layer waters of the Gulf Stream and its extension, the North Atlantic Current, to the cold waters flowing southward between 1000 and 4000m depth, is one of the key controls of the large-scale oceanic overturning circulation. In the North Atlantic it is responsible for carrying heat far into the Nordic Seas, and, through the ensuing, deep reaching mixing of these waters in winter, for a sequestering of a significant share of the atmospheric load of anthropogenic trace gases like CO_2 and CFCs.

The atmospheric conditions over the subpolar North Atlantic have undergone strong fluctuations over the past 30-40 years, as reflected by the North Atlantic Oscillation (NAO).

The manifestation of this variability in the hydrographic conditions and currents of the North Atlantic involves a number of important questions: What is the impact of the changes in atmospheric forcing (i.e. wind, surface heat and freshwater flux) on the deep water renewal? What is the impact on the large-scale circulation? What is the role of deep water formation variability in the oceanic sequestration of anthropogenic CO_2? What is the relative importance of the different sources of North Atlantic Deep Water (NADW), and what are the critical processes determining their response to changing atmospheric conditions? An improved, quantitative understanding of these issues is a prerequiste for a reliable prediction of the fate of the North Atlantic circulation system in a changing climate, and it is needed as a foundation for the establishment of a cost-effective, "early warning" system suitable for detecting and interpreting signatures of anthropogenic climate change.

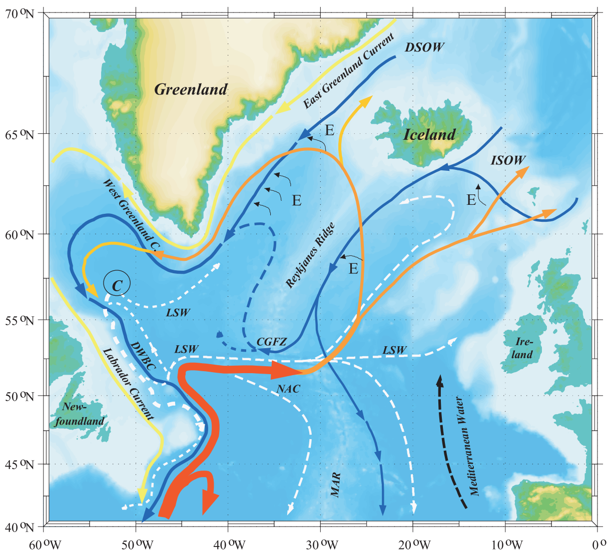

Figure 1: Schematic of the main elements of the near-surface and deep circulation in the subpolar North Atlantic. E: Entrainment, C: Convection, CGFZ: Charlie Gibbs Fracture Zone, MAR: Mid-Atlantic Ridge, DWBC: Deep Western Boundary Current, NAC: North Atlantic Current, LSW: Labrador Sea Water, ISOW: Iceland Scotland Overflow Water, DSOW: Denmark Strait Overflow Water.

A major venue for that research is the SFB 460 "Dynamics of thermohaline circulation variability". Beyond active collaboration between the observational and modelling groups of FB1, it also provides an important framework for interaction with biogeochemical groups of FB2, and with paleoceanographic studies related to large-scale circulation variability. The SFB work in the subpolar North Atlantic is complemented by a host of projects, supported by EU and other sources, which for example include new technological developments such as multidisciplinary time series stations, or real-time telemetry of moored instruments.

Deep Convection in the Labrador Sea

The principal means of ventilating the deep North Atlantic are i) the overflow and descent from the sills of the Denmark Strait (DSOW in Figure 1) and the Faroer-Shetland channel (ISOW in Figure 1) of cold, dense waters from the Nordic Seas, and ii) the deep vertical mixing of surface waters during episodes of extreme winter cooling in the Labrador Sea (C in figure 1). The various source waters, through miscellaneous small-scale mixing processes, are entrained into the deep reaching and narrow boundary currents characterizing the northern and western portions of the cyclonic circulation system between the Greenland-Iceland-Scot-

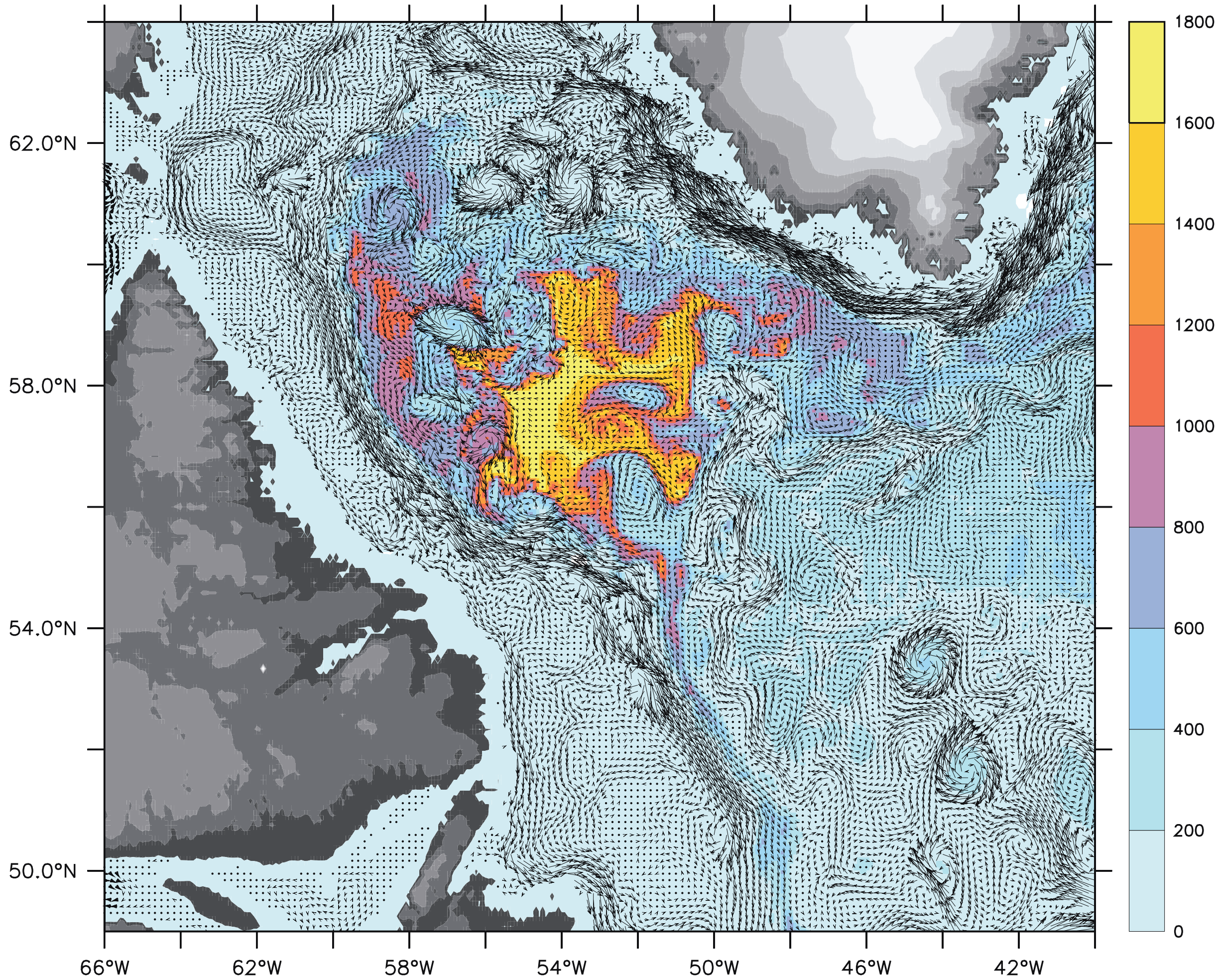

Figure 2: Near-surface circulation, and depth of the surface mixed layer (colored) in a snapshot representing a late winter situation, from a high resolution model simulation (horizontal grid size of about 5 km): the area of deepest convection (yellow) is confined to the western Labrador Sea, between 56 and 58 N, due to the invasion of buoyant surface waters by eddies spawned from the West Greenland Current.

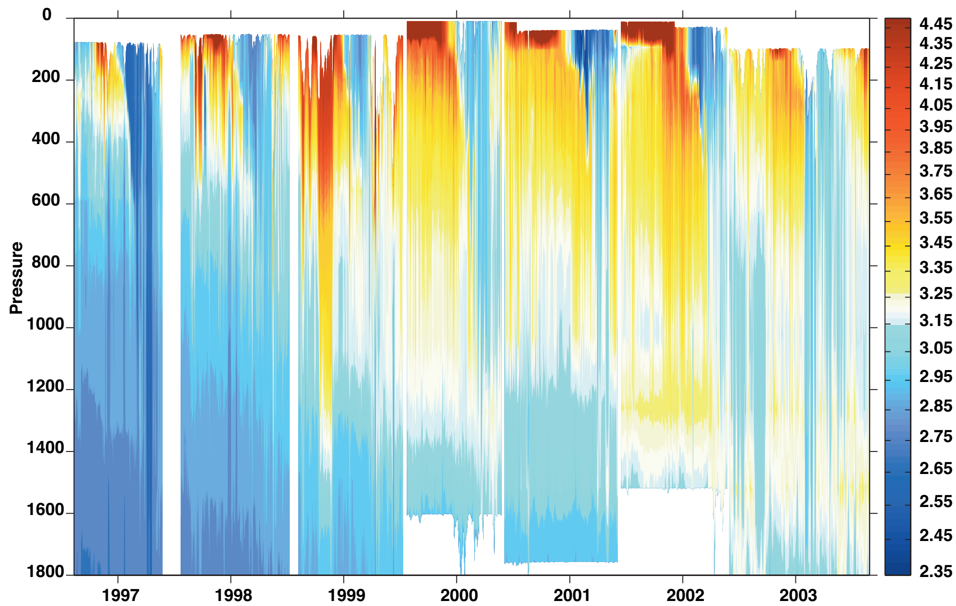

Figure 3: Observed temperature changes 1997-2003 in the centre of the Labrador Sea showing a warming tendency in most depths.

land ridge and the Grand Banks of Newfoundland known as "subpolar gyre"; the end products, affected by recirculation and mixing in the subpolar basins, eventually comprise the North Atlantic Deep Water exported southward with the western boundary current in 1000 to 4000 m depth (DWBC in figure 1).

The area where strong cooling events in late winter can reduce the stability of the water column sufficiently for deep convection to occur, is confined to the interior of the Labrador Sea (Figure 2), away from the boundary currents carrying remnants of relatively buoyant waters brought northward by the Gulf Stream and its extensions, the North Atlantic Current and Irminger Current. From the history of hydrographic observations it has long been evident that the deep wintertime mixing ("convection") in the Labrador Sea has experienced strong changes over the last decades: vigorous convection episodes, exceeding depths of 2000 m, during the 1970s and between 1989 and 1994, built up thick layers of a cold and dense Labrador Sea Water (LSW) in the subpolar North Atlantic; subsequent years with weak convection led to an erosion of the LSW layer, accompanied by a warming of the mid-depth ocean (Figure 3). While the variations in LSW thickness are reflected in the inventories of the CFCs in the subpolar North Atlantic, recent SFB measurements suggest a rather differing behavior of the uptake history of anthropogenic CO_2.

While the leading factor governing the convection intensity is the surface heat loss in winter, determined by the strength of the westerly winds, and thus, the large-scale atmospheric conditions as represented by the North Atlantic Oscillation (NAO) index, the "preconditioning" of the central Labrador Sea for deep convection, is affected by the intrusion of low-salinity waters of Arctic origin from the continental shelf off western Greenland. As suggested by recent satellite and in-situ observations, and simulations with high resolution models, the key mechanism for this lateral exchange are mesoscale eddies spawned from a localized instability area in the West Greenland Current: a realistic representation of such processes and their long-term evolution along with the strength of the boundary current system and its different source waters poses major challenges for climate modelling.

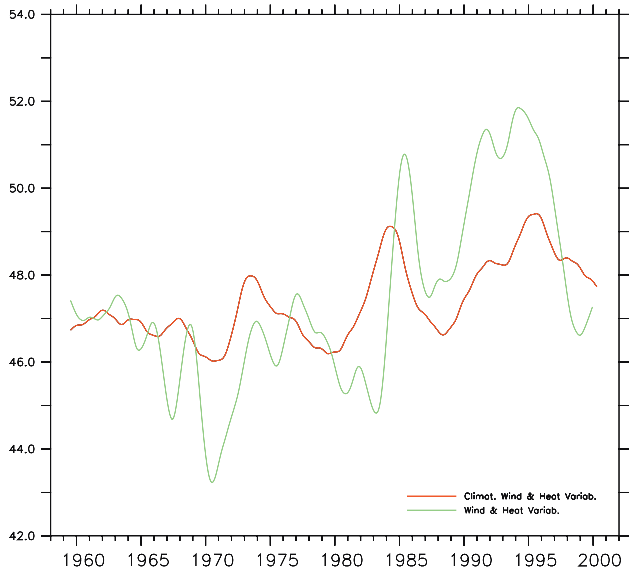

Figure 4: Strength of the subpolar gyre circulation, as manifested in the southward mass transport (in Sv, 1 Sv = 10^6 m^3/s) of the western boundary current along the Labrador continental shelf at 53 N, for model simulations driven by interannually varying heat fluxes and wind stresses (in green), and interannually varying heat fluxes, but climatological (repeated mean annual cycle) wind stresses (in red).

Variability in the Subpolar Gyre Circulation

While the variability in the convection intensity is readily apparent in the deep water's hydrographic properties (temperature, salinity), understanding its role in the dynamics of the North Atlantic current system has advanced much more slowly, owing to the scarcity of long-term measurements of mass transports, and the prominence of short-term fluctuations due to mesoscale eddies (which correspond to low and high pressure systems in the atmosphere but have longer temporal and smaller spatial scales) in many areas of the basin. Recent analyses involving satellite data on sea surface height changes, drifting buoys, and some multi-year records of boundary current transports, have been indicative of a significant decline in the cyclonic circulation of the subpolar gyre during the latter half of the 1990s. The interpretation of these findings is aided by model studies, by allowing a longer-term and basin-scale perspective, and by providing insight into possible dynamical mechanisms. Ocean circulation models driven by the available records (i.e., the products of reanalysis efforts) of atmospheric fluxes simulate a decadal variation in the strength of the subpolar gyre broadly consistent with the observational picture (and the gross trend in the NAO): i.e., an increase from a minimum transport in the early 1970s to a peak in 1994, followed by strong decline in the latter half of the 1990s (Figure 4). Variability in the surface heat fluxes is responsible for a corresponding, strong variability in the Labrador Sea convection intensity, whereas variability in the wind stresses directly effects the horizontal circulation. The superposition of these two dynamical mechanisms lead to complex temporal and spatial response patterns in the ocean, and prevents a simple correspondence between ocean transports, the deep water renewal, and the large-scale state of the atmosphere (NAO).

Towards an Ocean Climate Observing System

Despite the strong, decadal changes in the intensity of convective deep water formation in the Labrador Sea, variations in the net southward transport of deep water in the North Atlantic Ocean so far do not exceed 1-2 Sv, i.e., about 10% of its long-term mean value, without a clear trend. Model studies suggest that the large-scale, "meridional overturning" circulation is more strongly determined by the dense overflows from the Nordic Seas than by convection intensity. While the previous, long-held view was that of a relatively constant outflow rate of dense water, a recently obtained time series of transports from a multi-year SFB-array of bottom mounted instruments across the Denmark Strait, have for the first time given indications of interannual changes in this important control parameter. It has been proposed that the overturning circulation will eventually slow down due to anthropogenic climate change. Irrespective of the dynamical causes of possible future changes, devising an ocean observing system able to detect transport signals of a few Sverdrups magnitude in ocean current fields dominated by a broad spectrum of variability, is one of the "grand challenges" of physical oceanography. Meeting this task clearly involves the combination, through numerical models, of satellite observations of sea surface properties, of autonomous, freely drifting and profiling buoy systems for the deep ocean, and moored arrays for current measurements in "choke points" of the circulation.

High resolution modeling studies have begun to give first important hints on the viability of local measurement sites, particularly with respect to how representative for the large-scale circulation they are, and the signal-to-noise ratios to be expected. As illustrated by Figure 2, one of the few areas along the western boundary of the mid- and high-latitude North Atlantic not governed by intense mesoscale eddy fields, is the boundary current off the Labrador continental shelf; in addition, the model studies suggest this to be a rather exceptional site in that the variability in the boundary current transport is closely representative of the total transport of the subpolar gyre.

Claus Böning, Friedrich Schott and Jürgen Willebrand

4.2 SFB 574: Volatiles and Fluids in Subduction Zones: Climate Feedback and Trigger Mechanisms for Natural Disasters

Introduction

The Collaborative Research Program SFB 574 investigates the role of fluid and volatile recycling in subduction zones along the Central American convergent margin (Guatemala to Panama) through integrated geophysical, geological, geochemical, petrological and oceanographic studies performed by 12 focussed projects. During phase I (2001-2004), we have concentrated on a segment of the subduction zone system onshore and offshore Costa Rica and Nicaragua along which the angle of subduction, the nature of the incoming plate, and magmatic compositions along the volcanic arc were known to change significantly. Data collected during a total 4 months of shiptime on RV SONNE and 3 months on RV METEOR, during 15 man-months of fieldwork in Costa Rica and Nicaragua and modelling studies over the past 2.5 years have greatly expanded and deepened our understanding of fluid migration in and out of subduction zones and of the trigger mechanisms and probability of occurrence of natural disasters. In Phase II (2004-2008) we will finish work off Central America, and start working in an accretionary segment of the Chile margin.

Input into the Subduction System

Four segments (Figure 1) of the subducting Cocos plate were defined which formed partly at the East Pacific Rise and have normal ocean crust composition, and partly at the Cocos-Nazca spreading center, where crust composition was variably modified by the Galapagos hotspot volcanism. The distinct physical and chemical characteristics of these segments strongly influence both the structure of the forearc and the output at the arc.

The Central American margin is erosive, meaning that material from the overriding plate is removed at the plate boundary by the subducting plate as opposed to accretionary margins where sediments from the oceanic plate accrete at the continental slope. The oversteepening of the continental slope - a result of basal subduction erosion - has everywhere led to the destabilization of the continental slope and the development of slides and slumps. However, the rate of subduction erosion and the magnitude of slumping appear to reflect variations in the structure and composition of the incoming plate. For instance, the orientation of the inherited oceanic fabric controls the bending of the subducting plate and hence its dip angle (steeper off Nicaragua than off Costa Rica). Subduction of seamounts at Costa Rica both focusses seismicity and accelerates disruption of the overriding margin, thereby amplifying subduction erosion. The subduction of the Cocos Ridge has caused uplift of the margin and extinction of the volcanic arc.

Water within the oceanic plate is perhaps the most important component entering the subduction zone. Water is the transport medium for other fluid-mobile elements and it controls the strength of the plate boundary thus controlling the location of the seismogenic zone. As the sediment compacts under increasing pressure and loses porosity and as dehydration reactions release chemically bound water, the expelled fluids provide the means for the basal erosion of the overriding plate through hydrofracturing. Some of these fluids then travel to depth with the debris, some pass through the disrupted margin wedge through high-permeability conduits created by tectonic activity, partially remobilising the slope sediments, and reach the seafloor of the fore-arc region to be expelled into the ocean at numerous vent locations. The type of venting structure appears controlled by the input to the trench: in segments 1 and 2, the main venting structures are the large scars caused by the subduction of seamounts on the Cocos plate, although small mud mounds also actively vent (Fig. 2); in segments 3 and 4 where seamounts are fewer and/or smaller, large mud diapirs dominate (Figure 1).

Water enters the subduction system in several ways: (1) water is incorporated into the volcanic upper oceanic crust (including the seamounts) near the spreading center and (2) water pervades the sedimentary cover of the oceanic plate. A major new result of the SFB is the possibility that (3) a large fraction of the water input into the subduction zone occurs through the hydration of the igneous crust and mantle of the incoming plate through the permeable volcanic ridges and seamounts, and (4) along new faults formed as the plate

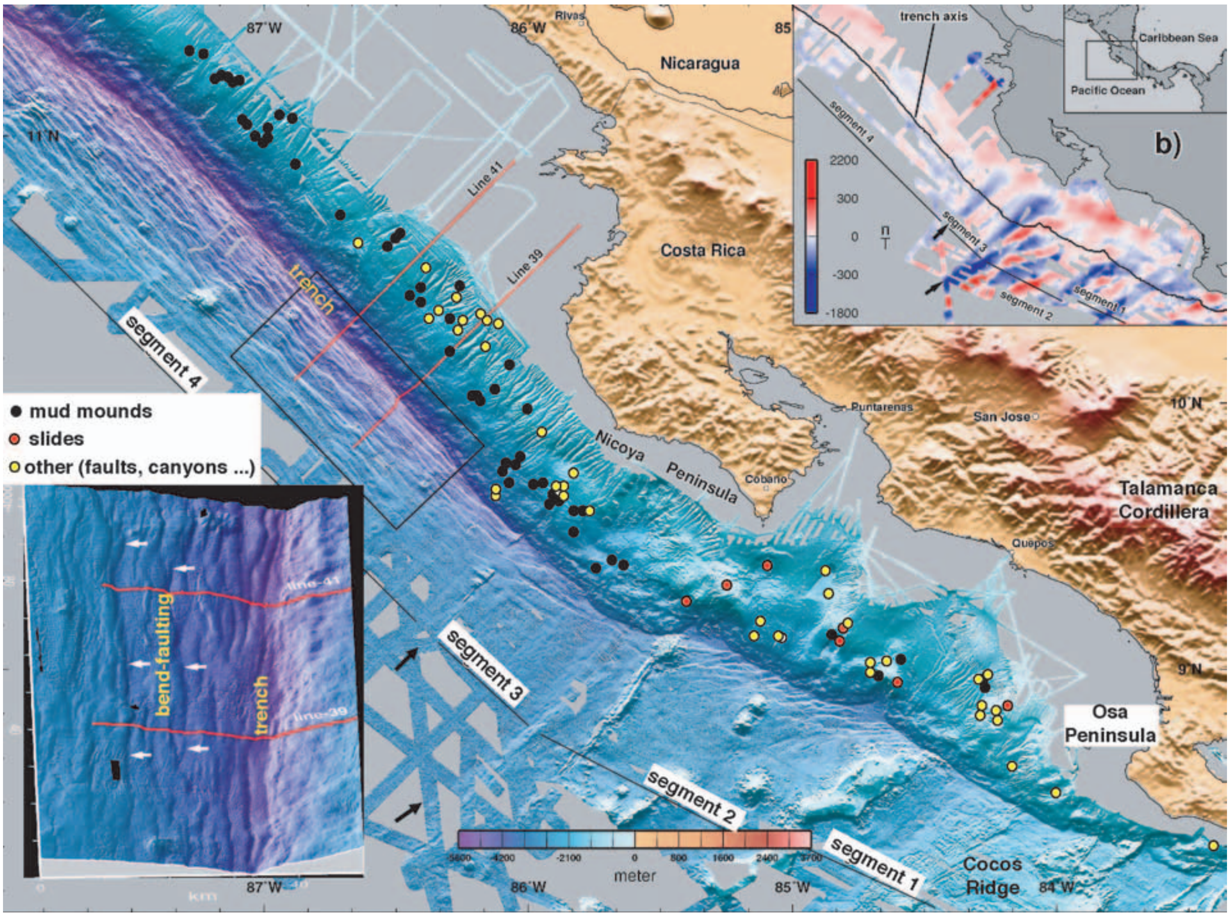

Figure 1: Bathymetric map offshore Costa Rica / Nicaragua, showing how the four segments of oceanic lithosphere entering the subduction zone influence the structure of the margin. Segment 1 is dominated by the Cocos Ridge, leading to the shallowest trench, relatively low-angle subduction, and the uplift of the Osa peninsula and the Cordillera de Talamanca. Segment 2 comprises crust formed under the influence of the Galapagos hotspot, and studded with numerous large seamounts and ridges. The subduction of such seamounts leads to the strong mechanical disruption of the continental margin and accelerated subduction erosion. Segment 3 comprises relatively smooth crust formed at the Cocos-Nazca spreading center away from the hotspot: the oceanic crustal fabric (shown by the magnetic anomalies in the inset top right) here trends at a high angle to the margin, and thus is not susceptible to reactivation at the outer rise. Segment 4 comprises crust formed at high spreading rates at the East Pacific Rise with a fabric approximately parallel to the trench and hence easily reactivated as the plate bends when approaching the trench. This has led to the development of deep faults (see inset bottom left) that probably allow the influx of water to depth and the consequent hydration of the oceanic crust and mantle. The segmentation of the incoming plate also appears to control the main type of forearc dewatering: slides (red dots) are most important where seamounts are being subducted (segment 2); elsewhere mounds (black dots) and other venting locations (yellow dots) dominate.

bends on approaching the trench (Figure 1). Both these processes have major implications for the volatile budget at convergent margins. Water bound within hydrated crustal minerals and perhaps particularly within hydrated (serpentinised) upper mantle is first released at depths > 100 km and temperatures > 500°C, providing an ideal source for the water-induced melting of the mantle wedge beneath the volcanic arc.

Fluids recovered above one of the more active mounds along the margin (the surface expression of mud diapirs and/or mud volcanoes) have an isotopic signature consistent with an origin through clay dehydration at a temperature of 105±20°C. As this corresponds to the temperature at the plate boundary beneath the mound (from heat flow measurements), it is likely that the fluids come from the plate boundary: subducted-plate fragments are found in mound sediments. Bright reflections there may indicate high fluid pressures resulting from such dehydration: the downdip disappearance of the reflective zone appears to correlate with the onset of seismicity. This is thus

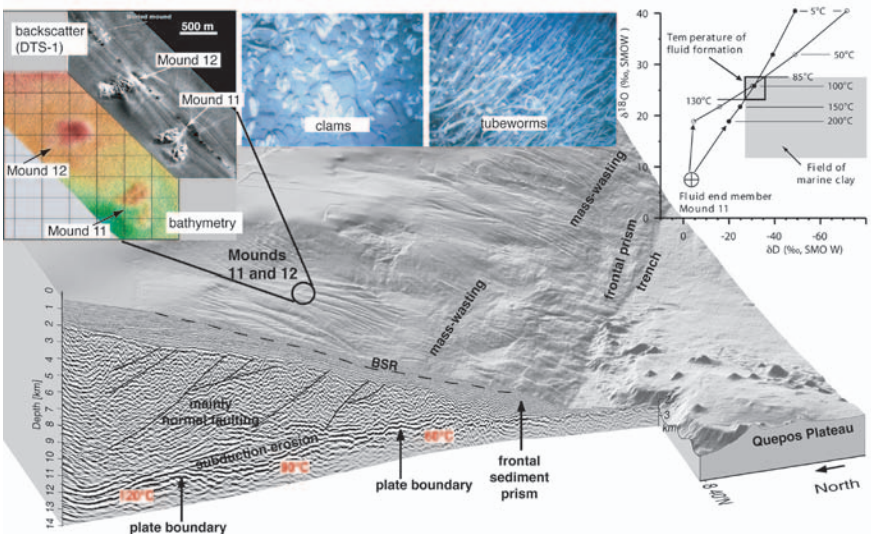

Figure 2: Investigating the relationship between margin structure and fluid outflow at a variety of scales. Large-scale margin structure is revealed by swath-bathymetry and seismic profiling (main figure). The latter reveals the geometry of the plate boundary; temperatures here are estimated from the depth to the BSR (= base of hydrate stability field). The swath-bathymetry reveals a number of small mounds on the margin slope: closer investigation of these with first side-scan sonar (inset top left) and subsequently video images (top center), allow selection of sites for fluid sampling. The $\delta^{18}O$ of expelled fluids here can be compared with the theoretical values expected for marine clay, intersecting at a temperature of 85-123°C (top right). This is similar to the temperature predicted at the plate boundary from the depth to the base of the hydrate stability field, the BSR. A plate boundary origin for the fluids expelled is support by other aspects of their chemistry.

evidence for a link between dehydration, fluid venting and the updip limit of the seismogenic zone. Seismic images show that the forearc region is cut by normal fault reaching close to the plate boundary: these probably provide the fluid conduits through the basement of the margin wedge (Figure 2).

Output through the Volcanic Arc

One of the goals of the SFB is tracking the amount and chemistry of volatile output across the entire subduction system, including the volatile fluxes along the Central American Volcanic Arc (CAVA). Three approaches were used: (1) analysis of volatile contents in primitive arc magmas as a measure of volatile transfer from the mantle wedge to the arc volcanoes, (2) analysis of volatile emission during highly explosive eruptions of arc magmas representing sporadic massive volatile inputs into the stratosphere, and (3) measurement of gas flux and composition at permanently degassing volcanoes as a continuous input into the troposphere.

The composition of the incoming plate shows a broad change from Nicaragua, where it is dominated by EPR-generated crust and marine sediments (~425 m of carbonate overlain by hemipelagic sediments) to central and southern Costa Rica, where the composition of the subducting slab and erosive input have been heavily influenced by the Galapagos hotspot (Figure 1). The variable input correlates both temporally and spatially with the output at the volcanic arc (Figure 3). Chemical tracers of subducted marine sediments are highest in Nicaragua and decrease systematically toward central Costa Rica. On the other hand, tracers of subducted basalt - composing the crust of the downgoing slab but also contained in input eroded from the continental slope - are highest in central Costa Rica (Figure 3), where basalts from both sources have Galapagos hotspot-type signatures. Nicaraguan magmas can be derived from a depleted, normal mid-ocean-ridge-basalt-type mantle wedge to which hydrous fluids with a marine-sediment-dominated signature from the subducting slab had been added. The central Costa Rican magmas, on the other hand, could be derived from a mantle wedge mixed with hydrous and carbonate-rich silicate melts from the basaltic input. The eroded input appears to play a significant role in determining the composition of the volcanic output because variations in the Pb and Nd isotopic composition of the erupted volcanic rocks in Costa Rica correlate in part with changes in the composition of the forearc sediments and thus erosive input.

Geological Hazards at Subduction Zones

Finally a major theme of SFB 574 is geohazards. In particular, earthquakes, volcanic activity, slope failure and tsunamis cause subduction-related geo-hazards. The most abundant and strongest earthquakes originate in the seismogenic zone above the downgoing plate (Figure 2). Several field campaigns using onshore and offshore seismic networks have recorded some 20,000 seismic events that are used to characterize the location, shape and

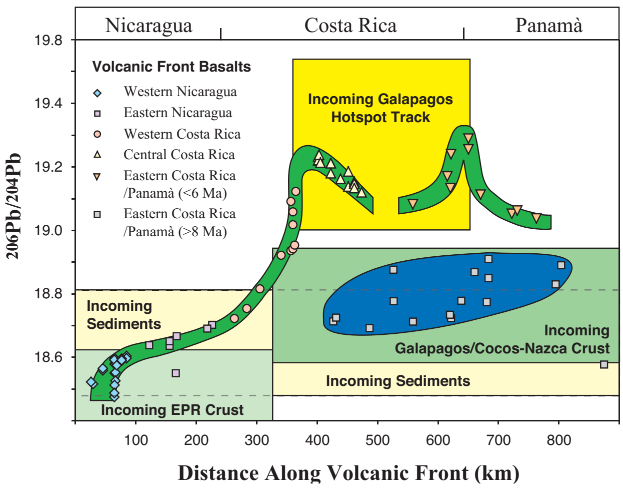

Figure 3: Variation of $^{206}Pb/^{204}Pb$ isotope ratios along the volcanic front (VF) from northwestern Nicaragua to western Panama. The Pb isotope data from the young, <6 Ma volcanic front (green band) displays a maximum on an extension of the subducting, morphological Galapagos hotspot track (yellow). The decrease in Pb isotope ratios towards the center of the Pb isotope maximum correlates with less radiogenic Pb in the center of the zoned hotspot track. Older VF rocks ≥7 Ma from central Costa Rica to western Panama (blue field) have less radiogenic Pb isotopic compositions because the subduction of the Galapagos hotspot track only began 5-8 Ma ago.

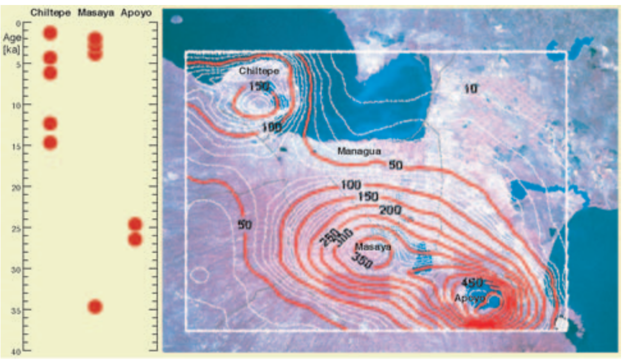

Figure 4: Contours of average expected fallout thickness (cm) from a Plinian-magnitude eruption in west-central Nicaragua (cumulative tephra thickness divided by number of eruptions at each location, regardless of vent position). Values greater than 50 cm would imply complete destruction of buildings; 10 cm is sufficient to collapse shacks in the region. Chiltepe volcano north of Managua City displays the most regular large-magnitude activity during the recent past.

physical nature of the seismogenic zone in Costa Rica, which lies at around 20 km depth below the forearc, ranges between 50 to 80 km from the trench and has some 10-25 km vertical extent. Tsunamogenic landslides on the continental slope can be triggered by earthquakes but also by an increase in slope angle produced by basal subduction erosion and associated faulting of the forearc wedge (Figure 1) as well as by deformation coupled with seamount subduction (Figure 2). Large slope failures with dimensions capable of producing a tsunami that represents a threat to coastal populations have been mapped by high-resolution bathymetry along the entire Central American research area (Figure 1). The largest slump scarps are associated with seamount subduction but many smaller scarps follow the water-depth contour marking the upper stability limit of gas hydrates in the continental slope. Gas hydrates, which temporarily stabilize the slope sediments, can lead to even more dramatic failure when they dissociate, e.g. by ascending fore-arc fluids.

Volcanic hazards include permanent volcanic degassing (fumarole gases seriously affect crops, buildings and local population health) and explosive volcanism. Roughly two million people (40% of Nicaragua's population) live in the greater Managua area, bracketed by Masaya Caldera and Chiltepe Volcanic Complex both of which erupted explosively during the past few thousand years. Hazards from such eruptions include toxic gases, heavy ash fall, pyroclastic density currents and volcanogenic tsunamis in the two large lakes. A hazard map has been compiled to identify high-risk areas (Figure 4). The common local architecture is not designed to withstand large tephra loads; the average fallout thicknesses of past eruptions would predict near-total structural failures in major parts of west-central Nicaragua during a future Plinian eruption. Areas of complete devastation by pyroclastic surges of past magnitudes extend across western and southern Managua City. Explosive eruptions from vents in or near the large lakes could generate tsunamis (as in the past) threatening lowlands along the populated lake shores up to several kilometers in-land.

IFM-GEOMAR Contributions

Hensen, C., Wallmann, K., Schmidt, M., Ranero, C.R., and Suess, E., 2004: Fluid expulsion related to mud extrusion off Costa Rica – a window to the subducting slab. *Geology*, **32**, 201-204.

Ranero, C. R., Phipps Morgan, J., McIntosh, K., and Reichert, C., 2002: Bending-related faulting and mantle serpentinization at the Middle America Trench. *Nature*, **404**, 748-752.

Tim Reston, Chair SFB 574

4.3 DFG-Priority Program 1144: From Mantle to Ocean: Transdisciplinary Studies of Spreading Axes

The huge cracks in the Earth´s surface formed when the tectonic plates move apart run, for the most part, through the ocean basins, forming a 60.000 km-long, globe-encircling volcanic system known as the mid-ocean ridges. Along these ridges magma generated deep in the Earth rises and erupts on the seafloor. The results are bizarre landscapes (strictly speaking "bathyscapes"), toxic hotsprings and an abundance of life thriving independent of sunlight all of which are constantly being remodelled by eruptions and earthquakes. An interesting and largely unknown part of our planet for sure, but how important is this volcanic activity at the bottom of the ocean (and the life it supports) for the world as a whole? What part does or did it have to play, for example, in the production of mineral deposits, in determining the composition of the oceans, in the deep sea food chain, in the origin of life? In view of the enormous length of the ridges, answering these questions will certainly require a global, coordinated international effort. Towards the end of 2003 the German part of this effort got an enormous boost in the form both of the German Research Foundation (DFG) 6-year priority program "From Mantle to Ocean: Energy-, Material- and Life Cycles at Spreading

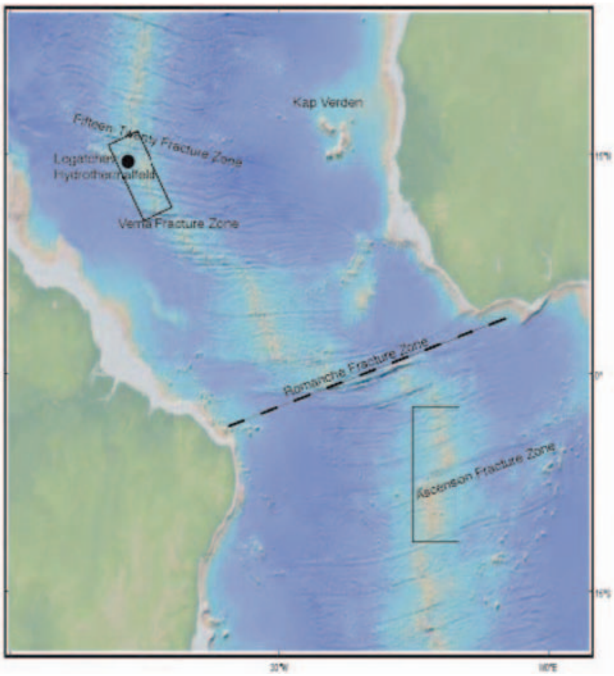

Figure 1: Locations of the two study areas for the DFG Priority Project 1144.

Figure 2: Deploying a Remotely Operated Vehicle from the „Meteor" (© MARUM).

Axes" and by taking over the leadership of the international ridge-studies coordination body InterRidge. Both of these programs are, togehter with other partners in marine sciences in Germany, run and coordinated by petrologists from Research Division 4 at the IFM-GEOMAR, making Kiel a key global center for mid-ocean ridge studies.

The aim of the DFG priority program is to carry out a multi-disciplinary study of two characteristic areas of the mid-ocean ridge system in the Atlantic, at 15°N and 4-11°S (Fig. 1). These areas were chosen because they lie north and south of the huge Romanche Fracture Zone, a 1000 km offset in the ridge which may act as a barrier to living creatures trying to move from one hot vent to the other along the ridge. Repeat visits to the two areas over at least the next 6 years will allow the scientists to gain a detailed knowledge of the volcanic systems located there, how they differ from one another, how they change over short periods of time and how they interact with the global oceanic systems.

The program has two particularly innovative features:

- The large range of disciplines of the researchers studying these areas – we are at sea with geologists, biologists, fluid chemists, oceanographers and geophysicists all at the same time. This makes for a truly transdisciplinary study of the ridge systems and also a very full ship!

- The use of a state-of-the-art remotely-operated vehicle (ROV) for precise well-located sampling and observation of the seafloor (Figure 2, 3).

The first cruise to the northern area took place in January 2004 and included scientists from Research Divisions 2, 3 and 4. The so-called Logatchev hydrothermal field was sampled and mapped in detail in order to obtain the basic information required for the long-term study. The ROV revealed a fascinating seafloor covered with active sites and showing such features as smoking craters, black smoker chimneys (Figure 4) and diffuse outflows, together with an abundance of life. The chimneys themselves and the surrounding seafloor are built of copper-rich metal sulfides (Figure 5), ores

Figure 3: Sampling of vent shrimps Rimicaris using a "slurp gun".

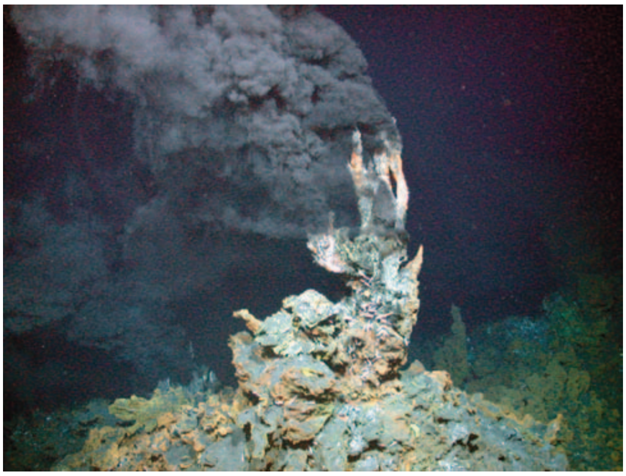

Figure 4: Black smoker vent at the Logatchev field, the northern SPP1144 area (© MARUM).

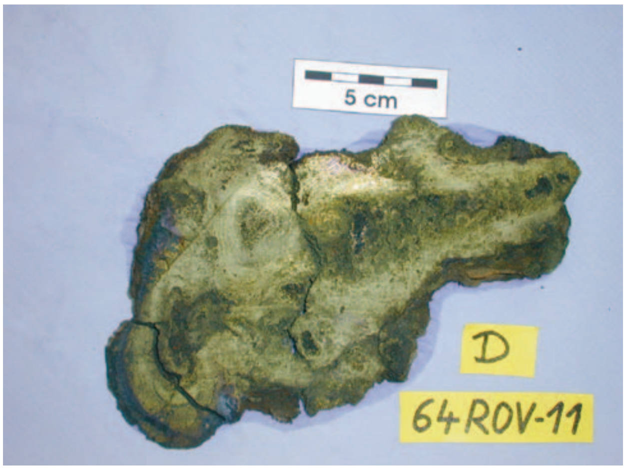

Figure 5: Section of a black smoker chimney – the concentric layers of sulphide mineralisation are clearly visible.

which in many ways are similar to those exploited commercially on land. The heat source driving this vigorous water circulation comes in part from magma deep below the seafloor, in part from alteration of the seafloor rocks by seawater.

These processes produce large quantities of sulfide, methane and hydrogen, food for free-living and symbiotic bacteria, the "grass" at the bottom of the ridge ecosystem food chain which is grazed by many larger creatures. Large differences in the composition of microbial communities at different locations in the hydrothermal vent field suggests the adaptation of microbial life to the specific physico-chemical conditions prevailing at individual vent sites. The observations made at Logatchev highlighted the importance of local parameters and the formation of steep chemical and physical gradients for the ridge ecosystems. They have led to the initiation of an ambitious mussel bank experiment, which will involve instrumenting a singe mussel bank with a whole array of equipment to look at the chemistry, the temperature and the flow-rates of the warm waters emanating from the seafloor and relating this to the biological production in the mussel field. Such detailed studies will enable us to estimate the importance of hydrothermal systems for the functioning of the whole deep-sea ecosystem.

Colin Devey

4.4 DFG-Priority Program 1162 AQUASHIFT: The Impact of Climate Variability on Aquatic Ecosystems

While prediction of future seasonal and regional temperature patterns is fairly well advanced, prediction of ecosystem responses to climate change lags far behind. Empirical evidence based on contemporaneous meteorological variability indicates that shifts in seasonal activity and growth patterns and in biogeographic distributions have taken place already.

From a single-species to a system perspective: The knowledge of single-species temperature tolerance ranges and optima have been a cornerstone of ecophysiology since decades. Similarly, there is ample evidence about climate-induced changes in geographic distribution and seasonal activity patterns. Little is known, however, about the consequences of such changes at the level of ecosystem properties and functioning. It is not known, whether species replacements and changes in interactions between species will act as buffers or as amplifiers of climate change impacts. The DFG-priority program AQUASHIFT (co-ordinated by U. Sommer, IFM-GEOMAR) is a joint effort of German marine and freshwater ecologists to fill that gap.

Match and mismatch in demand-supply relationships: In a seasonal climate, activity and growth of organisms also have seasonal patterns. Those seasonal patterns imply seasonal changes in food demand, in impact on competing species and in prey species, and in sensitivity to competition and predation by other species. There would be no reason for major concern, if all those shifts would be in parallel, e.g. if typical spring events would happen a few weeks earlier in a warming climate. However, climate change does not affect all species and seasonal patterns in the same way, Light, temperature and food dependent processes may respond differently to climate change. As a result, hitherto synchronized processes might become decoupled, leading to a mismatch between demand and supply. For example, sensitive life cycle stages with a particularly high food demand might die off, if they are shifted to low food periods (Fig. 1).

Physiological and genetic variability as well as microevolution (new genotypes or positive selection of previously rare genotypes) might act as an insurance against this mismatch. Similarly, the replacement of functionally similar species with a better adaptation to the new climate might restore the temporal match between demand and supply. However, the strength of the insurance effect is generally unknown. Moreover, the microevolutionary response of resident species and the replacement of species will take time.

Focus on the start of the season: Most regional climate models for central Europe predict, that the anticipated warming will more strongly affect the winter than the summer pe-

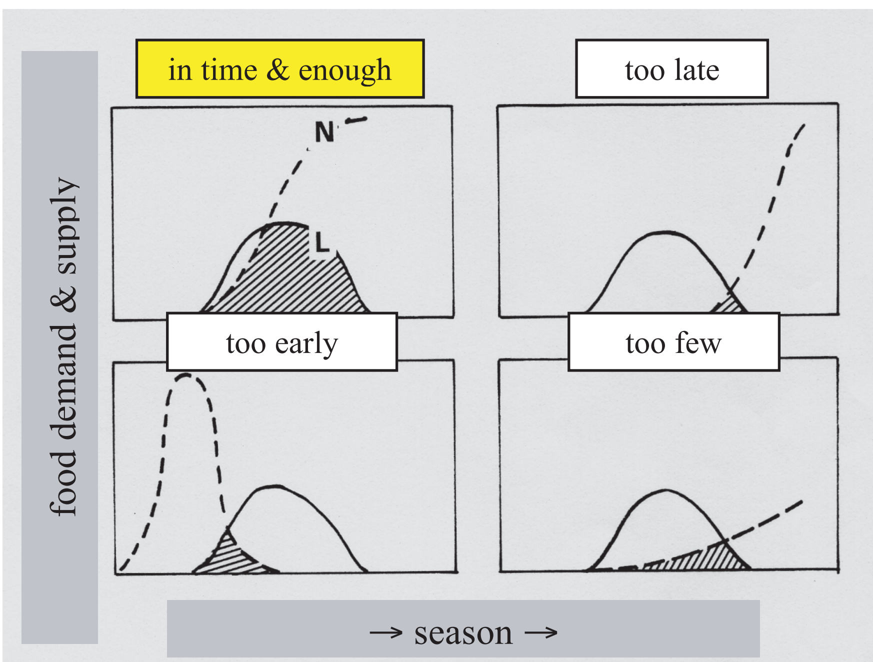

Figure 1: Illustration of the match-mismatch concept by Cushing's original hypothesis concerning the supply of copepod nauplii (N) and the demand by first-feeding fish larvae (L). Temporal mismatch between demand and supply occurs, if nauplii are too late (fish larvae will die of starvation) or if nauplii are too early (then they will develop into copepodites and will be too large when fish larvae start to feed - fish larvae will also die of starvation).

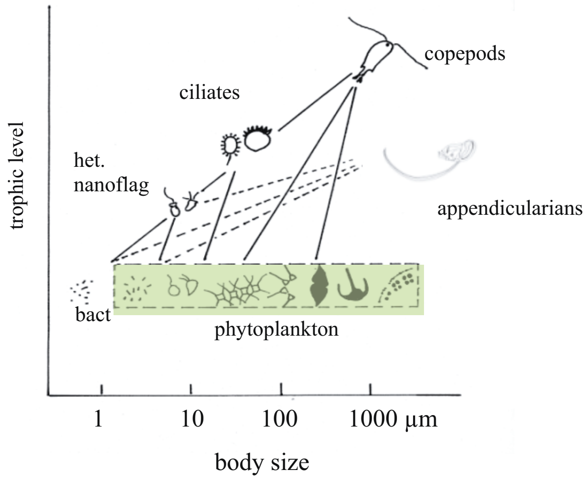

Figure 2: Schematic representation of the „lower" food web, as it will be studied in our mesocosms. Animals at higher trophic level than copepods will not be included because of limitations in experimental feasibility. We will, however, study the supply of copepod nauplii as a food for fish and fish larvae. Temporal shifts in food demand of fish larvae will be studied in a separate project at IFM-GEOMAR.

riod. For aquatic ecosystems, this means that release from cold stress during winters will become more important than increasing heat stress during summer. The primary biological response will therefore be most pronounced during the start of the growth season and at the end of the growth season. Therefore, the winter-spring transition will form the starting point for most projects, while secondary effects during summer can not be neglected.

The Kiel plankton mesocosms: The biggest cluster of projects within AQUASHIFT is located at the IFM-GEOMAR and dedicated to the experimental analysis of potential match-mismatch phenomena within the planktonic food web. We will study, how elevated winter temperatures (up to 6°C temperature elevation relative to in-situ conditions) influence the timing of germination, population growth and activity patterns during the first months of the seasonal growth cycle.

Normally, the start of the plankton growth season is characterized by the spring bloom of phytoplankton and a subsequent onset of heterotrophic (animal and bacterial) activities. Then, grazing of zooplankton on phytoplankton leads to a late spring "clear water phase", i.e. a period of low phytoplankton biomass. We anticipate, that winter warming will accelerate the onset of heterotrophic activities while there will be little change in the start of phytoplankton growth. The latter is primarily dependent on light, which is not affected by global change in the same way as temperature. Similar to the temporal de-coupling of light- and temperature dependent processes, also different heterotrophic processes might become de-coupled if they respond differently to climate change. Thus, mismatch phenomena might occur at every link of the planktonic food web (Fig. 2).

We will set up indoor experimental systems ("mesocosms") in which plankton from the Kiel Bight will be subjected to different temperature patterns: the natural pattern of sea surface temperature will form the control and winter temperatures will be increased by 2, 4,

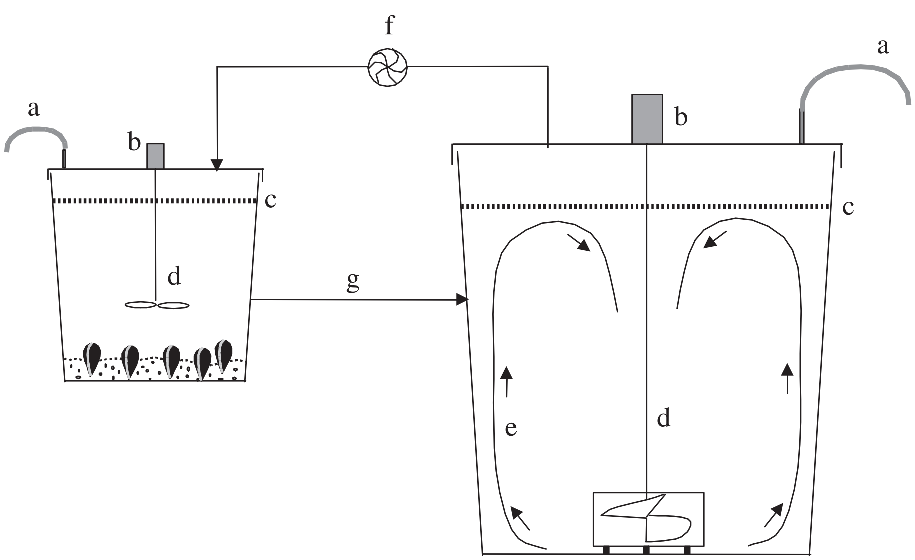

Figure 3: Scheme of the mesocosms; right: plankton chamber, left: benthos chamber
a) air supply
b) electric motor
c) water level
d) mixer
e) water circulation in the plankton chamber
f) pump for the flow between the plankton chamber and the benthos chamber
g) back-flow benthos chamber - plankton chamber

and 6°C in the different treatments. Towards spring, the temperature differences between treatments and control will be reduced. The mesocosms consist of two chambers: A plankton chamber of 1000 l and a benthos chamber of ca. 200 l. The benthos chamber is needed as a source of planktonic larvae of benthos animals (cf. blue mussel, Mytilus edulis) and of plankton organism germinating from benthic resting stages (cyts of certain phytoplankton species, resting eggs of zooplankton). Both, planktonic larvae and plankton germinating from resting stages, can have a strong imprint on the seasonal succession of plankton and have unknown sensitivities to climate change. The plankton and the benthos compartment have to be seaparated to avoid a too strong influence of mussel filtration rates on plankton population dynamics.

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Ulrich Sommer

4.5 Contributions to International Research Programs

4.5.1 The Baltic Sea Experiment - BALTEX

In 2001, BMBF launched the German Climate Research Program "DEKLIM". Within this 5-year research program, the topic "Regional process studies in the Baltic Sea area" contributed directly to the BALTEX program which is one of the continental scale experiments within the international GEWEX (Global Energy and Water Cycle Experiment), a component of the World Climate Research Programme.
The main aims of BALTEX are:

- To develop and validate models, which interactively couple atmosphere to land surfaces, rivers and the Baltic Sea during all seasons;
- To gain a better understanding in all compartments and improve the models, including data assimilation.

IFM-GEOMAR contributes to this topic with two projects:

BASEWECS – Baltic Sea Water and Energy Cycle Study (2001-2004)

The main objective of BASEWECS (BAltic SEa Water and Energy Cycle Study) is the determination of the energy and water budget of the Baltic Sea. Improved knowledge of the energy and water budgets can only be obtained from sophisticated numerical models, including data assimilation and detailed model validation. A 3-dimensional coupled sea ice-ocean model driven by observed meteorological input fields and river runoff has been used to obtain the most accurate response of the Baltic Sea which is necessary to close the energy and water budget on a high level of accuracy. Four subprojects, namely:

- Energy, water, salt and sea ice cycle of the Baltic Sea (IFM-GEOMAR);
- Energy balance of the turbulent surface mixed layer (IOW);
- Water mass exchange through the Fehmarn Belt (IFM-GEOMAR);
- Monitoring the sea level of the Baltic Sea with different techniques to validate oceanographic models (IPG TU Dresden)

have contributed to run and validate the model and to improve certain components of the coupled system. BASEWECS was coordinated by IFM-GEOMAR. IFM-GEOMAR's coupled sea ice-ocean model of the Baltic Sea contributes substantially to the DEKLIM project BALTIMOS (Development and validation of a coupled model system (atmosphere-land-ocean) in the Baltic region, MPI of Meteorology HH).

APOLAS (Accurate areal Precipitation measurements Over LAnd and Sea, 2002-2005)

APOLAS main subject is the improvement of areal precipitation estimates by the use of new developed sensors. Therefore, measurements are performed at several coastal sites (IFM-GEOMAR building in Kiel, Westermarkelsdorf on the island of Fehmarn, and Zingst on the peninsula Darß) and on the R/V Alkor using ship rain gauges and optical disdrometers. At our disposal are also Micro Rain Radar measurements (operated by the Meteorologisches Institut der Universität Hamburg), Mini Sodar measurements (operated by the Max-Planck-Institut für Meteorologie, Hamburg), Joss-Waldvogel disdrometer measurements and weather radar data (both operated by the Deutscher Wetterdienst). Principal results from APOLAS are:

- Drop size distributions measured over sea show larger drops for equal rain rates compared to distributions gathered on land due to a preponderance of convective situations over sea. Therefore the relation between radar reflectivity and rain rate, both derived from disdrometer measurements, differ for the coastal sites and the Baltic Sea.
- Under windy conditions small drops are completely missing in the drop size spectra of the widely used Joss-Waldvogel disdrometer compared to spectra obtained with the optical disdrometer.

A method has been developed to derive precipitation fields over the Baltic Sea based on ship rain gauge measurements. To extent the existing data set, ship rain gauge measurements on merchant ships, traveling between Germany and Finland, are going on. Comparisons were performed between model (BALTIMOS), synoptic observations and generated fields of precipitation based on in-situ measurements onboard of merchant ships.

4.5.2 The Climate Variability and Predictability Experiment - CLIVAR

CLIVAR (Climate Variability and Predictability) is a major project of the World Climate Research Program (WCRP) which started 1995. The objective of CLIVAR is to understand and predict climate variations on time-scales from months up to centuries and to assess the impact of anthropogenic climate change. A specific focus is on the role of the oceans for climate variability. The BMBF-funded German CLIVAR-MARIN Program has been in place since 1998, with several projects at IFM-GEOMAR which address long-term changes of the ocean circulation in the Atlantic and Indian Oceans.

The Shallow Thermohaline Cell in the tropical South Atlantic connects the subduction regions of the eastern subtropics with the equatorial upwelling zone. Its role for tropical climate variability and on the larger-scale meridional circulation is studied. The field work includes repeat deployments of moored current meter arrays near 10°S which yield multiyear records of transport and water mass variability, and by repeated ship surveys of hydrographic and current variability. In addition, profiling floats were deployed to follow the warm water pathways in western tropical Atlantic. The observational work is supported by high-resolution ocean circulation modeling efforts.

The Atlantic Meridional Overturning Circulation (MOC) plays an important role for the climate system. A variety of processes are known to lead to MOC changes on decadal and longer time scales, but direct observational evidence is lacking. A program to observe the Deep Western Boundary Current at 16°N has been initiated at IFM-GEOMAR, in order to directly determine changes in the MOC. Advanced techniques have to be used for efficiently obtaining large-scale integrals of deep circulation, in combination with moored instruments and repeated ship surveys.

The monsoon circulation of the Indian Ocean is of particular interest because of its intense variability, its influence on climate variability over Africa and its role in the global thermohaline circulation. Observations with floats are complemented by studies with coupled ocean-atmosphere models, in order to better understand the dynamics of interannual and decadal variability.
The international CLIVAR workshop on North Atlantic Thermohaline Circulation Variability which was held September 2004 in Kiel attracted 160 participants from 16 countries and was organized by IFM-GEOMAR scientists who also contributed to the success of the 1st International CLIVAR Conference (June 2004 in Baltimore). Until 2003, IFM-GEOMAR hosted BMBF-funded external staff of the International CLIVAR Project Office.

4.5.3 GLOBEC

GLOBEC is an element of the International Geosphere-Biosphere Program (IGBP). It is co-sponsored by the Scientific Committee on Oceanic Research (SCOR) and the Intergovernmental Oceanographic Commission (IOC). The general objective is to: "Advance our understanding of the structure and functioning of the global ocean ecosystem, its major subsystems, and its response to physical forcing so that a capability can be developed to forecast the responses of the marine ecosystem to global change". GLOBEC provides a framework that encourages participation of national, multi-national and regional scientific efforts but does not impose a rigid template. Several regional GLOBEC programs have been initiated which aim at developing corresponding knowledge from different marine ecosystems for a global comparative perspective: the Southern Ocean Program (SO-GLOBEC), Cod and Climate Change (CCC), Small Pelagic Fishes and Climate Changes (SPACC), Climate Change and Carrying Capacity (CCCC) and Climate Impacts on Oceanic Top Predators (CLIOTOP).

The activities and expertise in the Research Division Marine Ecology at IFM-GEOMAR Kiel, as well as its focus on the shelf region and on the interactions between fishery and natural ecosystem components, are closely on line with the international GLOBEC objectives.

The German GLOBEC program includes a comparative study of the Baltic Sea and the North Sea and aims at a better understanding of the interactions between zooplankton and fish under the influence of physical processes. The Marine Ecology Division at IFM-GEOMAR leads two of eleven sub-projects dealing i) with the early life-stages of fish as well as with food availability and its effect on reproductive success in relation to the physical environment, and ii) with the analysis of mesozooplankton feeding selectivity. Within GLOBEC-Germany an interdisciplinary team of fishery biologists, planktologists, physiologists, geneticists, physical oceanographers and modelers address these complex questions. The program is interlinked with various initiatives conducted by international organizations, e.g. the European Commission (DG XIV), Intergovernmental Oceanographic Commission (IOC), International Council for the Exploration of the Sea (ICES) and Northwest Atlantic Fisheries Organization (NAFO).

4.5.4 Interridge

The tectonic plates which make up the Earth's surface grow by volcanic processes along the mostly-submarine mid-ocean ridges. InterRidge (IR) is an international organization that came into existence in 1993 to promote those aspects of mid-ocean ridge research that can only be achieved by international cooperation. At present IR is supported by 5 full-member nations (France, Germany, Japan, UK, USA) and 6 associate member nations (Canada, China, India, Korea, Norway, Portugal), 17 other nations have corresponding nation status, 2700 individuals are on the mailing list.

The four main functions of IR are: (a) to build and maintain an international ridge-research community; (b) to identify, through its working groups (which cover the fields "Ultraslow spreading ridges", "Ridge-hotspot interaction", "Back-arc spreading systems", "Mid-ocean ridge ecosystems", "Monitoring and observatories", "Deep earth sampling", "Global exploration" and "Biogeochemical interactions at deep-sea vents") and the workshops and conferences they organize, the important problems in ridge research and develop program plans for their solution; (c) act as a representative body for ridge scientists in policy discussions; (d) through education and outreach communicate the importance of ridge research to the general public and decision makers worldwide. In the past, IR has been instrumental in organizing the first-ever cruises to study ridges in some of the most inhospitable places on Earth, such as the Arctic Ocean and the Southwest Indian Ocean.
In May 2004, the Leibniz Institute of Marine Sciences became host to the InterRidge Office, nerve-centre of InterRidge, when the IR chair, Colin Devey, became head of the "Dynamics of the Ocean Floor" research group. It will be hosted by the Institute until at least the end of 2006.

A lot of InterRidge's work is about communication. Since the beginning of 2004 we have, besides producing newsletters and websites, helped coordinate a Ridge 2000 – InterRidge Theoretical Institute on back arc basins in Korea (May 2004) as well as an InterRidge workshop on Indian ridge systems in India (January 2005). Upcoming events being organized together with the US Ridge 2000 office are a field school and field trip led by Professor Joe Cann (UK) to study ophiolites in Cyprus (May 2005) and the third International Symposium on Seep and Hydrothermal Vent Biology to be held in California, USA (September 2005).

The IR working groups have also been active, with a "Mid-ocean ridge ecosystems" working group meeting held in Bremen (January 2004), and the first "Biogeochemical interactions at deep-sea vents" working group meeting held in San Francisco (December 2004). The "Monitoring and Observatories" working group is holding an International MOMAR implementation meeting in Portugal (April 2005), and the "Ultraslow-spreading ridges" working group is planning a meeting in Italy in 2006 to celebrate the International Polar Year. Outcomes of these working group meetings can be found on the InterRidge website (www.interridge.org).

Since IR moved to IFM-GEOMAR it has also gained recognition as a potential advising organization for international policy making agencies. In September 2004, the IR chair was asked to present a talk at an International Seabed Authority workshop in Jamaica. He discussed the work of InterRidge and its potential relevance to the establishment of environmental baselines as well as potential collaborations with the Authority. The "Mid-ocean ridge ecosystem" working group, together with the InterRidge Steering committee, is presently formulating a voluntary code of conduct for scientific work at hydrothermal vents to establish the position of scientists as stakeholders with expert knowledge.

Education and outreach also became a stronger focus for IR with the move to Kiel. IR teamed up with an educational media group (Future Vision: Educational Media Group) and other science organizations to develop innovative print and video media products for formal and informal audiences. The plan is to join groups that traditionally do not work together – scientists, writers, educators, video producers, graduate students – in a common mission: to develop an educational video package including six half-hour programs that tell the compelling stories of ridge science in an effective, accurate way.

4.5.5 ODP/IODP

IODP
INTEGRATED OCEAN DRILLING PROGRAM

The sediments and basement rocks of the ocean basins contain unique information about past conditions on Earth, about the processes producing the major tectonic plates and life in the deep biosphere. Sampling these regions with scientific drilling in the deep ocean requires multinational cooperation. The participation of IFM-GEOMAR and formerly GEOMAR in the Ocean Drilling Program (ODP) plays an essential part in achieving our research goals. During the last two years IFM-GEOMAR provided co-chief scientists for Leg 202 and Leg 204 on the *JOIDES Resolution*, a research vessel for deep ocean drilling.

The JOIDES Resolution anchored in the harbor of Valparaiso, Chile, the starting point of Leg 202.

Leg 202 operated at 11 sites in the southeast and equatorial Pacific and recovered marine sediments from Early Oligocene to Holocene times. Three major scientific objectives were on the agenda: Evolution of the southern Pacific and its response to the effects of major tectonic and climatic events such as the uplift of the Andes mountains, the closure of the Isthmus of Panama, and the major expansion of polar ice sheets in the high latitudes of the southern and northern hemispheres at different times. The scientific efforts focussed further on the investigations of existing linkages between climate and biogeochemical changes in the high southern latitudes and the equatorial Pacific with relation to the rhythmic changes in the Earth's orbit and further the relationship of such changes to well known glacial events in the northern hemisphere. One of the most exciting result was the successful recovery of ultra high resolution records off the Chilean continental margin over the last 260.000 years.

Leg 204, co-chaired by an IFM-GEOMAR scientist, focussed on the evaluation and the distribution of several gas hydrate deposits within the setting of the accretionary wedge offshore Oregon. These wedges are characterized by tectonic dewatering. The site, known as Hydrate Ridge, exhibits outcropping gas hydrate layers at the flanks. All necessary site surveys in preparation for this exciting Leg were previously performed by scientists of the research group marine environmental geology and marine geodynamics. The ridge is characterized by highly dynamic gas hydrate formation and dissociation and various authogenic carbonate deposits. During this Leg, nine sites were successfully drilled and logged at the ridge crest and the adjacent western slope basin. The sampled gas hydrates were analyzed with respect to their structural, microscopical, submicroscopical and chemical composition. The detection of gas bubbles and free gas included in the solid fabric of the gas hydrates is one of the most spectacular results and an indication that free gas seems to be much more important in connection with solid gas hydrates. This successful ODP Leg triggered a series of research projects funded for fourthcoming years.

Apart of these two ODP legs, IFM-GEOMAR participated in several other legs, focussing on the paleoceanographic and paleoclimatic evolution of the southwestern Tasman See during the Pleistocene to the Quaternary. The Pliocene startup of modern carbonate platforms as a comparative study between the Great Bahama Bank and the Australian Great Barrier Reef is another theme being investigated as well as projects on the geochemistry and the microfabric of igneous rocks forming the oceanic basement and their complicated history of alteration under the influence of seawater.

Since the beginning of the new ocean drilling phase within the framework of the Integrated Ocean Drilling Program (IODP) IFM-GEOMAR is involved in several proposals of which recently the Tahiti Great Barrier Reef project as well as the Porcupine drilling proposal were funded.

4.5.6 Surface Ocean - Lower Atmosphere Study - SOLAS

SOLAS (Surface Ocean - Lower Atmosphere Study) is an international research initiative which aims...

..to achieve quantitative understanding of the key biogeochemical-physical interactions and feedbacks between the ocean and the atmosphere, and how this coupled system affects and is affected by climate and environmental change.

It is sponsored by IGBP, SCOR, WCRP and CACGP. The scientific basis for SOLAS orginated with an International SOLAS Open Science Meeting which was hosted by the IfM and held in Damp, near Kiel, in February 2000 and was attended by more than 250 scientists from 22 different countries. Since that successful kick-off, IFM-GEOMAR has continued to play a leading role in the development of SOLAS. Notably, several IFM-GEOMAR scientists made major contributions to writing The Science Plan & Implementation Strategy (www. solas-int.org). In addition, IFM-GEOMAR was well represented at the International SOLAS Science Conference in Halifax, October 2004.

In 2002, IFM-GEOMAR scientists coordinated and supported one of the first major SOLAS-oriented field projects: a cruise of *METEOR* (NO. 55) across the tropical Atlantic from Curacao (Netherlands Antilles) to Doula (Cameroon). This pilot project for a national SOLAS study brought biological oceanographers, chemical oceanographers and atmospheric chemists together in the context of a highly dynamic environment for atmosphere-ocean interaction. Data from this cruise have already resulted in 13 peer-reviewed publications including the first Special Issue of an international journal devoted to SOLAS, and papers in Nature and Science. At least 3 additional papers are submitted.

Based in part on this pilot project, and also on parallel research activities into the effect of elevated CO_2 concentrations on marine ecosystems, a proposal for a national SOLAS project will be coordinated by IFM-GEOMAR and submitted in mid-2005.

4.6 Other Contributions to National Research Programs

4.6.1 BIOTEC*marin*

The Center of Excellence BIOTEC*marin* was initiated in 2001 within the frame of the research focus of the federal government (Ministry of Education and Research) on "natural products from the sea". The topic of this interdisciplinary national project is the biology of marine sponges and their associated microorganisms and the search for new natural products from these organisms and their promotion into the market. National partners investigate the sponge taxonomy and ecology (University Stuttgart), the cultivation of sponges (University Karlsruhe), the genome analysis of marine sponges (University Mainz), the chemical identification and structure elucidation of new natural products (Universities Würzburg and Düsseldorf), the diversity, isolation, identification of microorganisms producing biological active substances (University Würzburg, IFM-GEOMAR Kiel).

Scientifically the project aims at an understanding of the evolution and biological functioning of marine sponges together with their associate microorganisms. The specificity of these interactions and the diversity and identification of microorganisms specifically associated with marine sponges is one of the major goals treated by the microbiology groups. The analysis of the sponge genome will allow to conclude on the position of sponges in the evolution of life and on the genomic evolution of animals in general, including important physiological functions. Because sponges are known as the major source of new natural products from marine organisms, the central focus is on the identification of new natural products produced by sponges and their associate microorganisms.

A precondition for the funding by the federal ministry of Education and Research was the foundation of a company (BIOTEC*marin* GmbH) by the principal investigators in order to speed up the promotion of new products into the market. The major role of this company is to raise money for toxicology and for preclinical as well as clinical studies with new products active against viruses, multiresistant pathogenic bacteria or tumor cells. One of the top products is the new compound sorbicillacton A, which has antitumor activities and is produced from a fungus isolated from a marine sponge. In a joint effort of groups from IFM-GEOMAR (microbiology) and the Universities Würzburg (chemistry) and Mainz (physiology) together with external partners, the substance was produced, purified and applied in toxicological and preclinical studies. Currently negotiations for clinical studies with this substance are in progress.

The project funding is achieved by joint efforts of the federal ministry of Education and Research and different state ministries and universities (depending on the project partner). In addition, in phase II (2005-2007) part of the finances is supplied by BIOTEC*marin* GmbH. This part is envisaged to further increase in period III.

4.6.2 GEOTECHNOLOGIEN

Introduction

GEOTECHNOLOGIEN is a geoscientific research and development program funded (jointly) by the Federal Ministry of Education and Research (BMBF) and the Deutsche Forschungsgemeinschaft (DFG).

Over a period of approximately ten years, the program is promoting a total of 13 different research themes, each of which has special significance from a scientific, socio-political or economic point of view.

Within the reporting period, IFM-GEOMAR contributed to the following projects within the GEOTECHNOLOGIEN framework.

Focus 1: Gas Hydrate in the Geo System

Research on marine gas hydrate and the methane cycle has a tradition at IFM-GEOMAR. In summer 1996 during a cruise with *RV SONNE* offshore Oregon (USA) scientists of the former GEOMAR recovered the largest amount of gas hydrate from the seafloor. This discovery stimulated research on gas hydrate in Germany and induced funding of scientific programs with numerous innovative technologies within the special program GEOTECHNOLOGIEN of BMBF and DFG.

Within the first funding period "Gas hydrates in the Geosystem" (2000-2004) 15 projects were funded by the BMBF. IFM-GEOMAR contributed with 3 major projects (LOTUS, INGGAS, OMEGA) to this initiative. Due to the scientific success and international recognition of this programme a second funding period "Methane in the Geo-/Biosystem" was started in autumn 2004 with METRO, one of 4 funded projects.

LOTUS - Langzeit-**O**bserva**T**orien zur **U**ntersuchung der **S**teuermechanismen bei der Bildung und Rückbildung von Gashydraten (2001-2004)

The aim of the LOTUS program was to obtain new insights into the temporal variability of the controlling physico-chemical and biogeochemical parameters in the sediment and in the water column as well as their impact on the temporal and spatial variability of vents associated with near-surface gas hydrates through long-term in situ observatories.

INGGAS - INtegrierte **G**eophysikalische Charakterisierung und Quantifizierung von **GAS**hydraten (2000-2003)

INGGAS set out to develop geophysical equipment for the quantification and characterisation of gas hydrate bearing sediments. The project was co-ordinated at IFM-GEOMAR with additional partners in Hamburg, Bremen and Kiel. Within INGGAS, a deep-tow streamer system, including telemetry and USBL location system, and ocean bottom seismometers suitable for hydrate research were developed at IFM-GEOMAR.

OMEGA - Oberflächennahe **M**arin**E GA**shydrate (2001-2003)

The OMEGA project aims at the characterisation and quantification of near-surface gas hydrates under in-situ conditions. Geoacoustic mapping, autoclav sampling and geochemical analyses have been used to study gas hydrate deposits in the Black Sea, offshore Oregon and the Gulf of Mexico.

Other partners in this project were: Technical University Hamburg-Harburg, Technical University Berlin, and Alfred-Wegener-Institute Bremerhaven.

METRO - Methan und Methanhydrat im Schwarzen Meer: Strukturanalyse, Quantifizierung und Dynamik des Methan-Reservoirs (2004-2007)

The interdisciplinary METRO project intends to understand the formation and decomposition of gas hydrates and to quantify methane fluxes in the Black Sea. This goal will be achieved using in-situ sampling techniques, laboratory experiments, geochemical flux modelling and geoacoustic mapping. The project ist coordinated by the University Bremen.

Focus 2: Continental Margin

The program "Continental Margins – Hot Spots for the Earth's Potential Use and Hazard" is one of 13 foci in the GEOTECHNOLOGIEN program. IFM-GEOMAR scientists are involved in the follwing programs:

SUNDAARC/MERAMEX (2004-2007)

Within the GEOTECHNOLOGIEN initiative on continental margins the interdisciplinary project SUNDAARC was set up to investigate the high risk volcanism and its tectonic implications in Indonesia. The subproject MERAMEX (Merapi Amphibious Experiment) uses geophysical data from an onshore/offshore experiment to studied the setting of the Merapi volcano in central Java.

Other partners in this project are: Bundesanstalt für Geowissenschaften und Rohstoffe (coordination), GeoForschungsZentrum Potsdam, Christian-Albrechts-University, Kiel, and Ludwig-Maximilians-University, München.

TIPTEQ - from **T**he **I**ncoming **P**late to mega**T**hrust **E**arth**Q**uake processes (2004 to 2007) is a multi-disciplinary project aimed to study the south Chilean subduction zone. In 1960 the area was hit by the largest earthquake ever recorded by seismologists. Due to the fact that the incoming oceanic lithosphere is segmented into different segments characterised by a large age contrast, the area is an excellent natural laboratory to study the mechanisms controlling great subduction zone earthquakes.

Other partners in this project are: GeoForschungsZentrum Potsdam (coordination with IFM-GEOMAR), University Berlin, University Potsdam, University Hamburg, University Bremen, University Freiburg, and Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover.

5. Technology Development

5.1 Long-term Deep-sea Observatories Based On Lander Technology

Landers are autonomous carrier systems for a wide range of scientific applications at the sea floor. IFM-GEOMAR operates a suite of landers of modular design as a universal instrument carrier for investigations of the deep-sea benthic boundary layer. This "GEOMAR Lander System" is based on a tripod-shaped universal platform which can carry a different scientific payloads to monitor, measure and perform experiments at the deep-sea floor. Landers can be either deployed in the conventional free-fall mode or targeted deployed on hybrid fibre optical or coaxial cables with a special launching device. The launcher enables accurate positioning on meter scale, soft deployment and rapid disconnection of lander and launcher by an electric release. The bi-directional video and data telemetry provides online video transmission, power supply and surface control of various relay functions.

Figure 1: Fleet of 6 different landers on deck of RV SONNE demonstrating the wide range of scientific applications enabled by the modular design of the lander system.

Figure 2: Biogeochemical Observatory (BIGO) ready for deployment with the video launcher on top. BIGO allows to simulate different environmental conditions (oxygen content /organic influx) in situ and represents an ideal experimental platform to study the kinetics of prominent biogeochemical reactions and threshold levels involved in the regulation of seabed methane emission.

With recent developments in the project LOTUS and the SFB 574 these landers provide the platform for:

- gas hydrate stability experiments (HDSD),
- quantification of gas flow from acoustic bubble size imaging (GasQuant),
- integrated benthic boundary layer current measurements (LongRanger),
- quantification of particle flux (DOS),
- monitoring of mega-benthic activity (DOS),
- fluid and gas flow measurements at the sediment-water interface (FLUFO),
- biogeochemical fluxes at the sediment-water interface (BIGO).

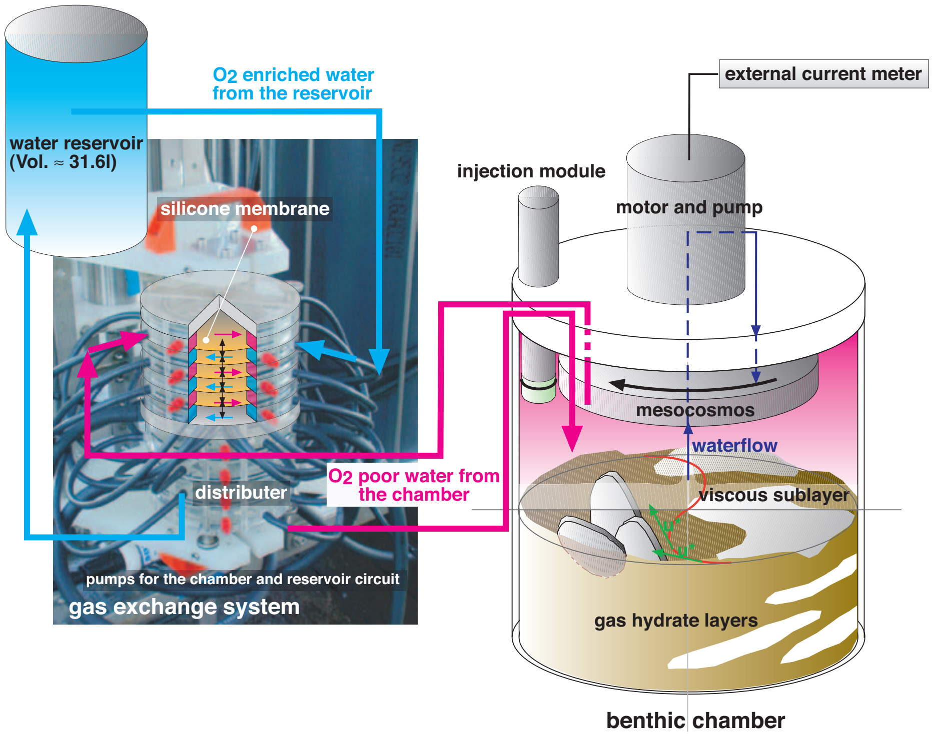


Figure 3: Scheme of the gas exchange system of BIGO. The maintenance of oxic conditions in BIGO by using a gas exchange system is the prerequisite to investigate benthic processes for prolonged time periods. Presently the gas exchange system either can maintain ambient oxygen level inside the chamber or can be set to different experimental levels. Data on methane emission rates confirm the control function of oxygen on methane emission rates from the sea floor containing gas hydrates.

These approaches represent major steps towards the development of deep-sea experimental systems and from stationary to dynamic benthic chambers. Furthermore, they enable us to resolve in situ natural processes and their variability at the appropriate time scale.

With the growing need of long-term sea floor observatories as presently outlined in the ESONET Programme (http://www.abdn.ac.uk/ecosystem/esonet/) lander will play a vital role. Targeted deployed landers with a wide range of instruments and sensors for physical, chemical, bio-geochemical and biological parameters will be used in autonomous mode in relatively inaccessable terrains (e.g. cold seep, hydrothermal vent settings). Typical observation periods are 1-2 years. Right now bi-directional communication with the lander is possible by using an acoustic link through a modem. The transmission rates and data quality, however, is hampered by the baud rate of the modem.

In the future, landers will also be incorporated as modules into glass-fibre optical cable systems. Autonomous lander clusters connected by optical cable and with data transmission to the surface and further on by satellite link to the shore are envisioned as an important contribution to future sea floor observatories. The lander cluster can consist of very diverse lander types for scientific observation, power supply and garage types for small autonomous (AUV, crawler) and tethered vehicles (ROV).

Olaf Pfannkuche, Peter Linke

5.2 Ocean Bottom Seismic Recorders

Similar to the principle that a hand-lens needs to be held close to the object being examined if it is to be seen in detail, detailed seismic studies of subseafloor structures require that the sensors be placed on or near the seafloor. This lead, some time ago, to the development of ocean bottom hydrophones (OBH) and Ocean Bottom Seismometers (OBS). Due to the remoteness of the deep ocean floor, the construction of an effective OBH/OBS has been a challenge for many. With the advance of modern, small and low power data storage media, it is now possible to build instruments that can be easily handled, are extremely robust and reliable, and can be operated within a reasonable budget.

IFM-GEOMAR currently operates the largest European fleet of such instruments, comprising a total of 75 instruments. The principle philosophy behind our design is modularity, so that components can be chosen and adjusted to the needs of an experiment. In short, an instrument consists of one or several sensors, a data logging unit, and an acoustic release to allow instrument recovery, all mounted to a frame holding syntactic foam for floatation and some relocation aids. Our design has been modified several times throughout the years, the latest version is shown in Figure 1. All components and the frame are manufactured by small industrial companies.

We have in principle two different data loggers, one for high resolution studies (200 to 10000 samples/s) with short term deployment times (maximum 30 days), and the second for long term (mainly seismological) investigations (up to 200 samples/s with operation life of up to 400 days). As seismic sensors, hydrophones as well as differential pressure gauges (for low frequency arrivals) and geophones with varying natural resonance (4.5 to 30 Hz) are employed. We have also investigated the use of broadband seismometers for long-term seismological investigation, however so far with only limited success.

Our instruments have been used intensively during the past decade both by ourselves as well as by other German institutions. In addition, since 1998 our fleet of OBH/S has been supported as a large scale facility by the EU, and many European researchers have had access to the instruments.

By the end of 2004, more than 3000 successful deployments have been made during about 75 cruises. The number of scientific papers resulting from these investigations is approaching 100. In the future, we will continue our efforts to improve the instruments and their reliability, and incorporate new technology as it becomes available. We foresee a continued high demand on the use of these instruments both from our own institute as well as from users outside IFM-GEOMAR.

Ernst Flüh

Figure 1: Instrument setup of the Ocean Bottom Seismometer 2002. The red cylinders comprise the syntactic foam that provides the floatation. In the middle, standing vertically, is the acoustic release. To the right, the yellow hard hat contains a seismometer, and a hydrophone is seen in front of it. The datalogger is in a titanium cylinder, wih underwater cables attached to the sensors. On the left far side, a radio beacon and a flash light are seen.

5.3 The Mass-Spectrometer Facilities

The mass-spectrometer facilities at IFM-GEOMAR are equipped with several gas mass-spectrometers (DELTA and Finnigan MAT253) for the determination of C-, O-, and Ar-isotopes, two thermal-ionisation mass-spectrometers (MAT262 RPQ+ and TRITON) for the determination of radiogenic and radioactive isotope ratios and element concentrations and an AXIOM MC-ICP-MS which allows the determination of elemental ratios, as well as of isotope ratios. The main difference between the thermal ionisation mass spectrometers (TIMS) and the MC-ICP-MS is the introduction system which limits the TIMS to elements with low ionisation potentials. In contrast, based on an electron plasma the MC-ICP-MS systems allows the ionisation of all known elements and isotopes in nature.

The precise determination of element concentrations, and element and isotope ratios is important in the marine sciences for process studies in the water column, for the reconstruction of present and past environmental conditions in the ocean and for the establishment of precise chronologies from suitable geological archives.

For example, from the measurement of the stable isotope systems like oxygen and carbon ($^{18}O/^{16}O$ and $^{13}C/^{12}C$) water temperature and salinity variations, the amount of continental ice masses and the strength of biological productivity in the water column can be reconstructed.

The radiogenic isotope systems of lead ($^{207,\ 206,\ 208}Pb/^{204}Pb$), neodymium ($^{143}Nd/^{144}Nd$), hafnium ($^{176}Hf/^{177}Hf$) and strontium ($^{87}Sr/^{86}Sr$) allow the reconstruction of sediment provenance, continental weathering and erosion, ocean circulation changes and process studies of crust/mantle interaction in the deep mantle. The radioactive isotope systems of uranium and thorium ($^{230}Th/^{234}U$, $^{234}U/^{238}U$) as well as protactinium and uranium ($^{231}Pa/^{235}U$) allow the study of the dynamics of particles while sinking through the water column. In particular, the establishment of precise chronologies using the radioactive isotopes of the U- and Th-decay chains is of special importance in paleoclimatology for comparison of global climate events in the geological past.

Figure 1: shows the AXIOM MC-ICP-MS system (with open torch box). Inside the laminar flow the desolvator CETAC ARIDUS (for sensitivity enhancement) can be seen.

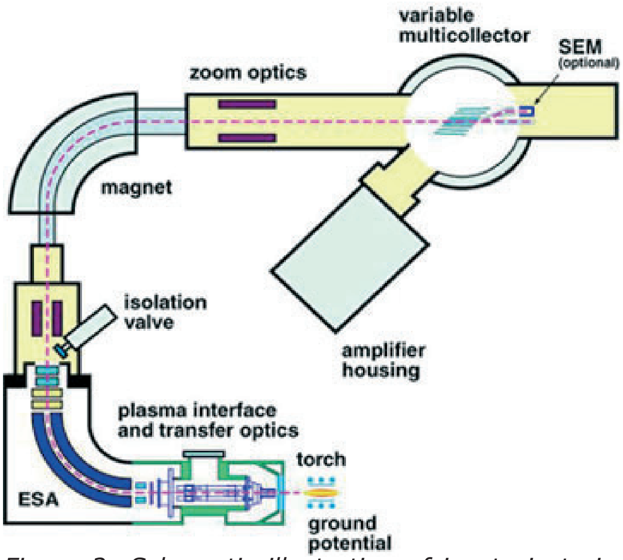


Figure 2: Schematic illustration of ion trajectories in the MC-ICP-MS. Sample atoms are ionized within the Ar-plasma, transferred into the high vacuum, accelerated, deflected by ESA and magnet (double-focussing) and finally collected by Faraday cups or SEM (multi-collection).

From the measurement of the so-called non-traditional stable isotope systems of calcium ($^{44}Ca/^{40}Ca$), magnesium ($^{26}Mg/^{24}Mg$), strontium ($^{88}Sr/^{86}Sr$) and boron ($^{11}B/^{10}B$) information about seawater temperature, continental weathering and erosion as well as pH-variations can be extracted.

Anton Eisenhauer

5.4 Deep-tow Instrumentation

A major research focus within IFM-GEOMAR are seafloor and sub-seafloor structures such as vents, mounds and faults. To obtain high resolution acoustic and seismic images of such features it is necessary to move the sensors as close as possible to the seafloor, which in deep water means towing the sensors far below the sea-surface. Within the framework of the Gas Hydrate Initiative (projects INGGAS and OMEGA, supported by the Federal Ministry of Education, Science, Research and Technology - BMBF), we have constructed a deep tow system consisting of a high resolution side-scan sonar and a deep tow-streamer. The system is rated for full ocean depths, the main limitation being the length of suitable cables on the research vessel (generally less than 10 km which limits the towing depth to about 4 km). The side-scan sonar and the deep tow streamer share a common USBL navigation system (Posidonia) and a telemetry system.

Figure 1: The deep-tow system on deck on the RV Sonne before deployment (February 2002). Background: the side-scan sonar. middleground the depressor weight (~ 2 tons), foreground, the deep-tow streamer showing hydrophones and engineeering nodes (black bullet-shapes) and yellow connecting segments.

Side-scan sonar works by transmitting a beam of acoustic energy sideways from the instrument, and recording the back-scattered signal as a function of time. Along-track resolution is controlled by either the width of the beam at the seafloor or the distance travelled between successive transmissions, whichever is greater; across-track resolution is an inverse function of frequency. As the width of the beam increases with distance from the instrument, resolution can be improved by towing the instrument as close to the seafloor as possible and transmitting frequently. The side-scan operates in two frequency ranges: 75 kHz or 400 kHz. At these frequencies, attenuation of the acoustic energy in the water column is severe also requiring that the instrument is towed as close to the seafloor as possible. The instrument is thus towed at either 100 m above the seafloor (75kHz mode), giving a resolution of 1 metre, or at 10 m above the seafloor (400 kHz mode) with a resolution of 25 cm. The side-scan sonar has been used successfully to image gas hydrates, carbonate build-ups, faults, sedimentary systems, and vents.

The vertical and lateral resolution of marine subsurface structures in reflection seismic images strongly depends on the seismic source and streamer system used for signal generation and data acquisition. The vertical resolution is controlled by the dominant frequency and bandwidth of the reflected signals and can be improved by using high(er)-frequency sources like GI- or waterguns in deep and boomers or sparkers in shallow water. The lateral resolution is determined by the size of the Fresnel zone, that is the portion of the sub-surface that contributes to an individual reflection and thus the lateral resolution of the seismic method. Fresnel zone radius depends on the source and streamer depth and on the depth of the reflector, respectively, on the velocity above the reflector and on the dominant frequency. Migration improves the in-line resolution by shrinking the in-line dimensions of the Fresnel zone but has no influence on the cross-line resolution. The latter can only be improved by lowering the streamer and - in the ideal case - the source towards to the sea floor.

The deep tow multichannel seismic streamer, consisting of 26 single hydrophone channels and three engineering nodes (recording pressure and orientation) has provided high resolution (<10m) images of the BSR (at the base of the gas hydrate zone), fluid conduits, faults, and buried carbonate build-ups. The main improvement by towing the streamer ~ 100 m above the seafloor comes from reducing the size of the Fresnel Zone by a factor of four. Migration of the data using special software further improves the in-line resolution. The system is ideally used with high frequency seismic sources such as the GI-guns (100-200 Hz) possessed by IFM-GEOMAR.

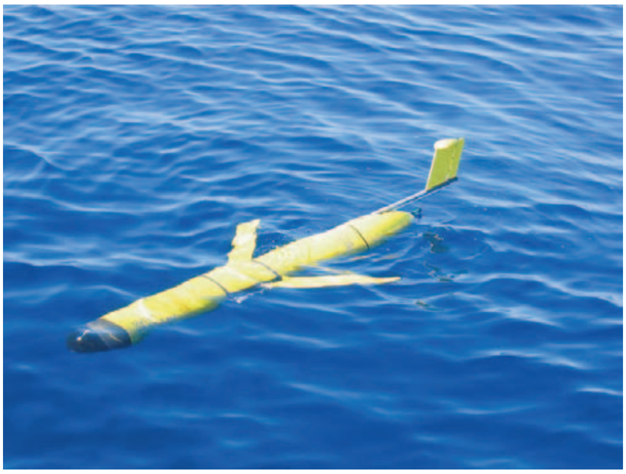
Tim Reston

5.5 New Technology for Basin-wide Monitoring: Gliders

A new technology is now in prototype development stage which has the potential to bring tremendous benefit to an observing system for a basinof the scale of the Mediterranean Sea. These are autonomous gliders, which can "fly" underwater on slightly inclined paths, using only their buoyancy for propagation. A typical dive/ascent to 1000 m depth moves the glider horizontally by around 2-4 km with an horizontal speed of about 20-40 cm/s. The glider can measure sea water properties along saw-tooth trajectories, such as temperature and salinity but also optical properties for biogeochemical applications. Data are telemetered via satellite in near-real-time while the glider is at the surface. The glider steers itself autonomously, but can also be controlled remotely to change its mission programming or to command it back to the base laboratory.

A first mission outside the USA started in September 2004 with a glider able to dive to 200 m depth as part of the EU-Project MFSTEP, the Mediterranean Fore-casting System toward Environmental Predictions. The glider has been deployed end of September 2004 by IFM-GEOMAR (Kiel) and IAMC (Messina) to repeat a hydrographic section between Italy and Libya.

In approximately three months of operations during the initial phase, this glider has collected 4254 profiles of temperature and salinity, repeating 6 times a day, 8-diving cycles to 200 m depth. The average horizontal distance between the profiles is around 400 m. In February 2005, this glider was upgraded with an optical sensor to obtain oxygen data in addition. At the same time, a deep glider prototype able to dive to 1000 m depth was deployed on a neighbouring route. In about three weeks, this deep glider has collected 159 temperature and salinity profiles, repeating 6 times a day, 2-diving cycles to 1000 m depth. The average distance between the profiles is around 2 km.



Glider data can be accessed in near-real-time (< 1 hour delay) at the following website: http://www.ifm.uni-kiel.de/fb/fb1/po2/research/mfstep/product.html.

The principle advantages of the gliders are:
- long endurance allowing automatic measurements in a continuous mode,
- remote steering possibilities allowing repeated sections,
- sampling in a virtual mooring mode at a nearly fixed location,
- event controlled modes, and to
- arrange adaptive sampling, i.e. enhanced measurements in a region of special interest,
- possibility to measure physical and biogeochemical parameters including optical properties,
- very high density and resolution of the measurements (in-situ tele-detection),
- possibility to deploy a fleet of gliders at moderate costs in comparison with conventional ship-borne operations.

Details of future glider programming and missions need to consider
- present glider capabilities,
- scientific analyses of existing information about the Ionian Basin, where up to two gliders were operating in winter 2004/05, and
- requirements for the overall marine forecasting system.

The data flow and data management required for the gliders has already been implemented successfully jointly with the French maritime agency IFREMER-Coriolis in Brest.

Pierre Testor and Walter Zenk

6. Central Facilities & Services

6.1 Aquarium

In addition to its principal function of public education and outreach, the public aquarium is connected to the scientific research of the institute. An intensive international scientific cooperation exists especially in the area of mariculture. Cooperating countries include Brazil, Vietnam, Jordan, and China. Besides ornamental culture the development of environmentally sound aquaculture systems has been an important objective. Modern re-circulating aquaculture systems that allow for a recycling of matter and energy were investigated. In such systems, organisms of different trophic levels are combined in a simplified artificial ecosystem. Fundamental research is mainly done in co-operation with the Research Division 2 and 3 of IFM-GEOMAR and external partners like the ZMT (Zentrum für Marine Tropenökologie) in Bremen and the Syddansk University in Odense (Denmark), to name a few examples. Within the reporting period, research funds for eight projects were obtained from the EU, BMBF, DBU, and SES (Senior Experten Service, Bonn) and facilitated the build-up of the mariculture working group at IFM-GEOMAR. A comprehensive report (by N. Kube and U. Waller) on the potential and possible development of the blue biotechnology provides a basis for the development of this research field worldwide.

Assemblage of a state of the art recirculation system; MARE, Marine Artificial Recirculation Ecosystem, Bert Wecker (front) and Adrian Bischoff (back) (PhD).

Prototype II recirculation system; Jaime Orellana (PhD).

Mediterranean Sea aquarium display; Sparus auratus and Dicentrarchus labrax, both species were successfully grown to maturation as broodstock for aquaculture research.

The Kiel aquarium represents current state-of-the-art in life support engineering. Thirty years ago a so-called foam fractionator was used for the first time in Kiel for the conditioning of sea water. Today, almost every aquarium has this technology, which makes it possible to maintain even most sensitive organisms in captivity under adequate living conditions. The development of the re-circulation technology for the aquaculture of marine organisms is based on the same technology, which has been adapted to the special conditions in intensive aquaculture. A sound understanding of the biology and physiology was necessary to accomplish this. The mariculture working group at IFM-GEOMAR provided this knowledge derived from fundamental biological research and numerical modeling. This was a prerequisite for a successful transition to a landmark biotechnology in co-operation with the industry. A commercial-scale experimental re-circulation system was built and put into operation (PISA project funded by BMBF) by the end of 2004. The development of the mariculture research facility GMA (Gesellschaft für marine Aquakultur) was structured according to an internationally evaluated research concept and intensively promoted until the end of 2004.

After more than 30 years the aquarium urgently needs renovation to ensure the future operation and the support of biological research. The technical staff, a technical manager and two keepers, guarantees not only the professional operation of the aquarium but also supports colleagues from various research areas of IFM-GEOMAR and Kiel University. Much of the research would not have been possible without the consultation through the scientific management and the help of the technical staff. A large number of masters (Diploma) and doctoral theses have resulted from this work.

Museumsnacht 2002

Visitors on board Polarfuchs during the Museumsnacht 2002.

An important event every year is the "long night of the museums" in which the aquarium introduces aspects of its own research and research from other areas of the IFM-GEOMAR. Every year up to 2,500 visitors are welcomed not only to learn but also to enjoy the evening. Science presented by students, champagne and sushi together with pleasant music were the extras for a perfect evening in 2004.

The Kiel aquarium is said to be the most important museum of the state capital of Schleswig-Holstein. Overall, around 85,000 visitors are welcomed every year and about 150 guided tours informed the visitors about the aquatic environment. More than 30 trainees learned about the research and the daily working routine every year, either in the aquarium or in the mariculture working group.

The aquarium's cooperation with television and broadcasting stations, weekly magazines and newspapers made a significant contribution to the press coverage of IFM-GEOMAR in the media. Thus, the aquarium contributes very successfully to the public outreach of IFM-GEOMAR.

6.2 Administration

In order to prepare the merger of IfM and GEOMAR, the administration provided and implemented integration conceptions with respect to rooms, personnel, and work organization in the new institute.

After the merger, the administration of the entire institute was re-located to the east shore campus (Building 4). The administration now consists of five organizational units: Purchase and Supply, Budgets and Finances, Personnel, Technical Services and Controlling (for details see Appendix 1). A reduction of staff due to the merging process was not yet possible.

The steering committee, which accompanied the merging process, recommended a new software system to be used by the administration. Accordingly, additional funds served to introduce such system which will be in use as of January 1, 2005. It meets the increasing requirements for efficiency of work, decentralization, and transparency. The technical feasibilities necessary for a modern administrative apparatus can be adapted by means of this system. In addition, a new technique of cost and activity accounting was developed to suit the purposes of the new institute. This accounting technique, together with a new performance-related allocation of funds, will also be used as from the beginning of 2005. The administration provided the relevant calculation basis and data in 2004.

6.3 Central Workshop, Central Technical Facilities - Establishment of a Technology and Logistics Center

IFM-GEOMAR provides a large variety of technical groups such as for gear development, deep-sea instrumentation, CTD and sensor calibration, electronics and preparation of expeditions which are mainly associated with the research units. These groups were so far spatially separated and only a limited co-operation existed. The institute also operates a central workshop in the West Shore Building with presently seven employees and one apprentice. This workshop supports the research units by gear development and construction of prototypes, modification and repair of instruments and the construction of test arrangements, the latter mainly for education and PhD students.

The growing technical demands in oceanographic research and the expansion of the institute´s facilities for deep sea observations such as oceanographic moorings, 8 lander observatories, deep towed side scan sonar, fleet of OBSs, glider, etc. enhanced the strong demand for a closer co-operation of the different technical groups and for a better co-ordinated and cost efficient sharing of instruments in a common facility grouped around the central workshop. IFM-GEOMAR´s strong commitments to programs in ocean observation such as GEOSS, ARGOS, ANIMATE, NEPTUNE and ESONET support the need for a strengthening of our technical capacity. This implies a multidisciplinary approach since most observation systems combine instruments from various oceanographic disciplines.

Fig 1: The planned IFM-GEOMAR Technology & Logistics Center (TLZ).

The availability of a large building formerly used as a technical training centre opened the possibility to unite all technical groups including the central workshop under one roof and to provide the required space for the technical modification and cruise preparation of the large deep sea observatories.

In fall 2004 a planning group with representatives from all research units and central facilities started with the room planning of the so-called Technology and Logistic Center (TLZ). The concept was formally approved shortly thereafter and the was signed in early 2005. Olaf Pfannkuche (RD2) was appointed as head of the TLZ.

Presently the building is subject to detailed technical re-planning for a refit including the supply and security systems. The refit will start in summer 2005. It is partly financed by the owner, by institute means and a grant from the Schleswig-Holstein Government.

The building is located on the east shore campus adjacent to the GEOMAR main building. The construction of a $1500m^2$ storage hall for instruments and gear opposite to the new TLZ is also planned for 2006. The first user groups will move into the TLZ in fall 2005. In spring 2006 the central workshop and all technical groups will be transferred to the TLZ. With about $3000m^2$ floor space the new TLZ meets our future technical demands and integrates all technical groups of the research units.

6.4 Data and Computer Center

With the merger of IFM and GEOMAR, the two separate computing centers have merged into one center which serves about 400 employees. Additionally, central compute, application and file servers are administrated and operated. Four operating systems (Windows, Linux, TRU64 and Macintosh) and different application software products are managed by the center. The network management of both sites is mainly performed by the staff, with additional support from the university. Since 2003 the main servers operated under TRU64 are substituted by modern Linux servers. The old central servers on the east shore campus have been substituted by new machines, including application servers for mail and web services. Additionally, the storage capacity of about 18 TB has been extended to 48 TB. Since 2004, two Itanium2 (4 processors) compute server were installed. A new concept of data storage and backup has been developed and realised (20 TB, CX 600). Older workstations under OS TRU64 are gradually substituted by modern Linux PCs. A central administration and backup system for these Linux PCs has been implemented. A WLAN was setup for lecture and conference areas, with further extensions being planned for 2005. A VPN (Virtual Private Network) has been installed to allow a safe remote access from everywhere in the world. A new common mail system has been successfully installed. Since 2003 a Gigabit-link connects east and west sites and permits data exchange between both sites and provides the internet access for the east site. For high performance computations IFM-GEOMAR has access to a parallel vector processor computer NEC SX-5 with 16 CPUs and 32 GB memory and a parallel computer SGI ALTIX with 128 CPUs and 512 GB shared memory at the University of Kiel. 60% of the total CPU-time is reserved for IFM-GEOMAR.

In 2004 a number of tasks which were mainly caused by the merging process of the institutes IFM and GEOMAR have been performed by the computer centers staff. Specific tasks are the introduction of a common IP address range, user authentification and email system. Two technicians could be employed for new tasks. The introduction of new administration software (MACH) has been supported, and the new hard- and software is mainly administrated by the computer center. The "active domain" concept has been introduced which allows for a central administration of Windows PCs. A content management system (CMS), which organizes the internet presentation of IFM-GEOMAR has been set up and will be operated by the computer center.

6.5 Fishbase

FishBase is a large online information system with key data on currently 28,500 species of fish. It is run by an international consortium coordinated at IFM-GEOMAR.

Usage of FishBase on the Internet continuous to grow and stood at over 12 million hits from over 600,000 monthly visitors in May 2004, making fish more popular than birds or butterflies. Most users enter the system through common names and look at species summary information and at photos. An example for the Atlantic cod is displayed below. But there is also substantial usage of the "specialist" pages which contain information on e.g. population dynamics, taxonomy, trophic ecology, reproduction or genetics. Of interest to assessment oriented fishery biologists will be easy access to catch data by country, new tools to analyse trophic level trends in catch data, a "Life-history" tool that calculates many population

Gadus morhua Linnaeus, 1758
Atlantic cod

photo by Morris, P.

Family:	Gadidae (Cods and haddocks)
Max. size:	200.0 cm TL (male/unsexed); max.weight: 96 kg; max. reported age: 25 years
Environment:	benthopelagic; brackish; marine ; depth range 1 - 600 m , oceanodromous
Distribution:	North Atlantic: Cape Hatteras to Ungava Bay along the North American coast; east and west coast of Greenland; around Iceland; coasts of Europe from the Bay of Biscay to the Barents Sea, including the region around Bear Island.
Diagnosis:	Dorsal spines (total): 0-0; Dorsal soft rays (total): 44-55; Anal spines: 0-0; Anal soft rays: 33-45; Vertebrae : 51-55. Light lateral line, curved above pectorals. Predorsal distance less than 1/3 of TL. Color varies from brownish to greenish or gray dorsally and on upper sides, becoming pale ventrally. Peritoneum silvery.
Biology:	This species is widely distributed in a variety of habitats, from the shoreline down to the continental shelf. Cod form schools during the day. Cod are omnivorous; they feed at dawn or dusk on invertebrates and fish, including young cod. Cod spawn once a year. They are marketed fresh, dried or salted, smoked and frozen; they are eaten steamed, fried, broiled, boiled, microwaved and baked (Ref. 9988). The most important stocks are the Norwegian Arctic stock in the Barents Sea and the Icelandic stock. The populations around Greenland and Newfoundland have declined dramatically (Ref. 35388). Over 12 nucleotide substitutions in the 307 base pair region of the mitochondrial cytochrome b gene differentiate this species from *Gadus ogac* (Ref. 40214).
Threatened:	Vulnerable (A1bd) , Sobel, J. , (Ref. 36508)
Dangerous:	harmless
Country info:	

Example of a typical output from FishBase: Atlantic Cod: http://www.fishbase.org/FieldGuide/FieldGuideSummary.cfm?genusname=Gadus&speciesname=morhua&pda=&sps=

parameters, improved tables to access data needed for ecosystem modelling, and a "Length-frequency wizard" which derives a number of relevant population parameters from suitable length-frequency samples. FishBase coordination includes the care for keeping the data base up to date by requesting copies of relevant publications and data sets. Many data regularly collected in routine or special survey programs were in the past often finally lost; FishBase can act as a permanent archive, and can make these data available worldwide for integrative analysis.

6.6 IFM-GEOMAR Library - a Place, a Portal, a Partner

For many years the libraries of both the former "Institut für Meereskunde" and "GEOMAR" have been the heart of the Kiel scientific marine community. As a result of the merger the newly created IFM-GEOMAR Library has now become one of the largest marine science libraries in Germany and is internationally recognized as the repository of a wealth of information on marine sciences and meteorology.

The library is a founding member of the German Organisation of Marine Science Libraries, and since several years editing the Organisation's Journals' Catalogue (AMB-ZV).

It is also an active contributing member of the German Working Group of Geo- and Environmental Sciences Libraries, the European Association of Aquatic Sciences Libraries and Information Centres (EURASLIC) and of the International Association of Aquatic and Marine Science Libraries and Information Centers (IAMSLIC). These associations provide a forum for exchanging and exploring ideas and issues of mutual concern, as well as for developing and implementing standards and procedures for research libraries.

These important cooperations were established and strengthened not only by exchanging information, help and interlibrary loan but also due to the fact that in Spring 2003 the library of the Institut für Meereskunde Kiel organized the 10th biennial meeting of the European Association of Aquatic Sciences Libraries and Information Centres (EURASLIC). The conference was a great success and hosted more than 50 participants from 14 European countries, in addition to representatives of four international organizations.

The IFM-GEOMAR Library is also an active contributing member of the "AK Bibliotheken" (Libraries' Working Group) within the "Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz" (Leibniz Association) which provides consortia ownership of databases and journals as well as a forum for discussing further initiatives appropriate to the modern library world.

Cooperation with the University Library Kiel and the Library of the Institute of Geosciences is very important for the day-to-day work of the library. Not only are copies of articles and other sources of information exchanged but - even more importantly – book orders are co-ordinated in such a way that collection overlap is prevented.

The University Library also helps to augment the textbook collection available for students from all fields of marine sciences and meteorology.

The library possesses an impressive collection of books on subjects related to the various fields of ocean science, e.g. ocean circulation and climate dynamics, marine biogeochemistry, marine ecology and the dynamics of the seafloor. The library's special collection, located on the west shore campus, includes many historical works, rare monographs, and journals of the library of the former "Institut für Meereskunde Berlin".

The collection comprises about 110,000 media items. Currently there are 794 open serial titles. The majority is obtained through exchange agreements with other research institutions.

The Open Access Web Catalogue can be used to search for titles within the Institute´s library as well as in other libraries, to access the users´ own loan accounts and to place advance reservations on books currently still out on loan.

The library's journal stock is listed in the German Union Catalogue of Journals "Zeitschriftendatenbank (ZDB)", and the IFM-GEOMAR Library is a participant of the "Electronic Journals Library" (EZB) which provides more effective use of scientific and academic journals which publish full text articles on the Internet. To date, 283 libraries and research institutions make use of this service in their daily work. A selection of electronic journals adapted to the respective library's requirements is generated for each participating institution.

Via a z39.50 interface the library is able to participate in the z39.50 Linking Libraries Project set up by IAMSLIC whose aim is to facilitate resource sharing among marine and aquatic science libraries worldwide.

The IFM-GEOMAR Library provides access to a variety of electronic journals and databases. Particularly important are the following databases: Web of Science, ASFA, FishBase and Georef, all of which can be searched through the homepage of the library.

The Library provides a number of services to members of the IFM-GEOMAR community:

- Comprehensive reference-section assistance and training on-demand in database use
- Document delivery services
- Digital processing center services such as copying, scanning, and graphic design; (xerox machine available on site)
- Workshops on current information technology
- Free access to the whole library collection
- Full text access to over 600 e-journals, books and databases
- Circulation services including electronic reserves

The IFM-GEOMAR Library´s web pages are continuously updated to ensure that information such as the library's address, opening hours, staff, borrowing information and the library catalogue, as well as links to other marine science libraries, interesting websites, booksellers and publishers is always current.

In addition to serving the IFM-GEOMAR scientists and students daily, the staff and resources of the IFM-GEOMAR Library are utilized year round by the research and education programs of the Kiel University and other marine-orientated projects.

The library also serves pupils from schools all over Schleswig-Holstein as well as being open to the general public.

In April, 2004 –in order to elicit more interest of the general public - the IFM-GEOMAR Library invited the author, Frank Schätzing, to come and read from his very successful German-language bestseller "Der Schwarm", a science fiction thriller having to do with the ocean and partly playing at the former GEOMAR with some of its scientists as main characters. A small exhibition provided scientific background for the reading. The event was open to the general public and was a great success.

6.7 Lithothek

The IFM-GEOMAR Lithothek holds a collection of more than 8,700 m of split sediment core samples. This includes 4,900 m of cores from the Red Sea (PREUSSAG collection). Additionally, samples of hard rocks, corals, sediment traps, seawaters, and pore waters are stored. These samples are available for current and future research projects. Cold storage is available for sections of box cores to especially preserve the Holocene sediment record. Samples are provided for research as well as for educational purposes and museum displays in limited quantities.

The Lithothek service is supported by technicians and is responsible for:

- Processing incoming and outgoing sediment cores and samples
- Archiving marine sample material
- Documenting available samples in a data bank (PANGAEA)

The Lithothek supports the increasing use of non-destructive devices for high resolution logging of marine sediments obtaining information about physical properties (GEOTEK MSCL: multiple-sensor split core logger). The core laboratory is set up for digital core photography, core descriptions, measurements, sampling and processing of samples. The Lithothek facility is used for the development and testing of sampling devices, storage of sample material, analysis and the preparations for expeditions.

The Lithothek on the east shore campus of IFM-GEOMAR.

The following sea-going facilities are available on request:

- Container for coring equipment (box corer, gravity corer, core cutter)
- Container for multi-sensor core logging (non- destructive measurements of P-wave velocity, density, magnetic susceptibility)

6.8 Seismic Processing and Analysis Facility

The seismic processing facility handles data from a wide range of seismic acquisition methods such as multichannel seismic, deep-tow streamer data, and multi-component ocean bottom recordings. We specialize in depth imaging in two and three dimensions by prestack depth migration. Where appropriate this can be followed by structural reconstruction of the main tectonic units to reveal the geological evolution. Furthermore, detailed subsurface velocity information from iterative migration analysis in layer stripping mode and tomographic inversions are used together with amplitude preserved migration algorithms and amplitude versus offset analysis to characterize the subsurface structures (e.g. quantifying porosity, and the abundance of methane hydrate).

The main pre-processing is made with the commercial software package SEISMOS from Western-GECO which is extremely flexible regarding data flow and acquisition technique. The prestack depth migration is applied iteratively with a user-friendly interactive module from GX-Technology for building the velocity model in two and three dimensions. The structural reconstruction software GeoSec from Paradigm Geophysical can be used to validate the interpretation. As preserved migration algorithms are not commercially widely used, additional in-house algorithms have been developed to extract amplitude and phase information of seismic data to characterize the subsurface structure.

The seismic processing facility represents a unique facility within Europe, as acknowledged by its funding as a Large Scale Facility under three successive EU programmes (framework 3,4, and 5). Within these programmes, training in the handling, processing and interpreting seismic data has been given to European guest scientists.

6.9 Research Vessels and Ship Operations

6.9.1 IFM-GEOMAR Research Vessels: Ownership, Funding and Operation

According to the IFM-GEOMAR main mission for basic marine research in the 'Blue Ocean', many of the institute's research groups participate in cruises on "METEOR" and "SONNE" as well as "Polarstern". Details for some of these cruises are referred to in the reports of the Research Divisions. Here, the focus is on the institute's research vessels.

IFM-GEOMAR operates the two medium-sized research vessels "POSEIDON" and "ALKOR", the research cutter "LITTORINA" and the boat "Polarfuchs". The institute represents their legal owners. By regions, the main research area for "POSEIDON" is the subtropical and subpolar North Atlantic, the Mediterranean and Black Seas. Because of the capability to sample long cores up to 12 m and to perform fishery research, the ship is also used in the Baltic and North Sea. "ALKOR" is mainly used for research in the Baltic and the North Sea including student's training courses. "LITTORINA" works mainly in the western Baltic, for coastal research and student courses while the usage of "Polarfuchs" is restricted to the Kiel Fjord and Bight.

Legal owner of both, "POSEIDON" and "ALKOR" is the state of Schleswig-Holstein. Crewing and technical management is performed by a private shipping company, the managing owner. Both vessels together with "HEINCKE" and "A.v. HUMBOLDT" (out of service since October 2004) belong to the national pool of "medium sized" research vessels. Cruises on these vessels are reviewed by a central Steering Group and scheduled in close cooperation by the participating institutes. Both ships are also part of the "Tripartite Agreement" on ship time exchange that IFREMER (France), NERC (UK) and BMBF (Germany) have signed and which has been joined by NIOZ from The Netherlands in 2003. The managing owner of "POSEIDON" and ALKOR" has been the Reederei Forschungsschiffahrt R/F, Bremen since the vessels started their service in 1976 and 1990, respectively. Now, since January 2004 after a European wide bid, the Schiffahrtsgesellschaft Briese, Leer, has become the managing owner for both ships.

"LITTORINA" belongs to and the crew is paid for by the University of Kiel. She is in service since 1975. By contract with the university, the institute has taken over the responsibility for crewing, managing and scientific operation, and bears the running costs.

Legal owner of "Polarfuchs", a former aid- and life-boat of "Polarstern", is the Federal Republic of Germany. The boat that was no longer needed on for polar research, and by contract with the "Alfred Wegener-Institut für Polar- und Meeresforschung", the institute could transfer it to Kiel for regional coastal research. The institute bears all costs for the boat and is responsible for scientific scheduling.

The basic institutional funding allows for approximately 210 days ship time to use on each of the four vessels. This includes ship time for cruises of other public research institutes in Germany, and barter cruises within the "Tripartite Agreement". In particular "ALKOR" contributes significantly to practical courses for students at sea. Through external charter, the number of used ship days per year could be increased significantly in the recent years, in particular on "POSEIDON" and "ALKOR". The statistics in terms of ship days by users is summarized in Table 1 below.

Table 1: *Overview of ship days used by IFM-GEOMAR and partners on IFM-GEOMAR research vessels, 2002-2004. Pool partners are the AWI, the University of Hamburg and the IOW; national partners are all other other public research institutes; barter cruises within the 'Tripartite Agreement', with the FWG, and on "LITTORINA" within the technical agreement with 3L-ELAC (since 2003).*

Ship	User	2002	2003	2004
"POSEIDON"	IFM-GEOMAR	85	61	95
	University of Kiel	43	0	0
	Pool partners	21	25	21
	National partners	29	56	59
	Barter cruises	0	45	59
	Charter cruises	64	43	40
	Transfer cruises	31	33	20
	Total ship days	**273**	**263**	**294**
"ALKOR"	IFM-GEOMAR	95	63	80
	University of Kiel	10	1	18
	Pool partners	21	53	57
	National partners	4	14	0
	Barter cruises	0	0	22
	Charter cruises	37	20	15
	Student courses	65	58	33
	Transfer cruises	0	0	2
	Total ship days	**232**	**209**	**227**
"LITTORINA"	IFM-GEOMAR	32	54	60
	University of Kiel	81	106	96
	Pool partners	7	0	0
	National partners	9	0	3
	Barter cruises	0	16	20
	Charter cruises	0	0	0
	Student courses	15	40	17
	Total ship days	**128**	**216**	**196**
"Polarfuchs"	IFM-GEOMAR	71	97	102
	University of Kiel	25	21	20
	Pool partners	0	0	0
	National partners	0	0	3
	Barter cruises	0	0	0
	Charter cruises	0	0	2
	Student courses	7	9	5
	Total ship days	**103**	**127**	**132**

"POSEIDON" (1976; 1059 BRT; 61 m)

In 2002 operations started with an IOW based geological cruise in the Baltic Sea. The ship then was transferred to Lisbon where four cruises within the eastern subtropical Atlantic were conducted. Research encompassed the time series stations K276 and ESTOC, work by the interdisciplinary research group IP1 of IfM, and a geophysical cruise south of the Azores for the University of Kiel. For the first time in international charter, "POSEIDON" made a geological survey off the Portuguese coast for IPIMAR, Lisbon. The following transect across the North Atlantic to St. Johns, Canada, was used to deploy the first ARGO buoys for IFREMER (France). The summer months until end of September were spent in remote areas like the Labrador Sea (SFB460), the Irminger and Iceland seas, in the Denmark Strait, and in the Faroer-Bank Channel to investigate the overflow (SFB460, Univ. Hamburg), to set up a new EU funded time series station, ANIMATE/CIS (IfM), and for geological surveys north of Iceland and west of Ireland (GEOMAR).

In 2003, again the service of the time series stations ESTOC near the Canary Islands, K276 in the Azores Front, and the new sites PAP in the Porcupine Abyssal Plain and CIS in the Irminger Sea were key tasks during several "POSEIDON" cruises for the IfM. The Universities of Hamburg and Bremen used the ship for one month of physical oceanography cruises each, in the Adriatic Sea and in the Faroer Bank Channel, and the University of Bremen off Portugal for marine geology on the continental shelf break. Three barter cruises with 45 days were conducted under the "Tripartite Agreement", partly returning time used on European partner ships.

Beside the routine work at the time series stations K276, ESTOC and CIS, the year 2004, had several highlights: a British 2-ship experiment on plankton growth off the Canaries with "CHARLES DARWIN" and "POSEIDON", the use of the ROV CHEROKEE in Demark Strait, and the use of the submersible JAGO during two legs within the Black Sea block of 2 months to search for and to investigate 'hot spots'. Barter days accumulated to 59 days.

Summarizing, "POSEIDON" has extensively been used for specialized cruises like service of time series stations with deep sea sampling casts, surveys with small ROV's (CHEROKEE type) and a small manned submersible (JAGO) that require only a relative small number of scientists and technicians onboard and that can be conducted within a one-year or less planning schedule.

"ALKOR" (1990; 1000 BRT; 55 m)

Major monitoring and research cruises in the reporting period were conducted for ICES and for the GLOBEC, STORE, LIFECO and CODESSEY programmes, partly under charter. Practical courses for students accumulate to app. two months ship time each year. In 2002, "ALKOR" represented the institute at the 100th anniversary of ICES in Copenhagen, certainly one of the highlights in representation. In 2004, two barter agreements became effective for the first time on "ALKOR": a 7-days cruise for NIOZ, Texel, off the Netherlands and a 2-weeks cruise in October 2004 for the German naval research center, FWG, in a Norwegian fjord. Other short cruises were organized for small projects and instrument tests.

In summary, "ALKOR" has continued to be the institute's workhorse for research in the Baltic and North Sea and for student courses.

"LITTORINA" (1975; 168 BRT; 30 m)

This rather small cutter was used by IFM-GEOMAR mainly for student courses, in particular for providing life samples for laboratory courses. Several rather short research cruises of one to two weeks length led to the western Baltic and the German Bight; often a side scan sonar and the newly installed multibean echosounding system for shallow waters was used for seabed investigations. The latter system has been installed in 2003 within a cooperational contract between the private company L3-ELAC and the institute allowing scientific usage of the system bartered against shiptime on "LITTORINA". Also in 2003, the cutter had a three weeks long cruise to investigate environmental conditions in habitats of different salinities, with several port calls, even in Finland.

"Polarfuchs" (1982; 16 BRT; 13 m)
During about 120 days per year, this research boat is used for day-long cruises, mostly within the Kiel Fjord and Eckernförde Bight and mainly sampling living material for student courses and providing samples for master theses. It also serves as shuttle to service the meteorological station installed on the Kiel Bight lighthouse.

Technical and scientific equipment
High standards in technical and scientific equipment of the ships are essential for high quality research. In 2002, the institute started to equip "POSEIDON" with two CTD/rosette systems from SeaBird Electronics; technical support is provided by the laboratory for measurement technics. In 2003, the motion sensor for the mobile multibeam echo sounding system of "POSEIDON", so far used on a leasing basis, was purchased. In addition, the bridges of "PO-

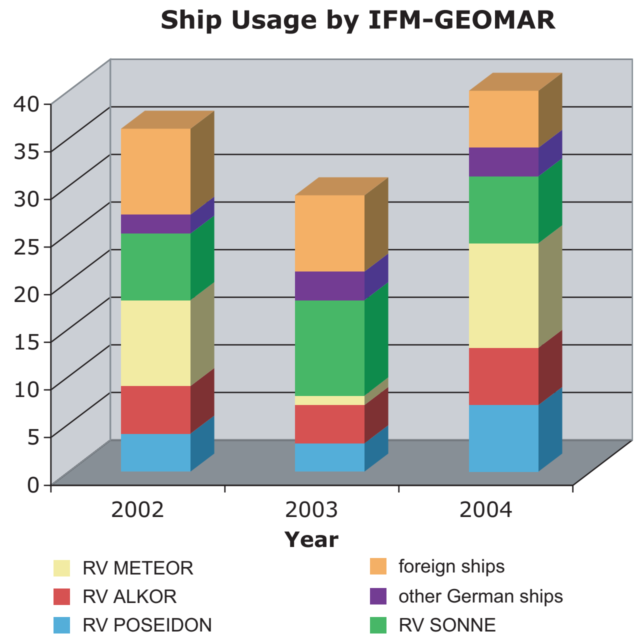
SEIDON" and "ALKOR" were modernized and equipped with new daylight radars, electronic sea charts and an Automatic Identification System, AIS. AIS was also installed on "LITTORINA", and on "POSEIDON" the analogue satellite communcation system was replaced by a digital via INMARSAT B. Finally, in 2004 a new 75 kHz mobile ADCP replaced the old 150 kHz ADCP on "POSEIDON". It can be installed in the moonpool together with a water pump system, a second thermosalinograph, and a hydrophone.

"POSEIDON" replacement discussion

As "POSEIDON" approaches 30 years of service in 2006, the maintainance costs are increasing and is becomes almost impossible to meet modern technical standards at reasonable costs. A working group consisting of members of IFM-GEOMAR and representatives of the main users has been established at the end of 2004. This working group has defined a profile for a replacement vessel; key recommendations are that the replacement vessel should be a medium sized multipurpose ship for the North Atlantic, with a one-year or less planning time before cruises start. Special winches should be mobile. As an alternative, the option to replace "POSEIDON" by a used, but more modern vessel for the years until 2015 is investigated. RV "GAUSS" (currently BSH) has been identified as a possible candidate.

6.9.2 Major Expeditions

Apart from research cruises on the four vessels of IFM-GEOMAR, scientists also heavily use other German and foreign research vessels for expeditions. Scientists from IFM-GEOMAR conducted 103 cruise expeditions as chief scientists. Overall, more than 25 research vessels from 10 countries were used (see Appendix 4).



RV METEOR (60% of the cruises by IFM-GEOMAR)

RV SONNE (© Reederei Forschungsschiffahrt) (2002-2004: 80% of the cruises by IFM-GEOMAR).

7. IFM-GEOMAR Publications 2002-2004

Publication of scientific results occurs primarily in leading international, peer-reviewed scientific journals and books. Peer review is the main mechanism of quality control. IFM-GEOMAR scientists published more than 200 peer-reviewed papers every year (see below). **Amongst them 23 papers in Nature and Science**. Participation in the review process by most IFM-GEOMAR scientists also contributes to quality control within the scientific community. In addition, several scientists serve as editors or on the editorial boards of leading journals, e.g., amongst others: Biogeosciences, Deep-Sea Research, Geochemistry, Geophysics, Geosystems (G3), International Journal of Earth Sciences, Marine Ecology, and Marine Geology. For a complete list see Section 8.2.

Occasional publications with review character in other journals may be targeted on either information or education of specific audiences, or to document special events (e.g., conferences).

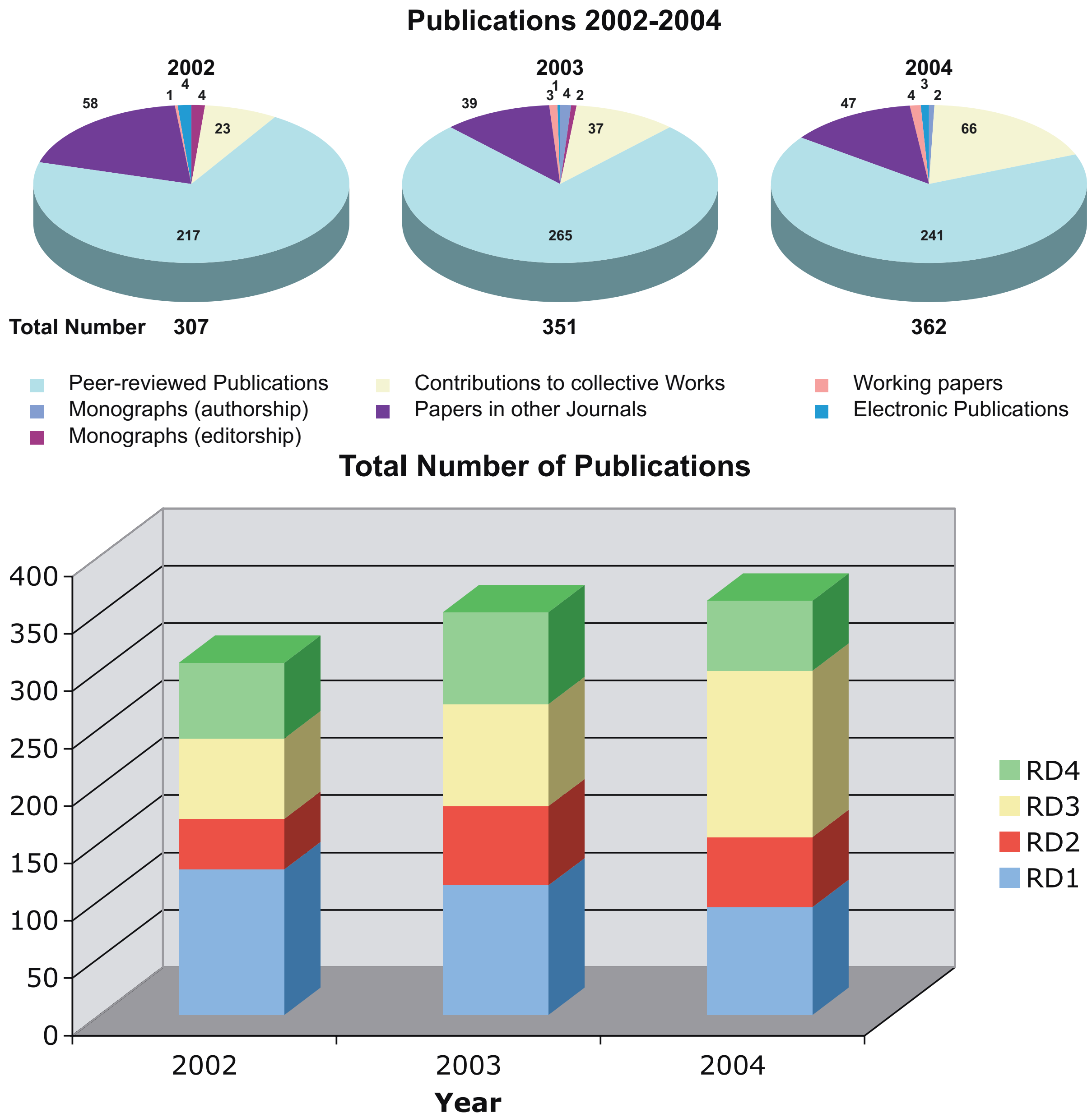


Fig. 1: Statistics of IFM-GEOMAR publications during the reporting period.

7.1 Monographs (Authors)

2002

2003

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Latif, M., 2003: Hitzerekorde und Jahrhundertflut. Herausforderung Klimawandel. Was wir jetzt tun müssen. Heyne Verlag, 160 pp.

Lotze, H.K., Milewski, I., **Worm, B.**, and Koller, Z., 2003: Nutrient pollution: a eutrophication survey of eelgrass beds in estuaries and coastal bays in northern and eastern New Brunswick. Conservation Council of New Brunswick, Fredericton, NB, Canada, 60 pp.

Schmincke, H.-U., 2003: Als in Deutschland die Berge noch Feuer spien. *Deutscher Nationalatlas*. Leipzig, 60-63.

2004

Latif, M., 2004: Klima. Fischer Kompakt 16125. S. Fischer Verlag Frankfurt a.M., 127 pp.

Schmincke, H.-U., 2004: Volcanism. Springer Berlin-Heidelberg-New York. 334, ISBN 3-540-43650-

7.2 Monographs (Editors)

2002

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Kassens, H., **Biebow, N.**, **Dullo, W.-C.**, Galimov, E., Cherkashov, G., Hubberten, H.-W., Kotlyakov, V., Lisitzin, A.P., Negendank, J.W.F., Pryamikov, S., Thiede, J., and Troyan, V., (Eds.), 2002: Climate Drivers of the North. Terra Nostra, 2002/3, 120 pp.

Reijmer, J.J.G., (Ed.), 2002: Carbonate margin development (Bahama transect, ODP Leg 166). *Marine Geology*, **185**, 1/2.

Sommer, U., and **Worm, B.**, 2002: Competition and coexistence. Springer, Berlin, 221 pp.

2003

Reijmer, J.J.G., Betzler, C., and Mutti, M., (Eds.), 2003: New perspectives in carbonate sedimentology. *International Journal of Earth Sciences - Geologische Rundschau*, **92** (4), 200 pp.

van Weering, T., **Dullo, W.-Chr.**, and Henriet, J.P., (Eds.), 2003: Geosphere-Biosphere coupling: cold seep related carbonate mound formation and ecology. *Marine Geology*, **198**, 190 pp.

7.3 Collected Editions

2002

Boetius, A., Jørgensen, B.B., Amann, R., Henriet, J.P., Hinrichs, K.U., **Lochte, K.**, McGregor, and B.J., Voordouw, G., 2002: Microbial systems in sedimentary environments of continental margins. In: Wefer, G., Billet, D., Hebbeln, D., Jørgensen, B.B., Schlüter, M., and Weering, T.C. (Eds.): *Ocean Margin Systems*. Springer, Berlin, 479-495.

Bohrmann, G., Suess, E., Greinert, J., Teichert, B., and Naehr, T., 2002: Gas hydrate carbonates from Hydrate Ridge, Cascadia margin: Indicators of near-seafloor clathrate deposits. *Proc. 4th Intl. Gas Hydrate Research Conf.*, Yokohama, Japan, 102-107.

Dullo, W.-Chr., Bernoulli, D., and Franke, W., 2002: Preface. In: Milestones in Geosciences. *International Journal of Earth Sciences - Geologische Rundschau*, **91**, 1.

Frentzel-Beyme, B.Z., and **Köster, F.W.**, 2002: On the biology of the sharpnose sevengill shark *Hetranchias perlo* (BONNATERRE 1788) from the Great Meteor Seamount (central eastern Atlantic). In: Vacchi, M., La Mesa, G., Serena, F., and Seret, B. (Eds.): *Proceedings 4th Europ. Elasm. Assoc. Meet.* ICRAM, ARPAT & SFI, Livorno, Italy, 77-96.

Froese, R., and Garilao, C.V., 2002: An annotated checklist of the elasmobranches of the South China Sea, with some global statistics on elasmobranch biodiversity, and an offer to taxonomists. In: Fowler, S.L., Reed, T.M., and Dipper F.A. (Eds.): *Elasmobranch biodiversity, conservation and management*: *Proceedings of the international seminar and workshop, Sabah, Malaysia*. IUCN, Gland, Switzerland, 82-85.

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Schott, F., (guest editor), 2002: Foreword. In: Milliman J. (Ed.): *Physical Oceanography of the Indian Ocean during the WOCE period*. *Deep Sea Research II*, **49** (7-8), Pergamon.

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Möllmann, C., Temming, A., Hirche, H.-J., **Stepputtis, D.**, Bernreuther, M., and Köster, F.W., 2004: Fish predation control of key copepod species in the Bornholm Basin. *ICES Council Meeting*, Vigo, Spain, **L:28**, 17 pp.

Neuenfeld, S., **Hinrichsen, H.-H.**, and Nielsen, A., 2004: A method to geolocate eastern Baltic cod by using Data Storage Tags (DSTs). *ICES Council Meeting,* Vigo, Spain, **L:06.**

Peck, M., **Clemmesen, C.**, Herrmann, J.-P., Stäcker, S., and Temming, A., 2004: The feeding-growth relationship in post-larval Baltic sprat (*Sprattus sprattus*): Comparison of somatic, nucleic acid- and otolith-based growth rates. *ICES Council Meeting,* Vigo, Spain, **L:25**, 21 pp.

Peinert, R., Bayrhuber, H., and **Lochte, K.**, 2004: Ozean und der globale Kohlenstoffkreislauf. *Praxis der Naturwissenschaften Biologie in der Schule*, **3**/53, 23-28.

Petereit, P., **Clemmesen, C.**, **Kraus, G.**, and **Schnack, D**., 2004: High resolution temperature influences on egg and early larval development of Baltic cod (*Gadus morhua*). *ICES Council Meeting*, Vigo, Spain, **K:03**, 12 pp.

Schulz, K., and **Riebesell, U.**, 2004: Der ozeanische Kalkregen. *Naturwiss. Rundsch.*, **678** (12), 686-688.

Stepputtis, D., 2004: Distribution of herring and sprat in the Baltic Sea in relation to physical features. *ICES Council Meeting*, Vigo, Spain, **L:23**, 10 pp.

Storch, S., Hillis-Starr, Z., and **Wilson, R. P.**, 2003: Caribbean round-trip ticket: the migration behavior of female hawksbill turtles recorded using data loggers. In: Seminoff, J.A. (Ed.): *Proceedings of the Twenty-Second Annual Symposium on Sea Turtle Biology and Conservation*. U.S. Dept. Commerce, NOAA Tech Memo NMFS-SEFSC-503, p. 54-55.

Ueberschär, B., 2004: Still a challenge: machine translation in the 21st century. *ENBI-Newsletter*, **1**, 12-23 pp.

Voss, R., **Clemmesen, C.**, Baumann, H., and Dickmann, M., 2004: Recruitment sucesss in Baltic sprat: coupling of food availability, larval condition and survival. *ICES Council Meeting*, Vigo, Spain, **O:02**, 16 pp.

Wegner, **C.**, Hölemann, J., and Churun, V., 2004: The Russian-German TRANSDRIFT IX Expedition of RV "Ivan Kireyev" 2003. In: Schirrmeister, L. (Ed.) Expeditions in Siberia in 2003. *Reports on Polar and Marine Research*, **489**, 210-231.

Worm, B., and **Lotze, H.K.**, 2004: Ecosystem impact and management of fisheries in Canadian Marine Protected Areas. World Wildlife Fund, Toronto, Canada.

Zillmer, M., 2004: Seismic reflections at the KTB site. *DGG-Mitteilungen*, (Sonderband G. Müller Kolloquium).

Zumholz, K., Hansteen, T.H., and **Piatkowski, U.**, 2004: Trace element variations in cephalopod statoliths – a natural internal tag for tracking migrations? *HASYLAB Annual Report, Deutsches Elektronen-Synchroton DESY*.

7.7 Working Papers

2002

Hoffmann-Wieck, G., and Nakoinz, O., 2002: Die Schlei als ein bedeutendes geo-archäologisches Archiv der Landesgeschichte Schleswig-Holsteins. In: Daschkeit, A., and Sterr, H. (Eds.): *Aktuelle Ergebnisse der Küstenforschung*. 20. Tagung des Arbeitskreises Küsten und Meere 30.05.-01.06.2002 in Kiel. Berichte, Forschungen des Forschungs- und Technologiezentrums Westküste.

2003

Bumke, K., and **Clemens, M.**, 2003: APOLAS: Sub-project precipitation measurements over sea, new sensors and analysis. DEKLIM-Report, German Aerospace Center, Bonn, 244-245.

Bumke, K., **Clemens, M.**, Grassl, H., Pang, S., Peters, G., Seltmann, J.E.E., Siebenborn, T., and Wagner, A., 2003: APOLAS, Accurate areal precipitation measurements over land and sea. DEKLIM-report. German Aerospace Center, Bonn, 237-239.

Schott, F., Carton, J., Hazeleger, W., Johns, W., Kushnir, Y., Reason, C., and Xie, S.-P., 2003: TACE (Tropical Atlantic Climate Experiment): White paper for CLIVAR Atl. Panel.

2004

Billant, A., Desaubies, Y., Grit, C., **Send**, **U.**, and **Böhme**, **L.**, 2004: Sensor evaluation. In: Development of a realtime in situ observing system in the North Atlantic Ocean by an array of Lagrangian profiling floats. EU contract EVK2 CT – 2000 – 00087, Gyroscope Final Report, 38-45.

Guinehut, S., Larnicol, G., LeTraon, P.-Y., and **Send, U.**, 2004: Array and experiment design. In: Development of a realtime in situ observing system in the North Atlantic Ocean by an array of Lagrangian profiling floats, EU contract EVK2 CT – 2000 – 00087, Gyroscope Final Report, 14-23.

Hauschildt, H., and **Macke, A.**, 2004: Precipitable water in cloudy areas - feasibility study. In: Visiting Scientist Report within the SAF on Climate Monitoring, VS-PLAN 7.7.

Lankhorst, M., 2004: Technical behavior of APEX floats. In: Development of a realtime in situ observing system in the North Atlantic Ocean by an array of Lagrangian profiling floats. EU contract EVK2 CT – 2000 – 00087, Gyroscope Final Report, 34-37.

7.8 Electronic Publications

2002

Froese, R., and Pauly, D., 2002: FishBase. World Wide Web electronic publication, www.fishbase.org.

Froese, R., and Bisby, F.A., 2002: Species 2000 & ITIS catalogue of life: indexing the world's known species. CD-ROM, Los Baños, Philippines.

Sommer, U., 2002: Experimental systems in aquatic ecology. *Encyclopedia of Life Sciences*, art. 3180, www.els.net.

Ueberschär, B., and **Froese, R.**, 2002: LarvalBase. World Wide Web Electronic publication, www.larvalbase.org.

2003

Froese, R., Bisby, F.A., and Wilson, K.L., 2003: Species 2000 & ITIS catalogue of life 2003: indexing the world's known species. CD-ROM, Species 2000, Los Baños, Philippines.

2004

Becker, C., **Brepohl, D.,** Feuchtmayr, H., Zöllner, E., **Sommer, F., Clemmesen, C., Sommer, U.,** and Boersma, M., 2004: Impacts of copepods on marine seston and resulting effects on *Calanus finmarchicus* RNA/DNA ratios in mesocosm experiments. *Mar. Biol.*, World Wide Web Electronic publication: 10.1007/s00227-004-1459-7.

Hennings, I., **Herbers, D.,** Prinz, K., and Ziemer, F., 2004: First results of the OROMA experiment in the Lister Tief of the German Bight in the North Sea, EARSeL eProceedings, 3, 86-104. http://www.earsel.org/eProceedings.

Lankhorst, M., **Nielsen, M.**, and **Zenk, W.**, 2004: RAFOS float trajectories from the Labrador Sea Water level in the Iceland Basin, 1997-2003 (http://www.ifm-geomar.de/index.php?id=999&L=1).

8. Scientific Exchange and Cooperation

8.1 Expert Activities and Important Functions

Please note that not all functions extend over the complete reporting period 2002-2004. Specific years or partial coverage are indicated.

Bange, H.:
- Member, CARBOEUROPE (EU-Integrated Project) - initiative on greenhouse gas emissions from the European Coastal Zone.

Bauch, H.:
- Scientific secretary and member of the Steering Committee of the PAGES program QUEEN (Quaternary Environment of the Eurasian North) (until 2002).
- Member, Working Group on Arctic Shelf Seas - ICARP II (International Conference on Arctic Research Planning).
- Reviewer for NSF (USA), NERC (UK), NSERC (CDN), Research Council of Norway, and CFCAS (CDN)

Bialas, J.:
- Member, "Deck Gear" Committee, R/V MERIAN.

Böning, C.:
- Member, Scientific Steering Group of the World Ocean Circulation Experiment (WOCE) (until 2002).
- Chair, WGCM/CLIVAR Working Group on Ocean Model Development
- Chair, SFB 460 "Dynamik thermohaliner Zirkulationsschwankungen", CAU Kiel
- Member, JSC/CLIVAR Working Group on Coupled Modelling
- Member, Science Advisory Board of the German Climate Computer Centre (DKRZ)
- Member, Scientific Advisory Group, Community Earth System Models (COSMOS) initiative
- Reviewer for DFG, NSF US), NERC (UK)

Brandt, P.:
- Co-chair: Task-Team 6 "Oceanic campaigns" International AMMA-Program; chair of the project "Oceanic Processes" European AMMA-Program.

Brückmann, W.:
- Member, Steering Committee, International Research Consortium for Continental Margins (IRCCM)
- German Representative, Steering Committee, "International MARGINS Program" (InterMARGINS)
- Reviewer for DFG, NSF (MARGINS Program), ODP & IODP (2002/03)

Bumke, K.:
Member, BALTEX Working Group on Energy and Water Cycles

Clemmesen, C.:
- Member, ICES WG Recruitment Processes
- Member, Deutsche Wissenschaftliche Kommission für Meeresforschung (DWK)

Dengg, J.:
- Member, "OPA System Developers Committee" (2004)

Devey, C.:
- Coordinator, DFG Priority Program 1144 "From the Mantle to the Ocean"
- Chair, International InterRidge Office
- Advisor, United Nations International Seabed Authority (since 2004)
- Member, "Senatskommission für Ozeanographie", Deutsche Forschungsgemeinschaft
- Co-Chair, DFG-Arbeitsgruppe zur „Freiheit der Meeresforschung"
- Reviewer for DFG, IFREMER, NERC
- Member. IUGC commission „Solid Earth Composition and Evolution (SECE)"

Diekmann, R.:
- Member, ICES WG Zooplankton Ecology

Dullo, W.-Chr.:
- Chair, Board of Governors, "Bildungsstiftung Schleswig-Holstein"
- Member, Executive Committee of the "Geologische Vereinigung"
- Member, "Senatskommission für Ozeanographie", Deutsche Forschungsgemeinschaft
- Member, "Bibliotheksausschuss", Deutsche Forschungsgemeinschaft
- German representative, Commission internationale pour l'éxploration scientifique de la mer Méditerranée (CIESM)
- Member, Scientific Advisory Committee, "Forschungsdialog: System Erde" at the "Institut für Pädagogik der Naturwissenschaften (IPN), Kiel"
- Member, Steering Committee IRCCM, IUB-Bremen
- Chair, Advisory Board of the "Deutsches Meeresmuseum" Stralsund
- Founding member and Vice Chairman of the "Maritimes Forum Kiel"
- Chair, "Vereins zur Förderung der GeoUnion Alfred-Wegener-Stiftung" (since 2003)

- Chair, Annette Barthelt Stiftung
- Reviewer for DFG, NSF (USA), NIOZ (The Netherlands)
- Member, Award Committee for Humboldt- and Wilhelm Bessel Research Awards (Alexander von Humboldt Foundation)

Eden, C.:
- Reviewer for NSF (USA)

Eisenhauer, A.:
- Co-chair, Environmental Geochemistry Section, German Mineralogical Society
- Member, Associate SCOR Planning Group for GEOTRACES (since 2004)

Fischer, J.:
- Member, ARGO Steering Team (since 2004).

Flueh, E.:
- Member, SONNE Review Panel (BMBF)
- Member, Review Panel, CONACIT, Chile (2003)
- Member, Review Panel, CSIC, Spain (since 2003)
- Member, Review Panel, IRC, Ireland (2004)

Freitag, K.:
- Coordinator, International InterRidge Office

Freundt, A.:
- Scientific Secretary SFB 574 (since 2002)
- Reviewer for NSF (USA)

Froese, R.:
- Member, Species 2000 (Management Team)
- Member, International Committee Ocean Biogeographic Information System (OBIS)

Hanel, R.:
- Member, ICES WG Application of Genetics in Fisheries and Mariculture Group

Hansen, H.P.:
- Member, ICES/HELCOM SG-QAC (Steering Group on Quality Assurance of Chemical variables)

Hay, W.W.:
- Member, Scientific Advisory Board of the Netherlands School of Sedimentary Geology, Vreje Universiteit Amsterdam (since 2004).

Herzig, P.M.:
- Maritime Coordinator of the State of Schleswig-Holstein
- Chair, German Marine Research Consortium
- Member, "Senat und Hauptausschuss", Deutsche Forschungsgemeinschaft
- Member, Senate Commission on Geosciences, Deutsche Forschungsgemeinschaft
- Member, Executive Board, International Marine Minerals Society, USA
- Elected Reviewer, Deutsche Forschungsgemeinschaft
- Advisor, United Nations International Seabed Authority
- Member, Scientific Advisory Board, GeoForschungsZentrum Potsdam
- Chair, Review Board, R/V METEOR cruises & projects, Deutsche Forschungsgemeinschaft
- German Representative, Interim Planning Committee, ODP/IODP
- German Representative, Interim Science Committee, ODP/IODP

Hinrichsen, H.-H.:
- Co-chair, ICES Study Group on Closed Spawning Areas of Eastern Baltic Cod
- Member, ICES Study Group on Incorporation of Process Information into Stock-Recruitment Models
- Member, ICES WG Modeling of Physical/Biological Interactions

Hoernle, K.:
- Member, SONNE Review Panel, BMBF
- Member, InterRidge Work Group "Ridge-Hotspot Interaction"
- Reviewer for DFG, NSF (USA), NERC (UK), ARC (Australia), Swiss Research Council

Hoffmann-Wieck, G.:
- Politikberatung für die Abt. Küstenschutz des Innenministeriums (2003)

Hoppe, H.-G.:
- Member, "Vereinigung für Allgemeine und Angewandte Mikrobiologie: Arbeitsgruppe Wasser/Abwasser"

Imhoff, J.F.:
- Member, International Committee on Systematic Bacteriology, subcommittee on the Taxonomy of Bacteria
- German representative, The European Society for Marine Biotechnology

Karstensen, J.:
- Reviewer for NSF (USA)

Kassens, H.:
- Chair, Working Group "Arctic Shelf Seas" of ICARP II
- Member, Nansen Arctic Drilling Program (NAD)
- Member, International Arctic Polynya Program (IAPP)
- Member, Working group Shelf-Basin Exchange Initiative (SBE)"
- Chair, Working Group "Arctic Shelf Seas" of ICARP II (International Conference on Arctic Research Planning) (since 2003)
- Member, German National Committee for the Scientific Committee on Antarctic Research and for the International Arctic Science Committee (LA SCAR/IASC) (since 2004)
- Coordinator, "BMBF-Verbundvorhabens System Laptev-See"
- German Representative, Otto-Schmidt-Laboratory for Polar- and Marine Research St. Petersburg, Russia

Körtzinger, A.:
- Member, International IMBER Steering Committee

- Member, Transition Team, IMBER (Integrated Marine Biogeochemistry and Ecosystem Research) (until 2004)
- Member, Task Team, SOLAS-IMBER Carbon Panel (since 2004)
- Member, CLIVAR Atlantic Panel (since 2004)
- Member, Joint IMBER-SOLAS Carbon Implementation Panel (since 2004)

Köster, F.W.:
- Co-chair, ICES/GLOBEC North Atlantic Program and Regional Office
- Member, GLOBEC SPACC/IOC Study Group on the Use of Environmental Indices in the Management of Pelagic Fish Populations
- Member, Steering Committee, National GLOBEC-Program in North Sea and Baltic
- Member, "Deutsche Wissenschaftliche Kommission für Meeresforschung (DWK)"

Kraus, G.:
- Member, ICES Planning Group on Cod and Plaice Egg Surveys in the North Sea
- Member, ICES Study Group on Baltic Fish and Fisheries Issues in Support of the Baltic Sea Regional Project
- Member, ICES Study Group on Baltic Herring and Sprat Maturitiy
- Member, ICES WG Baltic Fisheries Assessment Working Group
- Northwest Atlantic Fisheries Organization (NAFO): Scientific Council Working Group on Reproductive Potential, TOR Co-leader

Kubetzke, U.:
- Co-chair, Deutscher Rat für Vogelschutz

Latif, M.:
- Member, Scientific Advisory Board, International Research Institute for Climate Prediction, Palisades, USA
- Member, JSC/CLIVAR Working Group on Coupled Modeling
- Reviewer, Austrian Climate Program "Startclim" (since 2004)
- Reviewer, BMBF-Program "ACSYS" (Arctic Climate System Study) (since 2004)

Lehmann, A.:
- Member, DFN Society (Deutsches Forschungsnetz Verein)
- Member, BALTEX Scientific Steering Group
- Member, BALTEX Working Group on Energy and Water Cycles
- Chair of Writing Team BALTEX Phase II Implementation Plan

Lochte, K.:
- Member, Wissenschaftsrat
- Vice-chair, Scientific Committee of IGBP (International Geosphere-Biosphere Program)
- Ch-chair, National Committee for Global Change Research
- Chair, Senate Commission of the German Research Council (DFG) for Oceanography
- Chair, Scientific Advisory Committee, Institute for Chemistry and Biology of the Sea (ICBM), University Oldenburg
- Member, Scientific Advisory Committee, Alfred-Wegener-Institute for Polar- and Marine Research (AWI), Bremerhaven (until 2003)
- Member, Scientific Advisory Committee, Potsdam Institute for Climate Impact Research (PIK)
- Member, Scientific Advisory Committee of the Royal Netherlands Institute for Sea Research (NIOZ) (until 2004)
- Member, Selection committee for WGL Research Awards
- Chair, Scientific Advisory Board of the Annette-Barthelt Foundation

Macke, A.:
- Member, GEWEX Radiation Panel
- Member, METEOSAT Third Generation Mission Team
- Reviwer, Department of Energy (DOE), USA
- Reviewer, Cambridge University Press, Academic Press, NERC (UK)
- Convener, EGU sessions (multiple)

Müller, T.:
- German Representative, Ocean Facilities Exchange Group in the Tri-Partite Agreement (OFEG)
- Member, Ocean Facilities Working Group (OFEG), Marine Board, European Science Foundation, (ESF)
- Member, "Bund-Länder Arbeitsgruppe Deutsche Forschungsschiffe (BLAG)"

Noé, S.U.:
- Active Member of the New York Academy of Sciences
- Member (Professional), of the American Association for the Advancement of Science

Oschlies, A.:
- Member, JGOFS Global Synthesis Working Group (until 2003).
- Reviewer for National Science Foundation (USA), NERC (UK & CDN)
- Reviewer "Forschergruppe WATT", DFG

Pfannkuche, O.:
- Scientific Advisory Committee of George Deacon Division, Southampton Oceanographic Centre, UK. (since 2003)
- Member, Steering Committee of ESONET (European Sea Floor Observatory Network) (since 2003)
- Chair, Advisory Board "Zentrum für angewandte Meereswissenschaften, Kiel"
- IFM-GEOMAR representative "Gesellschaft für marine Technologie (GMT)"

Piatkowski, U.:
- German representative, ICES Living Resources Committee
- Member, ICES WG Biology and Assessment of Deep-Sea Fisheries Resources
- Member, ICES WG Cephalopod Life Cycles and Fisheries
- Member, ICES WG on Elasmobranch Fishes
- Member, Deutsche Wissenschaftliche Kommission für Meeresforschung (DWK)
- Member, Scientific Steering Committee, Census of Marine Life (CoML) pilot project: Patterns and processes of the ecosystems of the northern mid-Atlantic (MAR-ECO)
- Reviewer, Natural Environment Research Council (NERC), UK

Ranero, C.:
- Member, Scientific Committee, ESF-Euromargins (since 2004)
- Secretary, Tectonic and structural geology Section of European Geoscience Union
  Reviewer, NSF (USA) (since 2004)

Reijmer, J.G.:
- Université Claude Bernard, Lyon, France: External Graduate Student Advisor (2003)
- Vrije Universiteit, Amsterdam, The Netherlands: External Graduate Student Advisor (2003)

Reston, T.:
- Chair, SFB 574: Volatiles and Fluids in Subduction Zones, (since 2004)
- German Representative, Scientific Steering Committee, ESF-Euromargins (2002)
- Member, Marine Studies Group of the Geological Society of London, UK
- Reviewer IFREMER, IODP and UK-NERC proposals

Riebesell, U.:
- Chair, Task Team, SOLAS-IMBER (since 2004)
- Member, Faculty of 1000 (www.facultyof1000.com) (since 2004)

Rohlf, N.:
- Member, ICES Herring Assessment Working Group
- Member, ICES Planning Group on Cod and Plaice Egg Surveys in the North Sea
- Member, ICES Planning Group for Herring Surveys in the North Sea

Rumohr, H.:
- Associate member, "Deutsche Wissenschaftliche Kommission für Meeresforschung" (DWK)
- Member, International Council for the Exploration of the Seas (ICES)
- Chair, ICES Benthos Ecology Working Group
- Chair, ICES Marine Habitat Committee
- Ex-officio member, ICES Consultative Council (CONC), ICES Advisory Committee Marine Environment (ACME), ICES Advisory Committee Environment (ACE)

Ruprecht, E.:
- Elected reviewer at the DFG
- Reviewer for the Bavarian Government on "Erhöhte UV-Strahlung in Bayern: Folgen und Maßnahmen" (until 2004)
- Reviewer for the "Deutscher Wetterdienst" (until 2003)
- Representative of German Meteorological Society to the German Physical Society

Schmidt, J.O.:
- Member, ICES WG Zooplankton Ecology

Schnack, D.:
- Chair, "Deutsche Wissenschaftliche Kommission für Meeresforschung" (DWK)
- Member, ICES, Council of national delegates
- Member, ICES Planning Group for Herring Surveys in the North Sea
- Member, Scientific Advisory Board, "Deutscher Fischereiverband"
- Member, International Advisory Board of POLMARF of the Sea Fisheries Institute MIR, Gdynia, Poland

Schott, F.:
- Member, Senate, "Deutsche Forschungsgemeinschaft"
- Member, CLIVAR Atlantic Panel
- Chair, SFB 460 "Dynamik thermohaliner Zirkulationsschwankungen", CAU Kiel (until 2002)
- Coordinator, BMBF-Project CLIVAR/marin (until 2002)
- Member, National Committee for Global Change Research (until 2003)
- Member, DFG Senate Commission for Oceanography (until 2004)
- Chairman, Advisory Board "METEOR"(until 2004)
- Adviser, Brazil Atlantic Climate Program (2004)
- Reviewer, CLIVAR Self Assessment (2004)
- Reviewer, German Climate Computer Center (DKRZ) (2004)
- Reviewer for DFG, NSF (USA), NOAA (USA), NERC (UK), Norwegian Res. Council, Dutch Council for Earth and Life Sciences

Schönfeld, J.:
- Member, Sub-Commission of Cretacious-Stratigraphy, German Stratigraphic Commission
- Reviewer for projects of NSF (USA), NERC (UK), NSERC (CDN), Research Council of Norway
- Reviewer for Leverhulme Trust (2003)
- Member, Invited co-supervisor for the Portuguese Science Foundation (2004)

Sommer, U.:

- Chair, Board of Trustees, Max-Planck-Institute of Limnology
- Coordinator, DBU (German Foundation for the Environment) priority program Baltic Sea
- Coordinator, DFG priority program 1162 "AQUASHIFT"

Send, U.:
- Member, ARGO International Science Team (until 2003)
- Member, CLIVAR Ocean Observation Panel (until 2003)
- Co-Chairman of Science Team for a Global Time-series Observatory System (until 2003)
- Coordinator, EU-Project ANIMATE
- IFREMER (Brest): Invited external expert for the evaluation of the LPO-Institute (2002)
- CNRS, Paris: Invited external Reviewer for the evaluation of French research projects
- Reviewer, National Science Foundation (USA)
- Reviewer, National Research Council (NRC) (USA) (until 2003/04)
- Member, MERSEA Executive Committee (since 2004)
- Subcoordinator, EU Project MERSEA WP3 (since 2004)

Spielhagen, R.F.:
- Member, Steering Committee of CARE (Climate of the Arctic and its Role for Europe) project (EU Specific Support Action)
- Member, Steering Committee of APEX initiative (Arctic Paleoclimate and its Extremes)
- Reviewer, NSF (USA)

Suess, E.:
- Member, Board of Directors, Geochemical Society (until 2004)
- Chair, SFB 574: Volatiles and Fluids in Subduction Zones (until 2004)
- Managing Director, German Marine Research Consortium (since 2004)

Tiedemann, R.:
- Member, IODP WG "Climate and Tectonics"

Timmermann, A.:
- Member, Steering Committee of "Laboratori de Recerca del Clima, Universitat de Barcelona", Spain
- Secretary of the "Nonlinear Processes in Geophysics Section" of the EGU
- Reviewer, CLIVAR/NOAA (USA) proposals
- Reviewer, NERC/NWO proposals
- Convener, EGU sessions (multiple)

Trippel, E.A.:
- Member, American Fisheries Society: Canadian Aquatic Resources Section
- Member, American Fisheries Society: Resource Policy Committee
- Chairman, Northwest Atlantic Fisheries Organization (NAFO), Scientific Council Working Group on Reproductive Potential
- Reviewer, Memorial of University of Newfoundland
- Member, Nova Scotia Aquaculture Development Committee
- Member, US National Oceanic and Atmospheric Administration (NOAA): Gulf of Mexico Marine Mamal State Assessments
- Member, US National Oceanic and Atmospheric Administration (NOAA): Scientific Review Group for U.S. Atlantic

Tomkiewicz, J.:
- Member, ICES WG Baltic Fisheries Assessment Working Group
- Northwest Atlantic Fisheries Organization (NAFO): Scientific Council Working Group on Reproductive Potential, TOR Co-leader

Voss, R.:
- Member, GLOBEC SPACC/IOC Study Group on Regional Scale Ecology of Small Pelagic Fish
- Member, ICES Study Group on Baltic Fish and Fisheries Issues in Support of the Baltic Sea Regional Project
- Member, ICES Study Group on Multispecies Assessments in the Baltic
- Member, ICES Study Group on Closed Spawning Areas of Eastern Baltic Cod
- Member, ICES Study Group on Multispecies Model Implementation in the Baltic

Visbeck, M.:
- Chair, CLIVAR Atlantic Panel
- Member, NOAA-OAR/OGP Climate observing system council
- Member, COPES Task Force (World Climate Research Programme)
- Reviewer, NSF (USA), NOAA (USA), NERC (UK)
- Reviewer, NERC-RAPID (UK)

Wallace, D.W.R.:
- Chair, IOC/SCOR Ocean CO_2 Panel (until 2004)
- Member, SOLAS International Steering Committee
- Member, International SOLAS Executive Committee
- Member, IGBP, Ocean Futures (now IMBER) Planning Group (until 2002)
- Member, UK SOLAS Steering Committee (since 2003)
- Chair, SOLAS Data Management Task Team (since 2004)
- Chair, CarboOcean Integrated Project (since 2004)
- Coordinator, Meteor 55 Expedition
- Coordinator, Meteor 60 Expedition
- Member, Scientific Advisory Board, Inst. Baltic Sea Research, Warnemünde

Waller, U.:
- Member, Deutsche Wissenschaftliche Kommission für Meeresforschung (DWK)

Willebrand, J.:
- Co-chair, CLIVAR Scientific Steering Group (until 2003)
- Member, Scientific Advisory Board, Plymouth Marine Laboratory
- Member, Stammkommission Max-Planck-Institute für Meteorologie Hamburg (until 2003)
- Convening Lead Author, IPCC Fourth Assessment Report
- Reviewer NSF (USA), NOAA (USA), NERC (UK), NSERC (CDN), DFG, BMBF

Wilson, R.:
- Member, Environmental review committee regarding work conducted in Antarctica for the Federal Ministry for the Environment, Nature Protection and Reactor Safety, Germany
- Member, Marine Sciences Peer Review Committee for NERC, UK
- Member, Scientific Steering Committee for Tagging of Pacific Pelagics (TOPP) in the Census of Marine Life Project
- Responsible for birds in the NEO European initiative

Zenk, W.:
- Member, Ocean Observations Panel for Climate (until 2003)
- Member, BMBF Steering Group "Mittelgroße Forschungsschiffe"
- Reviewer, NSF (USA)

Zumholz, K.:
- Member, ICES WG Cephalopod Life Cycles and Fisheries

8.2 Editorial Boards

Devey, C.:
- Journal of Petrology (Editorial Board).

Dullo, W.-C.:
- International Journal of Earth Sciences (Chief-Editor).
- Marine Ecology (Associate Editor).
- FACIES (Associate Editor).

Eisenhauer, A.:
- The Scientific World (Co-Editor).

Flöder, S.:
- Oecologia, Limnology and Oceanography

Froese, R.:
- Acta Ichthyologica et Piscatoria (Editorial Board).
- Journal of Applied Ichthyology (Editorial Board).

Gocke, K.:
- Anales del Instituto de Ciencias del Mar y Limnologia, Mexico (Editorial Advisor).
- Anales del Instituto de Investigaciones Marinas de Punta de Betin, Columbia (Editorial Advisor).
- Revista de Biologica Tropical, Costa Rica. (Editorial Advisor).

Herzig, P.M.:
- Mineralium Deposita (Editorial Board, until 2003)

Hoernle, K.:
- Journal of Volcanology and Geothermal Research (Editorial Board)

Hoppe, H.-G.:
- Aquatic Microbial Ecology, Germany (Review Editor).
- Marine Ecology Progress Series (Review Editor).
- The Journal of Microbiology, Korea (Advisory Board).

Imhoff, J.F.:
- International Microbiology.

Kubetzki, U.:
- Berichte zum Vogelschutz (Editor).

Latif, M.:
- Journal of Climate (Editor, until 2003).

Lochte, K.:
- Aquatic Microbial Ecology (Subject Editor, until 2004).

Riebesell, U.:
- Biogeosciences (Co-Editor).
- Journal of Sea Research.

Rosenthal, H.:
- Journal of Applied Ichthyology (Chief-Editor).

Schnack, D.:
- Archive of Fishery and Marine Research: (Editorial Board).
- Journal of Applied Ichthyology (Editor).

Sommer, U.:
- Aquatic Sciences
- Basic and Applied Ecology
- Ecological Studies
- Ecology Letters
- International Review of Hydrobiology
- Oecologia
- Protist

Suess, E.:
- Geochemistry, Geophysics, Geosystems (Editorial Board).

8.3 Prizes, Awards and Honorary Titles

Apart from publications and funded research proposals, prizes, awards and honorary titles reflect the success of IFM-GEOMAR staff members over the past years. The following IFM-GEOMAR staff has received awards and honors during the reporting period.

Baumann, H.:
- The Sally Leonard Richardson Award of the Early Life History Section of the American Fisheries Society, 2002.
- Annette-Barthelt Award for Marine Sciences, 2003

Dullo, W.-Chr.:
- Leibniz-Award, Deutsche Forschungsgemeinschaft, 2002.
- Member Deutsche Akademie der Naturwissenschaften LEOPOLDINA, 2004.

Froese, R.:
- Pew Marine Fellowship Award for Marine Conservation, Pew Foundation, USA, 2003.

Gussone, N.:
- Annette-Barthelt Award for Marine Sciences 2004

Hämmerli, A.:
- Wilhelmshaven Award for Marine and Coastal Research, 2002.

Latif, M.:
- Sverdrup Gold Medal, American Meteorological Society, 2002.
- Fellow, American Meteorological Society, 2002.
- Umweltpreis, Deutsche Umwelthilfe, 2004.

Rosenthal, H.:
- Honory Professorship, University of Szczecin (Poland), 2003.

Schmincke, H.-U.:
- Alexander von Humboldt Award of the JSPS (Japan Society for the Promotion of Science) 2003.
- Honory Member, IAVCEI (International Association of Volcanology and Chemistry of the Earth`s Interior), 2004.

Schott, F.:
- AGU Editor's Award for Excellence in Refereeing, 2002.
- Henry Stommel Research Award, American Meteorological Society, 2004.
- Fellow, American Meteorological Society, 2004.

Siedler, H.:
- Humboldt Award of the South African National Research Foundation, 2004.

Suess, E.:
- Gustav-Steinmann Medal of the Geologische Vereinigung, 2004.
- Honorary Professorship, University of Ganzhou, China, 2004.

Ueberschaer, B.:
- Research Award for Larval Base Project from Aktion Seeklar, 2002.

Worm, B.:
- Heinz-Meier-Leibnitz Award for Excellence in Research, Deutsche For-schungsgemeinschaft, 2004.

8.4 Patents

Bringmann, G. Lang, G., Gulder, T., Müller, W.E.G., Perovic, S., Schaumann, K., **Imhoff, J.F., Stöhr, R., Wiese, J.**, and **Schmaljohann, R.**, 2004: Verfahren zur Produktion und Aufreinigung von Sorbicillacton A, Germany, DE 10 2004 004 901.7.

Bringmann, G. Lang, G., Gulder, T., Schaumann, K., Steffens, S., **Imhoff, J.F.,** Müller, W.E.G., and Perovic, S.,, 2004: Sorbifuranone, Sorbetvinon, Sorbetvinol und Derivate dieser Verbindungen, Verfahren zu ihrer Herstellung, sie enthaltende Arzneimittel und deren Verwendung, Germany, DE 10 2004 005 106.2.

Eisenhauer, A., 2002: Anlage zum Kontaminationsfreien Eindampfen von Flüssigkeiten, Verfahrenspatent, Germany, Deutsches Patent- und Markenamt, Deutschland, DE200 10 381.4.

Petrick, G., 2003: Verfahren zum Austreiben von Gasen und leichtflüchtigen Substanzen aus Wasser mittels Hochfrequenz, Germany, Deutsches Patent- und Markenamt, DE000010164434A1.

Petrick, G., 2003: Verfahren zur Steigerung der quantitativen Ausbeute der Umwandlung von Methan zu Kohlendioxid mittels Oxidationskatalysatoren im „continous flow" Betrieb für die Analyse des stabilen Isotop δ^{13} Kohlenstoff Germany, Deutsches Patent- und Markenamt, DE000010164426A1.

Purkl, S., and **Eisenhauer, A.**, 2003: Vorrichtung zur Extraktion von Stoffen von einer Membran, Verfahrenspatent, Germany, Deutsches Patent- und Markenamt, Deutschland, DE201 14 558.8.

8.5 Visitors at IFM-GEOMAR

Apart from the institute colloquia and the SFB seminars (see Section 8.7) IFM-GEOMAR welcomed a large number of visitors during the reporting period. Highlights in this context were the following scholarship and grant holders spending long-term visits to the institute:

Belousov, A.: Russia, Humboldt Fellowship, April 2000 October 2003.

Berg, M.: USA, Humboldt Postdoctoral Fellowship, October 2001-October 2003.

Cronin, S.: New Zealand, Humboldt Fellowship, August 2001-January 2003.

Langlois, R.: USA, Fulbright Scholarship, August 2002 - February 2004.

Pinegina, T.: Humboldt Fellowship, Russia, October 2002-October 2003.

Ridame, C.: France, Marie-Curie-Individual-Fellowship, 25.3.2002-08.07.2003.

Siebe, C.: Humboldt Fellowship, Mexico, 01.09.2001-31.08.2002.

Tanhua, T.: Sweden, Marie-Curie-Individual-Fellowship, 01.09.2002-31.08.2004.

Worm, B.: Germany, Emmy-Noether-Fellow, 2000-2004).

A list of all visitors (staying longer than two weeks) from 2002-2004 is given in electronic Appendix E4.

8.6 Visits of IFM-GEOMAR Staff to other Institutions

IFM-GEOMAR staff members visit regularly partner institutions around the world as part of a sabbatical or extended research visit. These visits have fostered the cooperation between IFM-GEOMAR and marine research institutions world-wide and resulted in a number of high-level publications. A list of all visits (longer than two weeks) is given in electronic Appendix E4.

8.7 Colloquia & Seminars at IFM-GEOMAR

The institute colloquia and the SFB seminars are a main route for attracting a regular stream of visiting academics. A list of colloquia and SFB seminars is provided in the electronic Appendix E4.

8.8 Events

8.8.1 Conferences & Workshops at IFM-GEOMAR

Böning, C.: DRAKKAR Meeting, 06.03.-08.03.2003.

Böning, C.: "Workshop on North Atlantic Thermohaline Circulation Variability", 13.09.-16.09.2004.

Böning, C.: DRAKKAR Meeting, 16.09.-17.09.2004.

Bower, A., and **Zenk, W.**: OOPC VII Meeting, 05.06.-09.06.2002.

Eisenhauer, A.: Workshop "Ca-Isotopes: Fractionation and Application", 02.12.-04.12.2004.

Froese, R., and **Opitz, S.**: ECOFISH Summary Workshop. 23.05.-26.05.2004.

Froese, R.: Maps for All Marine Species, Programmers Workshop. 02.12.-03.12.2004.

Kassens, H., Biebow, N., **Georgeleit, K.**, **Heilemann, K.**, **Volkmann-Lark, K.**, **Klagge, T.**: International Conference "Climate Drivers of the North", 08.05.-11.05.2002.

Kassens, H., Volkmann-Lark, K.: 7th Workshop of the Otto-Schmidt-Laboratory for Polar- and Marine Research, 02.12.-04.12.2004.

Kraus, G.: ICES Planning Group on Cod and Plaice Egg surveys in the North Sea, 11.01.-12.01.2004.

Latif, M.: EU-Project "DEMETER", Final Workshop, 07.07.-08.07.2003.

Latif, M.: EU-Project "PREDICATE", 10.02.-13.02.2003.

Lochte, K., and **Herrmann, A.**: German JGOFS Workshop, 26.-27.09.2002.

Lochte, K., and **Herrmann, A.**: German JGOFS Workshop, 12.-13.06.2003.

Piatkowski, U.: 13. Verleihung des Annette-Barthelt-Preises für Meeresforschung zum Gedenken an die Terroropfer von Djibouti, Annette Barthelt, Daniel Reinschmidt, Marco Buchalla und Hans-Wilhelm Halbeisen. 16.03.2002.

Piatkowski, U.: 14. Verleihung des Annette-Barthelt-Preises für Meeresforschung zum Gedenken an die Terroropfer von Djibouti, Annette Barthelt, Daniel Reinschmidt, Marco Buchalla und Hans-Wilhelm Halbeisen, 22.03.2003.

Piatkowski, U.: 15. Verleihung des Annette-Barthelt-Preises für Meeresforschung zum Gedenken an die Terroropfer von Djibouti, Annette Barthelt, Daniel Reinschmidt, Marco Buchalla und Hans-Wilhelm Halbeisen. 20.03.2004.

Ranero, C.: Workshop CRISP Costa Rica Seismogenesis Proposal, 20.-22.10.2003.

Schönfeld, J.: International Conference "The Micropalaeontological Society – Foram Group Meeting, 25.04.-26.04.2003.

Schott, F.: CLIVAR "Tropical Atlantic Workshop", 19.08.-22.08.2002.

Send, U., and **Zenk, W.**: "MERSEA, First stand alone meeting", 19.09.-22.10.2004.

Ueberschär, B.: ENBI – 1st Workshop on Multilingual Access to European Biodiversity Sites, 06.10.-07.10.2003.

Ueberschär, B.: ENBI – 2nd Workshop on Multilingual Access to European Biodiversity Sites. 20.09.-21.09.2004.

8.8.2 External conferences/workshops (co)-organised by IFM-GEOMAR scientists

Bialas, J.: EU - Crimea Gas Hydrate Workshop, "The Central and South American Trench System", European Geophysical Society 2003, Nice, France, 06.-11.04.2003.

Busalacchi, T., Overpeck, J., Palmer, T., Shukla, J., Takeuchi, K., Trenberth, K., **Willebrand, J.**, and Wu, G.: International CLIVAR Conference, 20.06.-25.06.2004, Baltimore, U.S.A.

Devey, C.W., and **Lackschewitz, K.**: 1. Workshop SPP1144, Etelsen, Germany, "Vom Mantel zum Ozean", 01.-03.06.2004.

Dullo, W.-Chr., Biebow, N., and **Georgeleit, K.**: 5th Project-workshop "Fifth Workshop on Russian-German Cooperation in the Sea of Okhotsk - Kurile Island Arc System KOMEX II", Pacific Oceanological Institute of the Far eastern branch of the Russian Academy of Sciences, Vladivostok, Russia, 27.05.-30.05.2004.

Froese, R., and **Opitz, S.**: Expert Workshop on Further Integration of FishBase and Ecopath with EcoSim, La Paz, Mexico, 02.03.-05.03.2004.

Froese, R., and **Opitz, S.**: Expert Workshop on Harmonization of Aquatic Biodiversity Databases, Barcelona, Spain, 29.09.-01.10.2003.

Froese, R., and **Opitz, S.**: Expert Workshop on Indicators for Sustainable Fisheries Management, Dakar, Senegal, 14.04.-16.04.2003.

Froese, R., and **Opitz, S.**: Expert Workshop on Involving the Public in Monitoring of Aquatic Biodiversity, Heraklion, Greece, 02.07.-04.07.2003.

Kassens, H., and **Volkmann-Lark, K.**: „8. Arbeitstreffen im Rahmen der deutsch-russischen Fachvereinbarung über die Zusammenarbeit auf dem Gebiet der Meeres- und Polarforschung", St. Petersburg, Russia, 11.11.-14.11.2003.

Kassens, H., Georgeleit, K., and **Volkmann-Lark, K.**: „9. Arbeitstreffen im Rahmen der deutsch-russischen Fachvereinbarung über die Zusammenarbeit auf dem Gebiet der Meeres- und Polarforschung", Helgoland, Germany, 15.12.-16.12.2003.

Kopp, H.: "The Central and South American Trench System" European Geophysical Society 2003, Nice, France, 06.-11.04.2003

Kubetzki, U.: 137. Jahresversammlung der Deutschen Ornithologen-Gesellschaft, Kiel, Universität Kiel, 29.09.-04.10.2004

Lampitt, R., and **Send, U.**: ANIMATE annual meeting, Southampton Oceanography Centre, Southampton, U.K., 28.01.-29.01.2004.

Lampitt, R., and **Send, U.**: ANIMATE final meeting, Southampton Oceanography Centre, Southampton, U.K., 27.09.-28.09.2004.

Llinas, O., Villargarcia, M., and **Send, U.**: ANIMATE annual meeting, ICCM, Telde, Gran Canaria, Spain, 23.01.-24.01.2003.

Lochte, K., and Siere, M-A.: Workshop: SCOR/IMAGES working group LINKS, 10.09.2004, Biarritz, France.

Molinari, R., and **Schott, F.**: CLIVAR Tropical Atlantic Workshop NOAA/AOML, 25.03.-27.03.2004, Miami, FL, U.S.A.

Send, U., and Weller, R.: The International Time Series Science Team meeting (with POGO sponsorship), Honolulu, Hawaii, U.S.A., 16.02.-18.02.2002.

Send, U., and Weller, R.: The International Time Series Science Team Meeting, Villefranche, France, 03.04.-05.04.2003.

Send, U., and Weller, R.: The International Time Series Science Team Meeting, Caribe Hilton, Puerto Rico, 06.01.-09.01.2004.

Valdimarson, H., and **Send, U.**: ANIMATE annual meeting, Marine Research Institute, Reykjavik, Island, 11.09.-12.09.2002.

Wallace, D.W.R., and **Körtzinger, A.**: Workshop "Towards a West-African Science Logistics Centre in Cape Verde", São Vicente, Cape Verde, 08.06.-10.06.2004.

8.9 Scientific Presentations

The communication of results to the scientific community is mainly through peer-reviewed publications in scientific journals and books, and through oral presentations and poster contributions at conferences and workshops. The electronic Appendix E4 provides a list of scientific lectures from IFM-GEOMAR scientists within the past three years.

9. Curricula and Teaching Activities

9.1 Introduction

9.1.1 Teaching and Education at the University of Kiel

As an institute "at the University of Kiel", IFM-GEOMAR contributes with personnel and facilities to teaching and education at the Faculty of Mathematics and Natural Sciences of the Christian-Albrechts-University (CAU) of Kiel. IFM-GEOMAR is responsible for the curricula in

a) Physical Oceanography (full curriculum)
b) Meteorology (full curriculum)
c) Biological Oceanography (advanced courses)
d) Fishery Biology (advanced courses)
e) Marine Chemistry (minor in Natural Sciences)

In addition, substantial contributions are made to teaching in Geosciences (Geology, Geophysics, and Mineralogy) and Microbiology (Biology).
A list of all teaching courses for the academic year 2003/2004 is given in electronic Appendix E5. Diploma and PhD students are frequently attracted through these curricula, and their contribution to the research work in the institute is substantial throughout all research divisions. During 2002-2004, the following qualifications were completed in the respective research divisions: 4 Habilitations, 61 PhD theses, and 115 diploma theses (cf. Section 7.5).

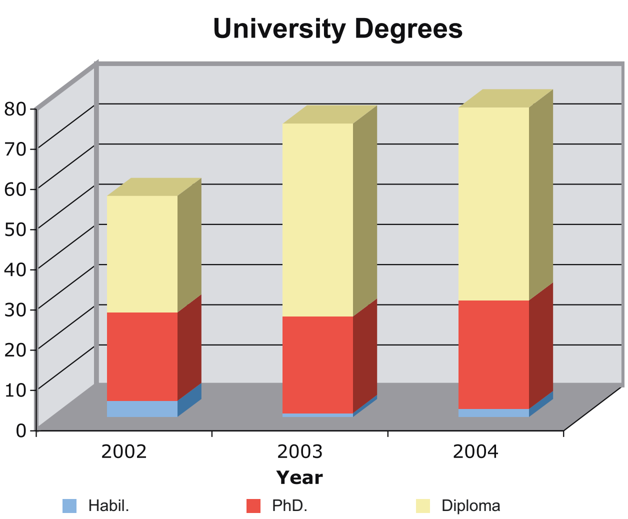


Fig. 1: University Degrees at IFM-GEOMAR.

9.1.2 International Education Programs

IFM-GEOMAR scientists are actively participating in a number of international education programs:

BIO-OCEAN is an EU-funded study program in Biological Oceanography carried out jointly with the University of Southern Denmark and offering an interdisciplinary combination of lectures, seminars and practicals which are held both in Kiel and in Odense, Denmark. All students participate in advanced courses in Biological Oceanography at both universities and obtain either the diploma in Biological Oceanography from the University of Kiel or the M.Sc. from the University of Southern Denmark. For more details, see Section 9.2.

In cooperation with national partners, two German-Russian initiatives for training exist:

POMOR is a DAAD-funded international master course at the St. Petersburg State University which aims at a high-level education of undergraduate students in actual and applied topics of modern polar and marine sciences For details see Section 9.3.

The BMBF-funded **Otto-Schmidt-Laboratory for Polar and Marine Research** in St. Petersburg, Russia held its first Spring School in April 2004, and provided support for 90 scientists from various Russian institutions.

GAME (Global Approach by Modular Experiments) is an international program funded by the Mercator Stiftung, Essen (www.stiftung-mercator.de) in which students obtain their diploma or master theses performing standardized experiments at different sites world-wide. The students work in German – non-German pairs during the entire project. Since 2002, over 40 students from 15 countries in five continents have participated in GAME. The project has 25 partners world-wide. For more details, see Section 9.5.

International SOLAS summer school: The IGBP and WCRP co-sponsored Surface Ocean Lower Atmosphere Study (SOLAS) is an interdisciplinary study of material exchanges between the atmosphere and the ocean, including the consideration of processes operating in the two boundary layers. This program requires the training of a new generation of interdisciplinary scientists with an appreciation of physical, biological and chemical processes in both the atmosphere and the ocean. IFM-GEOMAR contributed significantly to the first International Summer School held in Corsica in 2003.

Cooperation with China: Jointly with Christian-Albrechts University of Kiel and the University of Bremen, IFM-GEOMAR has started a cooperation with the Ocean University of China in Quingdao with the goal to establish a joint Sino-German Master Degree Program in Marine Sciences. High-level delegation visits took place in China and Germany, respectively. In order to proceed with the planning of this program, a position for a part-time science coordinator was established both, at IFM-GEOMAR and Bremen, respectively funded by the International Office of the BMBF. For more details see Section 9.6.

9.2 BIO-OCEAN - An International Study Program in Biological Oceanography

Since October 2003 the Christian-Albrechts-University of Kiel (CAU) in cooperation with the University of Southern Denmark (SDU) in Odense offers a joint international and multidisciplinary study program in Biological Oceanography (BIO-OCEAN). At the CAU this program is supported by IFM-GEOMAR. The project is co-financed by the structural fond program INTERREG IIIa of the European Union.

The students spend one term at each university, subsequently they complete their thesis and finish the study program after two years either with a Diploma in Kiel or a Master of Science in Odense. In Kiel the master degree will be established within the following years. Language of teaching is English. The performance of the students is evaluated according to the joint European ECTS – System (European Credit Transfer System).

The study program is open for all students of Biology. Admission requirements are the Bachelor of Science in Biology, or the German "Vordiplom" and two additional terms in Biology or the equivalent. Enrolement takes place during the winter term (20 study places are available). At present 30 students from 7 countries participate in the study program.

Apart from the scientific education in Biological Oceanography, Physical Oceanography, Marine Chemistry and Marine Geology the study program also encompasses economic and socio-political aspects of the marine environmental management. The program is designed to offer an excellent and comprehensive basis in Biological Oceanography for either a career in academic research, in applied marine sciences or in administration and resource management. The study program provides internationally recognized expertise in all disciplines of marine sciences from both Universities. An e-learning platform supports teaching and communication. Prominent part of the study program is a three-month internship in research institutes, marine orientated companies or in environmental agencies.

Students not only benefit from training in marine sciences, they improve their knowledge of the English language, conduct studies in different learning cultures and become familiar with different mentalities in small international student groups. These are important experiences for careers with an international orientation.

Contact:
Prof. Dr. Karin Lochte
Coordination: Dr. Stefan Sommer
e-learning: Dr. Dorothea Trapp
www.bio-ocean-study.com

9.3 POMOR – An Innovative Concept in the Study of Applied Marine and Polar Sciences

In modern science and on the academic labor market a key role is played by cooperation across disciplines, organizations and national borders. Cooperation safeguards competitiveness in an international competition. POMOR, a joint study program in applied marine and polar sciences headquartered at St. Petersburg State University Russia,, offers students the opportunity of increasing their value in this competition (Figure 1). As one aspect of continuing the centuries-old close connections between Russia and Germany, POMOR is an efficient means of promoting the cooperation in the field of education and research between these two countries and other European nations.

The program's major goal lies in providing young Russian students in their own country with an international training program based on the Bologna Agreement. The import of academic training and research programs from Germany and its western partners to their economically ambitious neighbor and partner Russia with its still young democracy safeguards scientific and economic cooperation between our nations in the long run.

Starting in fall 2002 the State University of Saint Petersburg has been offering the international English language Master Program POMOR. The program which lasts for two years was the first of its kind and fills a gap that has emerged in national and international research centers, universities, and companies. It imparts knowledge on the polar and marine environmental systems and applied aspects including the scientific approaches and methods of the various disciplines as, for instance, oceanography, marine geosciences and marine biology (Figure 2). After the second semester, students undertake a one-month internship in a German partner institution. During this time, the student will learn about the tools necessary to successfully conduct field research, working conditions, administrative procedures, and corporate culture. The final thesis is a scientific work which bridges the gap between science and the real-work practice of polar and marine projects and provides the students with that vital skill any international research center and university requires. POMOR has an intake of up to 20 students every two years. Students who successfully complete the program will be awarded the German and Russian degree „Master of Sciences in Applied Polar and Marine Sciences" of the Universities in Bremen and Saint Petersburg.

Figure 1: POMOR is a joint initiative of the Saint Petersburg State University (SPbU), the University of Bremen, the Alfred Wegener Institute for Polar and Marine Research and the IFM-GEOMAR in cooperation with the Association of Universities in Northern Germany (Universities of Bremen, Greifswald, Hamburg, Kiel, Oldenburg and Rostock) and the Baltic Sea Research Institute in Warnemünde.

POMOR is a logical result of and a major step in the intensifying cooperation with Russia, which developed right after Perestroika. Bilateral programs of climate research in the Siberian Arctic and the adjoining Arctic Ocean made it necessary to establish a state-of-the-art research laboratory in Russia where the obtained samples and data could be processed jointly. Consequently, in 1999, the German-Russian Otto Schmidt Laboratory for Polar and Marine Research was opened at the State Research Center for Arctic and Antarctic Research in St. Petersburg to safeguard the joint processing of top quality research results. As, however, it is also of major importance to

Figure 2: POMOR offers an opportunity for advanced students who want to finish their studies with a master degree in marine and polar sciences. The courses are divided into six modules and a general block. In addition, students are getting practical training at the cooperating universities and research institutes. Courses are mainly given at St. Petersburg State University in close cooperation with the Otto Schmidt Laboratory for Polar and Marine Research.

recruit highly qualified young scientists from Russia for the applied polar and marine sciences, German and Russian research centers and universities set up a project team to put their experience into the establishment of the joint study program POMOR, which opened in fall 2002. In the near future POMOR is planned to be opened also to students from Germany and other West European partner countries. POMOR is funded by DAAD (Export of German Academic Training), BMBF, AWI, IFM-GEOMAR, and the Universities of Bremen, Hamburg and Kiel.

9.4 GAME - Global Approach by Modular Experiments

GAME is an innovative approach combining a new type of experimental up-scaling ("meta-research") with international networking and capacity building. The concept was developed in 2000 driven by a threefold motivation: to establish a worldwide cooperative network in experimental marine ecology, to promote international exchange and capacity building of young scientists, and to produce ecological insights of general validity by exploring the same questions/problems in very different marine ecosystems.

The GAME concept

Each year, a topical theme of general interest for the ecological community is chosen, and an experimental design for the investigation of the unsolved question is developed. Then, collaborators in a world-wide pool of more than 25 partner institutes are contacted to check whether (i) they are interested and competent in the specific research topic and (ii) they have a master's student to carry out the research. Among the institutes that fulfil both criteria we select four from the Southern and four from the Northern hemisphere. In parallel, an equivalent number of German Diplom students are selected in a nation-wide recruitment process. All nominated students receive a scholarship over 10 months, including the coverage of all travel expenses.

During the first month of the program (phase I, Fig. 1) the foreign and the German students gather at the IFM-Geomar where they receive an intensive preparative course in experimental design, statistics, theoretical background of the theme in question, techniques and practical methods of the designed experiment.

Then, the students leave in pairs (a German and a foreign student) for the foreign student's home institute. During the following 6 months (phase II) they run twin experiments under the tutorship of a local ecologist and in close email contact with the coordinators at IFM-GEOMAR and with the other student teams.

For the last three months (phase III), all students return to IFM-GEOMAR for the individual and comparative analysis of the results, the preparation of at least one scientific article per team and the completion of their theses. In

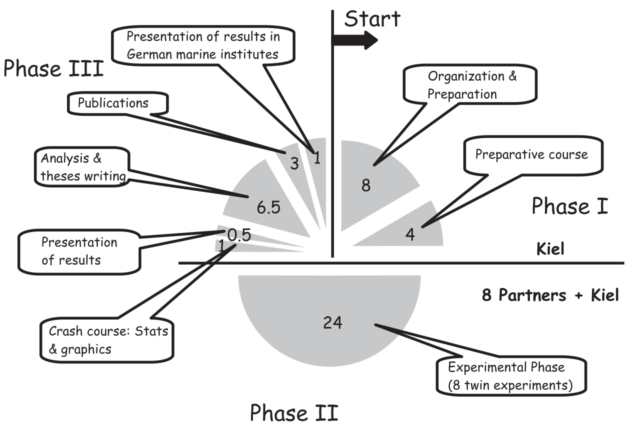


Fig. 1: GAME phases

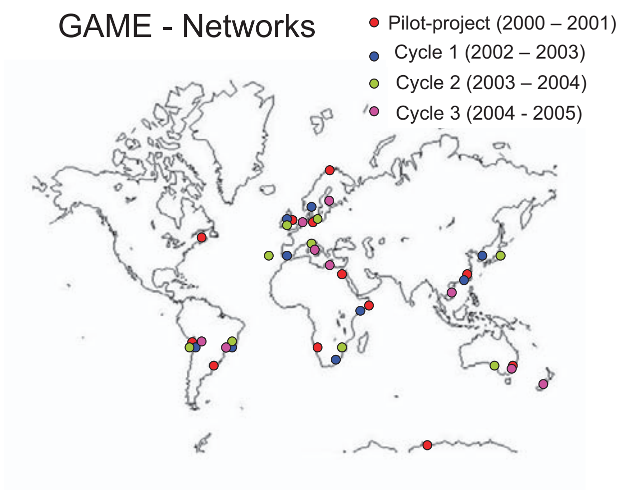


Fig. 2: Partners in the GAME Network

order to run the experiments during equivalent seasons, Northern and Southern Hemisphere projects are shifted by six months.

Preliminary achievements

Capacity building:
Since the birth of the concept, a pilot run and 1 1/2 normal runs have been achieved. Twenty-four students have accomplished their master's, eight are still in the process. The participants come from marine institutes located in Chile, Brazil, South Africa, Australia, New Zealand, Kenya, Israel, China, South Korea, Japan, Portugal, England, Ireland, Sweden, Norway, Italy, Egypt, Malaysia and Germany. Several articles are published (4) or in revision (8), others are in preparation.

Meta-research:
The new approach of studying one question by identical methods in a variety of systems already during the first 2 completed series of modular experiments produced some new scientific perceptions.

In the pilot run, the effects of ambient UV radiation on the diversity of 10 marine communities from Antarctica to northern Norway and from Chile to eastern Australia were investigated. Unexpectedly, it turned out that UVA was more stressful than UVB but that due to an ecological buffering at the community level all negative effects were only transient.

In the first completed run of GAME, the regulation of chemical defences in the macroalgae of 9 coastal ecosystems between England and South Korea and between Sweden and South Africa was assessed. Not only many more species than expected, especially among the red algae, exhibited the capacity to tune their defences to the intensity of herbivory. Frequently, algae of one species even seemed capable to "talk" and "listen": attacked individuals apparently emit chemical signals which allow neighbouring conspecifics to induce their defences before being attacked.

While the second regular cycle is still under way, the results from the Southern Hemisphere countries suggest, that the current model of the interacting effects of productivity and disturbance on community diversity is not of general value and may have to be rejected.

Thus, the practised meta-research can produce new insights, generalizable results and allows large-scale testing of theories.

Networking:
Possibly the most sustainable achievement of GAME is the creation of networks (Fig. 2) between institutions and among young scientists. According to our still young experience, the strong links developing among the 16 students of each cycle persist beyond the project's duration. Many of the students stay in close contact, exchange questions, opinions, information about PhD positions and job offers. The cooperation among the 25 or so institutes also steadily intensifies. Institutes participating in more than one cycle form the links between student networks of different years.

In summary, GAME apparently is a good tool for linking scientists and running interesting research.

The start-up funding during the first 3-6 years is provided by the Stiftung Mercator in their focus "Innovations in the German University System".

9.5 Cooperation with China

Preparation of a joint Master Program in Marine Sciences in cooperation with the Universities of Kiel and Bremen in Germany and the Ocean University of China in Qingdao.

The German Federal Ministry of Education and Research of Germany (BMBF) and the Ministry of Education of China (MoE) initiated discussions on a Chinese-German Cooperation in Education in September, 2003. In this context, the possibility was discussed to establish a joint Chinese-German Center for Marine Sciences in Qingdao in close cooperation with the Universities of Kiel and Bremen and the research institutions associated with them. The first major goal of the joint activities is the development a joint Master Program in Marine Sciences open to both Chinese and German students.

In order to become acquainted with the research and educational facilities of the universities involved and to intensify the dialogue between the universities` lecturers, Chinese lecturers visited the German institutions (August 7-14, 2004), and German faculty members made a return visit to Qingdao (November 13-20, 2004). A joint Summer School in Qingdao in 2005 as well as joint lectures and seminars in Qingdao, Bremen, and Kiel are planned as first steps towards the establishment of the Master Program. It is furthermore intended to establish a joint Ph.D. program as well as an exchange of students and guest lecturers. The implementation of the Master Program is planned to be completed by September, 2007. English master programs in Environmental Physics, Tropical Marine Ecology, and Marine Geosciences are already offered at the University of Bremen. Additional master programs, e.g. in Biological Oceanography in Kiel, are planned to be made available for the Chinese-German Cooperation until winter term 2006/2007. In parallel with these activities, the course offerings in Bremen and Kiel will be restructured with respect to the ongoing reorganization of the diploma into master study programs. Most of the newly developed course modules will be open to international students and can be used for international cooperations.

Visit of a Chinese Delegation to IFM-GEOMAR in August 2004.

The Ocean University of China will offer a one-year preparatory course for Chinese students starting in September, 2005.

The joint coordination of the project has started October 1, 2004, at the Center for Tropical Marine Ecology in Bremen (Dr. Petra Westhaus-Ekau), the Leibniz Institute of Marine Sciences in Kiel (Dr. Stefan Sommer), and the Ocean University of China in Qingdao (Dr. Rui Chen). The Ministries of Culture of the Federal States of Schleswig-Holstein and Bremen (Dr. Ulrich Stier, Ministry of Education, Science, Research and Culture, State of Schleswig-Holstein; Dr. Holger Bienhold, Senator for Education and Science, State of Bremen) support the initiation of the Chinese-German Cooperation in Education.

10. Public Relations and Outreach

Marine research issues are of increasing interest to the general public. Thus, communication of scientifc results to the general public is of increasing importance, in particular for an institute like IFM-GEOMAR with primary focus on basic research. Multiple communication channels are used for information transfer. With respect to politicians, public administration, or commerce this includes advisory work in government committees and public foundations as well as public lectures. In addition, several information visits by groups from federal and state parliaments and governments to the institute were organized.

In press releases, interviews and through the internet, scientific results are regularly presented to the press and TV as well as radio stations.

In the following, examples for the different communication channels are provided.

Information to the media

IFM-GEOMAR reports regularly about new scientific results, important publications, expeditions and other relevant topics to the media. In 2004, 29 press releases were issued. The number of citations in the press regional/national is shown Fig. 1 for the second half of 2004 when a systematic assessment was introduced. In addition, key scientists of IFM-GEOMAR frequently give interviews to the press and TV/radio stations. In 2004, the most active scientist in this respect was Prof. Latif, with more than 20 TV and over 40 radio interviews on climate issues.

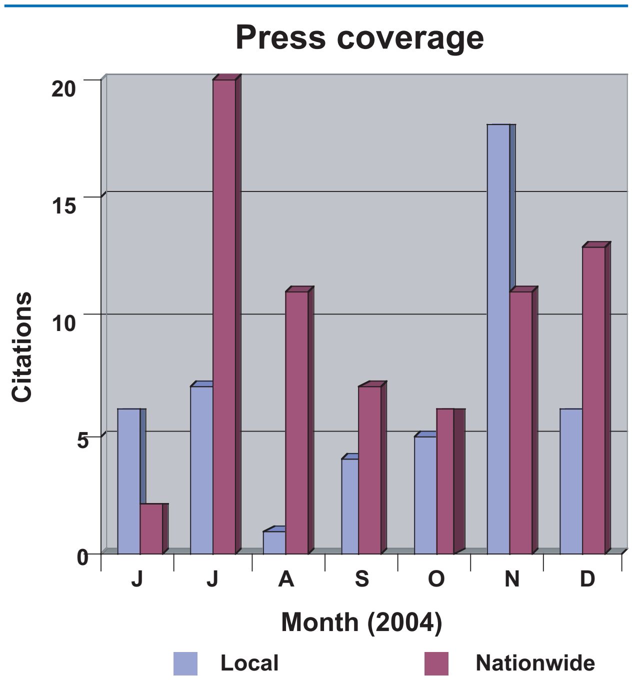


Fig. 1: Press-coverage in local an nation-wide papers in the second half of 2004.

Internet

A primary source of public information are the Internet pages of IFM-GEOMAR (www.ifm-geomar.de) which were redesigned in 2004 as part of the merger of both institutions and were launched in early 2005. Apart from a new layout, the redesign encompassed the introduction of a content management system and completely new content for most of the pages. Some of the information given on the web page is specially designed for the general public, in particular school children.

Public lectures

Numerous public lectures were given by IFM-GEOMAR scientists, in 2004 more than 40 (for details see electronic Appendix E6). For example, throughout 2002 ("Jahr der Geowissenschaften"), weekly public evening lectures „GEOThema der Woche" were held. Another regular public lecture series is offered every year during the "Kieler Woche" in the Aquarium. In addition, following a good tradition, many scientists are giving public lectures on various occasions on actual research topics as well as on other general themes related to marine research. They also contribute to the

The exhibition "Marine Research - Past, present and future" on the occasion of the Volvo-Ocean Race and the Kieler Woche 2002 attracted more than 60,000 visitors.

IFM-GEOMAR representation at the "Parlamentarischer Abend - Geotechnologien" in Berlin, November 24, 2004.

Visit of Heide Simonis (right with burning gas hydrate), Prime Minister of the State of Schleswig-Holstein and Angelika Volquartz, Major of Kiel, February 2004.

series of public lectures offered by the "Schleswig-Holsteinische Universitäts-Gesellschaft Kiel". Examples of topics covered are: climate, fish stocks, marine resources, marine natural products and geo-hazards.

Exhibitions and special events

Annual days of "open institute" and "open ship" where the work of the institute is presented attract many visitors. For example, 3.500 people took the chance to visit the research vessel METEOR during a one day open-ship in November 2003. METEOR's 3 day port call in Kiel was also used for guided tours for members of parliament and associated lectures and receptions. In 2002, a special exhibition on Marine Sciences in Kiel attracted more than 60.000 visitors within 6 weeks.

During the "Jahr der Geowissenschaften" (2002), an initiative of BMBF, IFM-GEOMAR contributed to an exhibition on a coaster that visited 62 cities in Germany and attracted about 120.000 visitors. In 2004, IFM-GEOMAR contributed to an exhibition on the "MS Technik" about the history of echo-sounding and hydrography with 75.000 visitors.

In the fall of 2004 IFM-GEOMAR made a substantial contribution to a "Parlamentarischer Abend" on Geotechnologies in Berlin, jointly organized by the KDM.

Aquarium

The public aquarium is a facility of IFM-GEOMAR which is visited by about 100,000 people per year. It provides a taste of the diversity of the inhabitants of regional rivers, lakes, the Baltic and North Seas and offers a small glimpse of the colorful world of tropical coral reefs. Water quality is maintained at optimal levels by employing mechanical and biological filters, protein skimmers and algae tanks. This enables cultivation of even delicate species for research purposes. In addition, six seals that are kept in a state-of-the-art indoor/outdoor facility are an attraction for Kiel. For details see also Section 6.1 (www.aquarium-kiel.de)

Schools

The interaction with schools plays an important role in the area of public relation and education. Apart from a large number of school classes visiting IFM-GEOMAR, two initiatives should be high-lighted: The initiative NaT-Working (funded by the Robert-Bosch-Foundation) is directed at high school students and teachers, and aims at a better understanding of marine Earth sciences. A number of schools are actively participating in this initiative by specially designed projects.

OzeanOnline is an opportunity in the context of practicals for school children who can provide their knowledge on marine science, learned within the practical, via the internet.

In addition, a large number of practicals (average duration about two weeks) for school children are offered, mostly in marine Biology and Chemistry (in 2004 about 40).

Other outreach

IFM-GEOMAR is an active partner of the "Naturerlebniszentrum (NEZ) Maasholm". In addition to a small field station for biological research, information to the general public is provided through a permanent exhibition and various events, including a public lecture series every summer. A 15-place school-laboratory at the NEZ was etsablished in 2004 with the financial support by the Technologiestiftung Schleswig-Holstein.

Appendix 1: Management and Organization

1. Directorate

The directorate of IFM-GEOMAR consists of the director (chair) and the leaders of the research divisions. Current members of the directorate are:

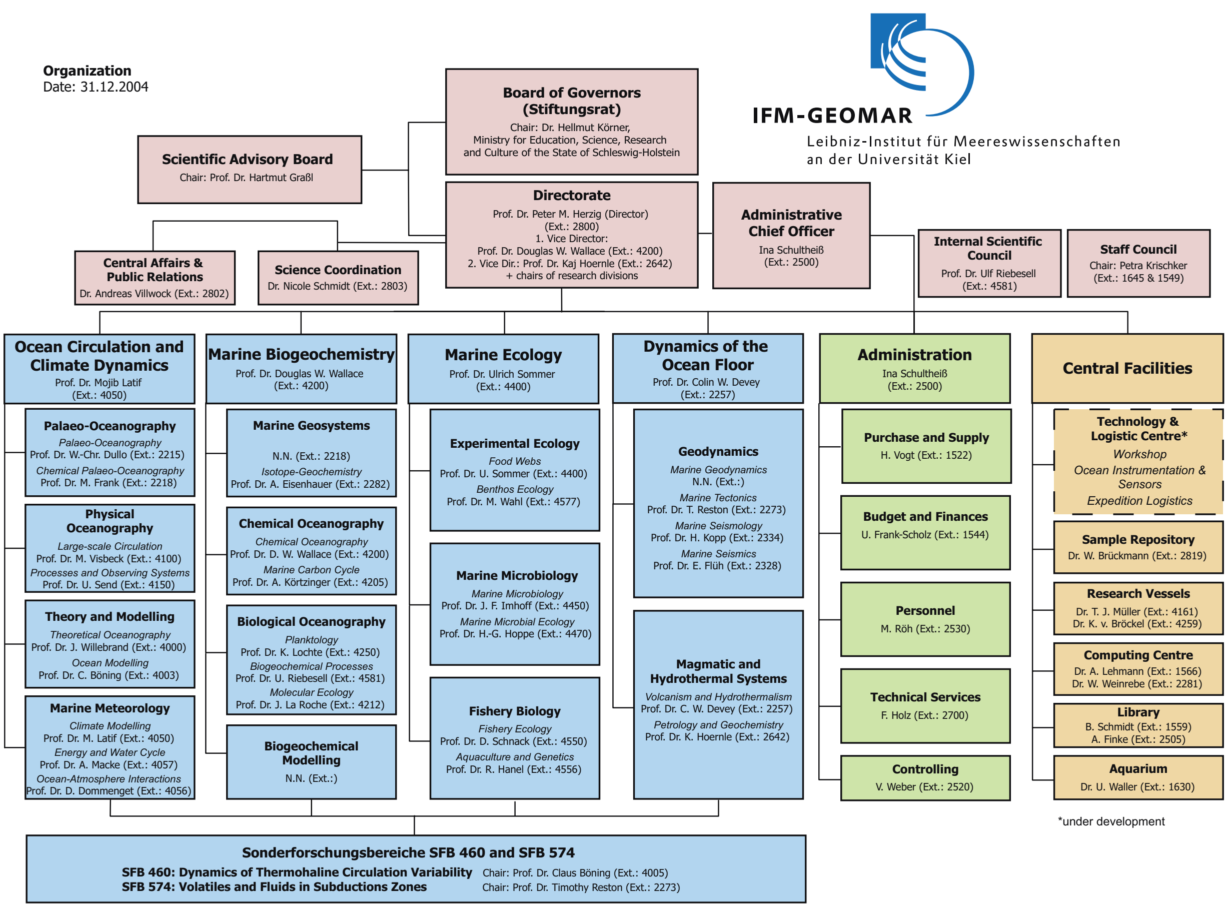
- **Prof. Dr. P.M. Herzig (Director)**
- Prof. Dr. M. Latif (RD1)
- Prof. Dr. D.W.R. Wallace (RD2)
- Prof. Dr. U. Sommer (RD3)
- Prof. Dr. C.W. Devey (RD4)

2. Board of Governors

- **Dr. H. Körner, Ministry for Education, Science, Research and Culture of the State of Schleswig-Holstein, Kiel (Chair)**
- RD R. Ollig, Federal Ministry for Education and Research, Bonn
- Prof. Dr. J. Eckert, Rector, Christian-Albrechts-University, Kiel
- Prof. Dr. J. Grotemeyer, Dean of the Faculty for Mathematics and Natural Sciences, Christian-Albrechts-University, Kiel
- Prof. Dr. H. Graßl, Chair, Scientific Advisory Board, Max-Planck-Institut for Meteorology, Hamburg
- Prof. Dr. J. Thiede, Alfred-Wegener-Institute for Polar and Marine Research, Bremerhaven
- Dipl.-Ing. D. Lindenau, Lindenau GmbH, Shipyards and Engineering Works, Kiel

Guests with consulting status:

- Dr. I. Hennings, Representative of the Scientific Staff (staff council)
- Mrs. B. Domeyer, Representative of the Non-scientific Staff (staff council)
- Mrs. B. Schmidt, Representative for Equal Rights
- Dr. B. Roß, Representative of the Ministry for Trade, Commerce, and Transportation of the State of Schleswig-Holstein
- Prof. Dr. P.M. Herzig, Director of IFM-GEOMAR
- Prof. Dr. D.W.R. Wallace, 1. Assistant Director of IFM-GEOMAR



- Prof. Dr. K. Hoernle, 2. Assistant Director of IFM-GEOMAR
- Prof. Dr. U. Riebesell, Chair, Scientific Council

Other guests:
- Mr. W.-R. Janzen, Managing Director, IHK Kiel
- Mrs. I. Schultheiß, Administrative Chief Officer, IFM-GEOMAR
- Dr. N. Schmidt, Science Coordinator, IFM-GEOMAR
- Dr. A. Villwock, Public Relations and Central Affairs, IFM-GEOMAR

3. Scientific Advisory Board

- Prof. Dr. D.L.T. Anderson, European Centre for Medium-Range, Weather Forecasts, Berkshire, UK
- Prof. Dr. E.A. Boyle, Department of Geology and Geophysics, Mass. Institute of Technology, Cambridge, USA
- **Prof. Dr. H. Grassl (Chair), Max-Planck-Institute for Meteorology, Hamburg**
- Prof. Dr. R. Hékinian, IFREMER, Brest, France
- Prof. Dr. N.G. Hogg, WHOI Woods Hole Oceanographic Institution, Physical Oceanography Woods Hole, MA, USA
- Prof. Dr. A.C. Mix, College of Oceanic & Atmospheric Sciences, Oregon State University, Corvallis, USA
- Prof. Dr. Y. Olsen, Norwegian University of Sciences and Technology, Institute of Biology, Trondheim, Norway
- Prof. Dr. J.A. Pearce, Department of Earth Science, Marine Geology and Geochemistry, Cardiff University, UK
- Prof. Dr. K. Richardson, University of Aarhus, Denmark
- Prof. Dr. D. Turner, Chalmers tekniska högskola, Göteborg, Sweden
- Prof. Dr. A. Watts, Department of Earth Sciences University of Oxford, UK
- Prof. Dr. D.H. Welte, Gesellschaft für Integrierte Explorationssysteme mbH, Jülich

4. Scientific Council

Prof. Dr. U. Riebesell (Chair), Prof. Dr. E. Flüh (Assistant).

Members (Member /Assistant):

a. Professors:

- W.-C. Dullo / M. Frank
- A. Macke / M. Latif
- M. Visbeck / N.N.
- J. Willebrand / C. Böning
- A. Eisenhauer / N.N.
- A. Körtzinger / D. Wallace
- U. Riebesell / K. Lochte
- N.N. / K. Lochte / D. Wallace
- J. Imhoff / D. Schnack
- M. Wahl / U. Sommer
- K. Hoernle / C. Devey
- T. Reston / N.N.

b. Assistant Professors and Scientists with "Habilitation":

- FB1: D. Dommenget / N.N.
- FB2: K. Wallmann / J. LaRoche
- FB3: R. Hanel / H.-G. Hoppe
- FB4: E. Flüh / A. Freundt

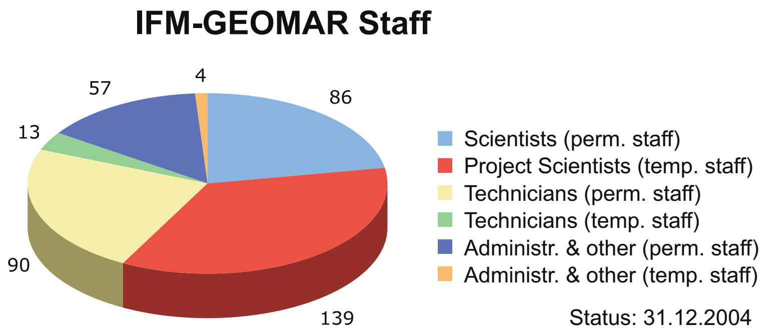
c. Scientific staff:

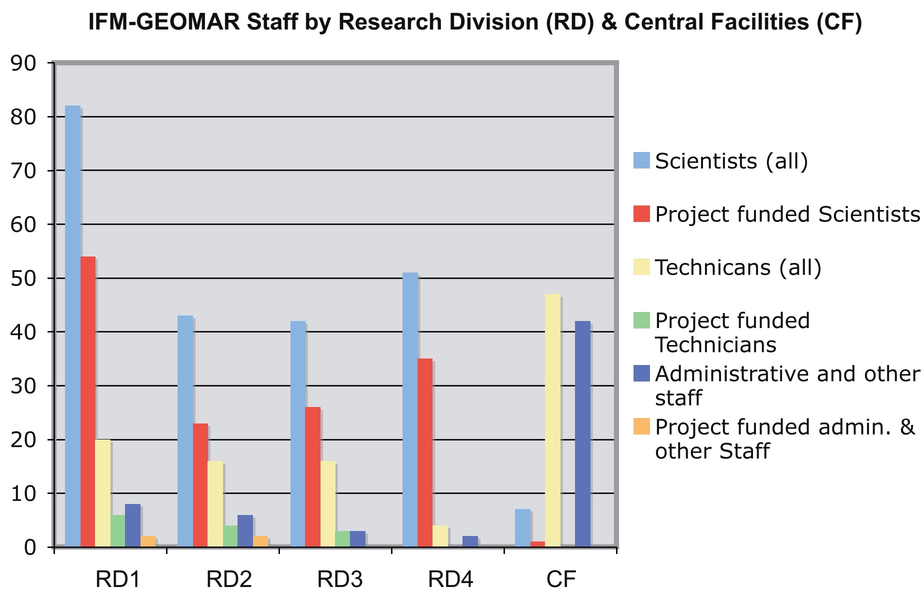
- FB1: T. Martin / J. Karstensen
- FB2: G. Rehder / B. Quack
- FB3: U. Piatkowski / G. Kraus
- FB4: D. Klaeschen / F. Hauff

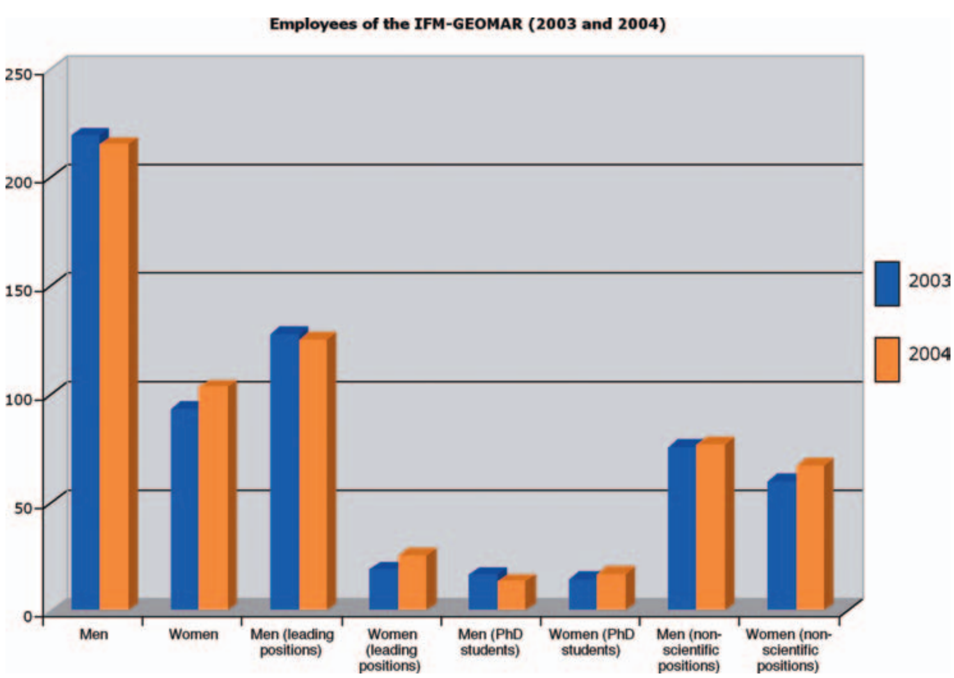
Appendix 2: Staff

A-2.1 Staff Statistics

Some basic statistics about the IFM-GEOMAR staff is provided in the summary figures on this page. External job offers and successful appointments of executive personnel are provided in section 2.2 and 2.3, respectively. Details about staff and staff departures are listed in the electronic Appendix E1.







A-2.2 Job Offers for External Positions

Prof. Dr. Douglas Wallace	University of Southampton, Southampton Oceanography Centre, Southampton, UK, July 2002 (not accepted: September 2002).
Dr. Friedrich Köster	Institute of Marine Fisheries, Charlottenlund, Denmark, March 2003.
Dr. Frederik Tilmann	Professorship, Cambridge University, Cambridge, UK, April 2003.
Prof. Dr. Matthias Hort	C4 Professorship, University Hamburg, May 2003.
Dr. Gerhard Bohrmann	C3 Professorship, University Bremen, October 2003.
Prof. Dr. Christian Dullo	Generaldirektor des Museum für Naturkunde, Humboldt University Berlin (Jan 2004) (not accepted: August 2004).
Prof. Dr. Rolf Käse	Visiting Professor, University Hamburg, December 2003 (for 2 years).
Prof. Dr. Helmut Hillebrand	C3 Professorship, University Cologne, Cologne, April 2004.
Prof. Dr. Jason Phipps Morgan	Professorship, Cornell University, Ithaca, USA, May 2004.
Prof. Dr. Uwe Send	Professorship, Scripps Institute of Oceanography, La Jolla, USA, July 2004.
Dr. Andreas Oschlies	Professorship, University of Southampton, Southampton Oceanography Centre, Southampton, UK, August 2004.
Dr. Axel Timmermann	University of Bremen, August 2003 (not accepted).
	Professorship, University Hawaii, Honolulu, USA, August 2004.
Dr. Boris Worm	Professorship, Dalhousie University, Halifax, Canada, September 2004.
Dr. Rory Wilson	Professorship, University of Swansea, Swansea, UK, October 2004.
Prof. Dr. Erwin Suess	Acting Director, Konsortium Deutsche Meeresforschung, Berlin, October 2004.
Dr. Ralf Tiedemann	W3 Professorship, University Bremen, November 2004.
Dr. John Reijmer	Professorship, Université Aix-Marseille, France, December 2004.
Dr. Klaus Wallmann	W2 Professorship, Institut für Ostseeforschung, Warnemünde, December 2004.
Dr. Cesar Rodriguez Ranero	Professorship, Barcelona, Spain, December 2004.

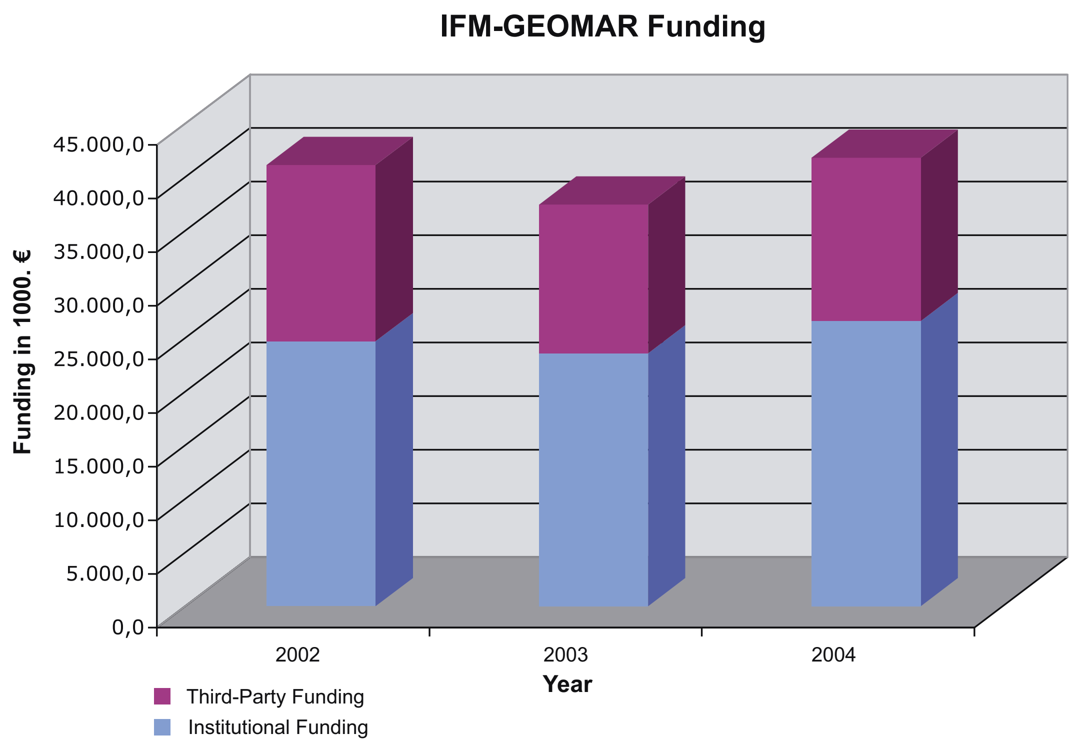
A-2.3 Successful Appointments to IFM-GEOMAR Positions

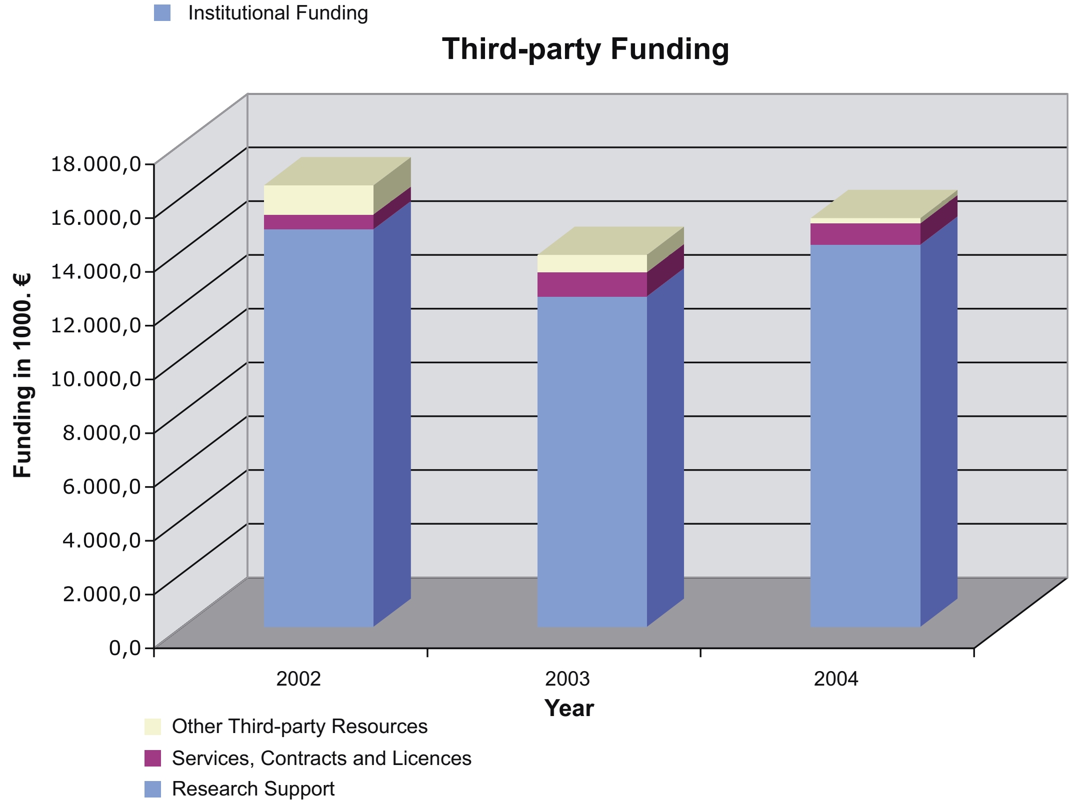
Prof. Dr. Christian Dullo	C4 Professorship, Paleo-Oceanography, GEOMAR, Kiel, June 2002.
Prof. Dr. Mojib Latif	C4 Professorship, Marine Meteorology, MPI for Meteorology, Hamburg, January 2003.
Prof. Dr. Martin Wahl	C3 Professorship, Experimental Ecology, Univ. Namibia, Windhoek, Nambia, January 2003
Prof. Dr. Ulf Riebesell	C3 Professorship, Biological Oceanography, AWI, Bremerhaven, October 2003.
Dr. Heidrun Kopp	Assistant Professor, Marine Geodynamics, GEOMAR, Kiel, August 2003.
Dr. Dietmar Dommenget	Assistant Professor, Marine Meteorology, SIO, La Jolla, USA, October 2003.
Dr. Andreas Macke	C3 Professorship, Marine Meteorology, IfM, Kiel, April 2004.
Dr. Reinhold Hanel	Assistant Professor, Fishery Biology, Univ. Innsbruck, Austria, April 2004.
Prof. Dr. Colin Devey	C4 Professorship, Marine Geodynamics, Univ. Bremen, May 2004.
Prof. Dr. Martin Visbeck	C4 Professorship, Physical Oceanography, Lamont Doherty Earth Observatory, Palisades, USA, October 2004.
Prof. Dr. Martin Frank	C3 Professorship, Chemical Paleo-Oceanography, ETH, Zürich, Switzerland, December 2004.

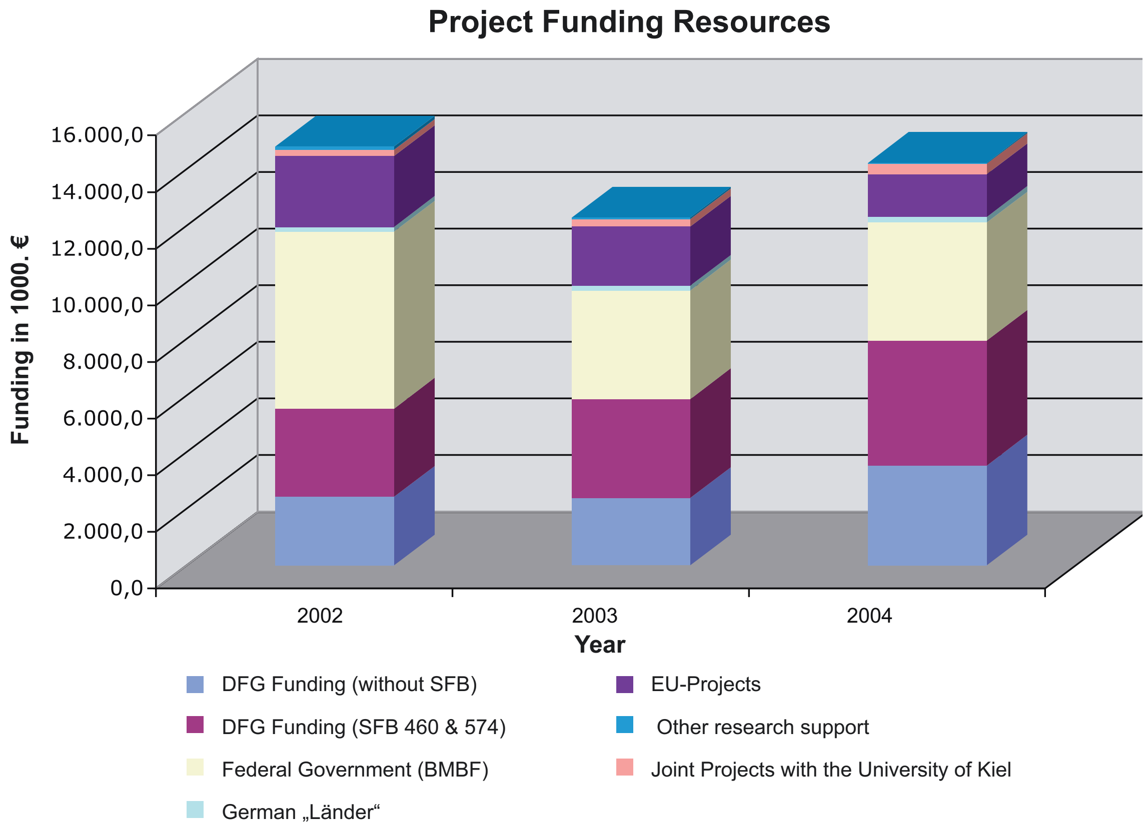
Appendix 3: Budgets

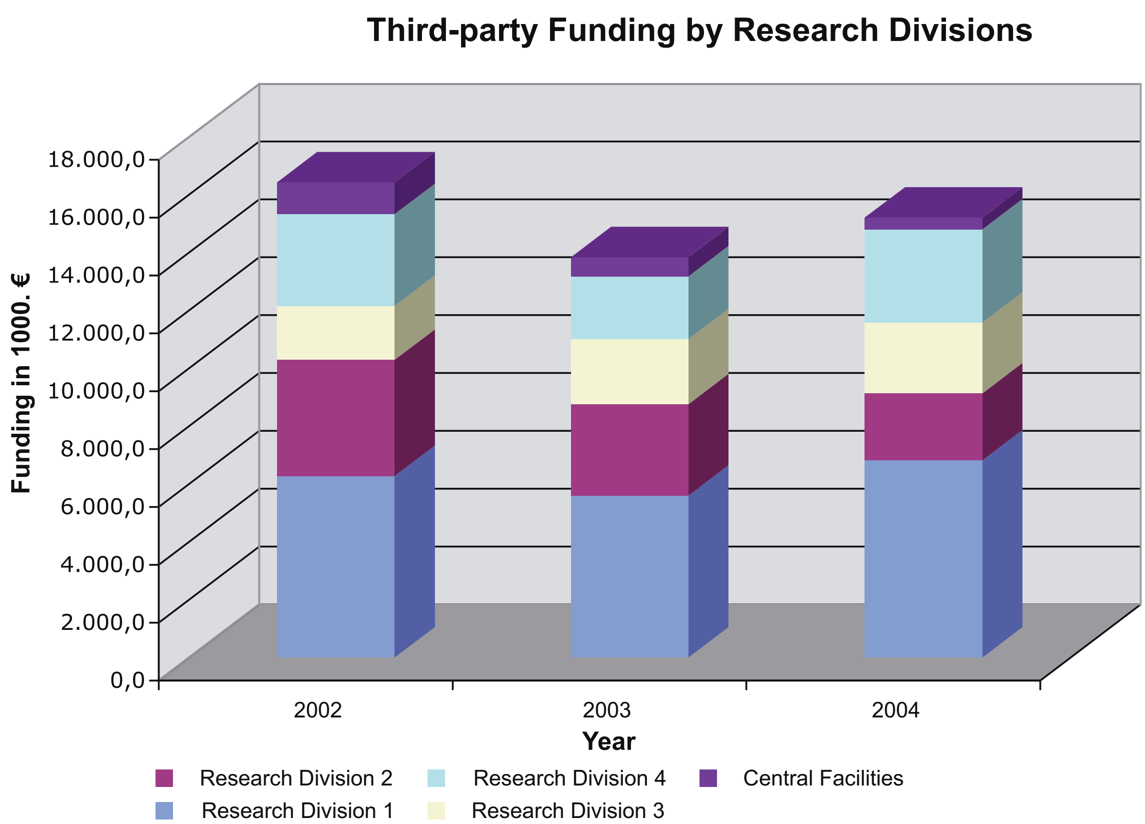
A-3.1 Budget Statistics

The following figures summarize the basic facts of the IFM-GEOMAR budget within the past three years. Details can be found in the subsequent sections. Note that for the years 2002 and 2003 the individual budgets of both institutes, IfM and GEOMAR were added for intercomparison with 2004.






Project Funding Resources
Funding in 1000. €
16.000,0
14.000,0
12.000,0
10.000,0
8.000,0
6.000,0
4.000,0
2.000,0
0,0
2002
2003
2004
Year
DFG Funding (without SFB)
DFG Funding (SFB 460 & 574)
Federal Government (BMBF)
German „Länder“
EU-Projects
Other research support
Joint Projects with the University of Kiel


Third-party Funding by Research Divisions
Funding in 1000. €
18.000,0
16.000,0
14.000,0
12.000,0
10.000,0
8.000,0
6.000,0
4.000,0
2.000,0
0,0
2002
2003
2004
Year
Research Division 2
Research Division 1
Research Division 4
Research Division 3
Central Facilities

A-3.2 Budget Tables

Table 1: Revenues and expenditures

(in € 1,000)

	2004 1)	**2003 7)**	**2002 7)**
Revenues[2)]			
Total	**41.826,1**	**37.457,0**	**41.169,5**
1. Institutional support	**26.614,3**	**23.606,0**	**24.734,0**
- German Länder[3)]	14.626,3	15.641,0	16.408,0
- Federal Government[3)]	11.988,0	7.965,0	8.326,0
- Other institutional support[4)]	0,0	0,0	0,0
Proportion of institutional support in overall financial resources (in %)	*63,6%*	*63,0%*	*60,1%*
2. Third-party resources	**15.211,8**	**13.851,0**	**16.435,5**
2.1 Research support	**14.233,9**	**12.295,7**	**14.796,4**
- DFG (German Research Council)	3.527,0	2.380,2	2.425,4
- DFG-SFB 406 und 574	4.418,7	3.497,9	3.117,5
- Federal Government	4.174,1	3.836,6	6.247,9
- German Länder	193,4	162,0	170,3
- EU project funding	1.513,1	2.092,1	2.504,2
- Foundations, other research support	365,2	260,0	220,1
- Joint projects with the University of Kiel	32,3	66,9	111,2
2.2 Services, contracts, licences, publications	**792,5**	**902,4**	**547,0**
- Contracts from private enterprises or public authorities, co-operation with industry	792,5	902,4	547,0
- Patent exploitation, licences	0,0	0,0	0,0
- Publications	0,0	0,0	0,0
- Other services	0,0	0,0	0,0
2.3 Other third-party resources	**195,4**	**652,9**	**1.092,1**
- Aquarium	17,1	27,3	29,0
- Misc. income (interest, etc.)	40,0	36,8	49,1
- Rentals	3,0	8,6	11,2
- Charter for Research Vessels	133,5	568,0	989,8
- Sale of vehicles	1,7	12,0	13,0
- Other sales	0,1	0,2	0,0
Proportion of third-party funding in overall financial resources (in %)	*36,4%*	*37,0%*	*39,9%*
3. Withdrawal from reserves and the like	**0,0**	**0,0**	**0,0**

Footnotes see next page.

Table 1: Revenues and expenditures (continued)

(in € 1,000)

	2004 [1)]	2003 [7)]	2002 [7)]
Expenditures			
Total	**39.398,0**	**44.769,8**	**47.174,7**
4.1 Personnel	17.077,0	15.697,0	15.328,0
4.2 Materials, supplies, equipment	14.842,0	23.373,0	24.208,0
4.3 Investments (not incl. building investments)	2.505,0	1.444,0	3.053,0
4.4 Building investments[5)]	523,0	691,0	1.357,0
4.5 Special Positions (where applicable)[6)]	0,0	0,0	0,0
4.6 Allocations to reserves and the like	0,0	0,0	0,0
4.7 DFG-SFB 460 and 574	4.418,7	3.497,9	3.117.5
4.8 Joint Projects with the University of Kiel	32,3	66,9	111,2
4.9 For information only: DFG charges	572,0	371,0	378,0

1) Previous complete calendar year; preliminary data where applicable
2) Actual revenues in each year classified by financial resource; not incl. money in transit
3) Support according to BLK decision
4) Special financing, EU funds
5) Building investments, multi-annual measures for building maintenance, land acquisition incl. demolition
6) Please explain
7) In addition charter costs in the years 2002 (5.934,1 T€) and 2003 (8.031,0 T€)

Table 2: Project Funding

(Revenues in € 1,000)

	2004	2003 [2)]	2002 [2)]
Total	**15.211,8**	**13.851,0**	**16.435,5**
- DFG (German Research Council)	3.527,0	2.380,2	2.425,4
- DFG-SFB 460 und 574	4.418,7	3.497,9	3.117,6
- Federal Government	4.174,1	3.836,6	6.247,9
- German Länder	193,4	162,0	170,2
- EU project funding	1.513,1	2.092,1	2.504,1
- Foundations, other research support	365,3	260,0	220,1
- Joint projects with the University	32,3	66,9	111,2
- Services, contracts, licences, publications	792,5	902,4	547,0
- Other third-party resources[1)]	195,4	652,9	1.092,1

1) For example: donations, member fees, etc.
2) Aidditional: charter costs in the years 2002 (5.934,1 T€) and 2003 (8.031,0 T€)

Details about all funded projects in the reporting period can be found in electronic Appendix E2.

Appendix 4: Acronyms

AABW	Antarctic Bottom Water
AAIW	Antarctic Intermediate Water
ACCE	Atlantic Climate Change Experiment
ACSYS	Arctic Climate System Study
ADCP	Acoustic Doppler Current Profiler
AGU	American Geophysical Union
AMAM	Automated nutrient analysis
AMS	American Meteorological Society
AMSU	Advanced Microwave Sounding Unit
ANIMATE	Atlantic Network of Interdisciplinary Moorings and Timeseries for Europe
APEX	Autonomous Profiling Explorers
APG	Autonom Profilierenden Geräteträger - Tiefendriftern
APOLAS	Accurate areal Precipitation measurements Over LAnd and Sea
AQUAWEB	DFG Project (Comparison of marine and limnetic food webs
ASFA	Aquatic Sciences and Fisheries Abstracts
ASLO	American Society of Limnology and Oceanography
AtlantNIRO	Atlantic Scientific Research Institute of Marine Fisheries and Oceanography, Russia, Kaliningrad, Russia
ATSAF	Arbeitsgruppe für tropische und subtropische Agrarforschung
AUV	Autonomous Unterwater Vehicle
AVHRR	Advanced Very High Resolution Radiometer
AWI	Alfred Wegener Institut für Polar- und Meeresforschung, Bremerhaven
BAHC	Biospheric Aspects of the Hydrological Cycle (IGBP)
BALTEX	Baltic Sea Experiment
BASECOEX	Capelin and herring in the Barents Sea - coexistence or exclusion (Norway)
BASEWECS	BAltic SEa Water and Energy Cycle Study
BASIC	Baltic Sea cyanobacteria
BASYS	Baltic Sea System Study
BATS	Bermuda Atlantic Time series Study
BEQUALM	Biological effects quality assurance in monitoring programmes
BfA	Bundesforschungsanstalt für Fischerei
BfN	Bundesamt für Naturschutz
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe
BIO	Bedford Institute for Oceanography
BMBF	Bundesministerium für Bildung und Forschung
BMVEL	Bundesministerium für Verbraucherschutz, Ernährung und Landwirtschaft
BSH	Bundesanstalt für Seeschifffahrt und Hydrographie
BSIOM	Baltic Sea Ice Ocean Model
BSR	Bottom-Simulating-Reflector
CACGP	Commission for Atmospheric Chemistry and Global Pollution
CANIGO	CANary Islands Azores Gibraltar Observations
CARINA	Carbon dioxide in the Atlantic Ocean
CAS	Commission on Atmospheric Sciences (WMO)
CAU	Christian-Albrechts-Universität zu Kiel
CAVA	Central American Volcanic Arc
CAVASSOO	Carbon variability studies by ships of opportunity
CCC	Cod and Climate Change
CCCC	Climate Change and Carrying Capacity
CDIAC	Carbon Dioxide Information Analysis Center, Oak Ridge, USA
CFCAS	Canadian Foundation for Climate and Atmospheric Sciences (CDN)
CEFAS	Centre for Environment, Fisheries and Aquaculture Science, Lowestoft, UK
CIESM	Commission internationale pour l'éxploration scientifique de la mer Méditerranée, France
CIMAS	Cooperative Institute for Marine and Atmospheric Studies, Miami, USA
CIRAMOSA	Compilation of regional cirrus macro- and microphysical properties
CliC	Climate and Cryosphere (WCRP)
CLIVAR	Climate Variability and Predictability Programme (WCRP)
CLIWA-Net	Cloud Liquid Water Network (BALTEX)
CMS	Commission on Moving Species
COADS	Comprehensive Ocean-Atmosphere Data Set
CoML	Census of Marine Life
COMWEB	Comparative analysis on coastal planktonic food webs
CORE	Cod recruitment in the Baltic (EU project)
COSMOS	Community Earth System Models
CRIMP	Center of Research on Marine Introduced Pests (Australia)
CSIRO	Commonwealth Scientific & Industrial Research Organisation (Australia)
CTD	Conductivity-Temperature-Depth
DBE	Deep Basin Experiment (WOCE)
DCESS	Danish Centre for Earth System Science
DEKLIM	BMBF Climate Research Programme
DFG	Deutsche Forschungsgemeinschaft
DGHM	Deutsche Gesellschaft für Hygiene Mikrobiologie
DGL	Deutsche Gesellschaft für Limnologie
DGM	Deutsche Gesellschaft für Meeresforschung
DGP	Deutsche Gesellschaft für Protozoology
DIFRES	Danish Institute for Fisheries Research, Lyngby, Denmark
DIGENIT	Diversität nitratreduzierender Bakterien (BMBF Project)
DLR	Deutsche Gesellschaft für Luft- und Raumfahrt
DMG	Deutsche Meteorologische Gesellschaft
DMS	Dimethyl sulphide
DMSP	dimethyl sulfonium proprionate
DOMINOE	Dissolved organic matter as a component of ocean ecosystem and carbon cycle
DON	Dissolved organic nitrogen
DON	dissolved organic nitrogen

Appendix 4: Acronmys

DSOW	Denmark Strait Overflow Water
DWBC	Deep Western Boundary Current
DWD	Deutscher Wetterdienst
DWK	Deutsche Wissenschaftliche Kommission für Meeresforschung
DYNAMO	Dynamics of North Atlantic Models
EASIZ	Ecology of the Antarctic Sea Ice Zone
ECMWF	European Centre for Medium Range Weather Forecasts
ECOSIM	Ecosystem Simulation
EEA	European Elasmobranch Association
EISENEX	The second iron enrichment experiment
ELOISE	European Land Ocean Interaction Analysis
ENBI	European Network of Biodiversity Information
ESONET	European Sea Floor Observatory Network
ESTOC	European Station for Time-Series in the Ocean Canary Islands
EU	European Union
EUAC	European Union of Aquarium Curators
EUC	Equatorial Undercurrent
EULIT	Effects of eutrophicated seawater on rocky shore ecosystems studied in large littoral mesocosms
EURASLIC	European Association of Aquatic Libraries and Information Centres
FB	Forschungsbereich
FLAME	Family of Linked Atlantic Model Experiments
FTZ	Forschungs- und Technologiezentrum der CAU, Büsum
GBB	Great Bahama Bank
GBIF	Global Biodiversity Information Facility
GCOS	Global Climate Observing System
GeoB	Institut für Geowissenschaften, Univ. Bremen
GEWEX	Global Energy and Water Cycle Experiment
GfÖ	Gesellschaft für Ökologie
GFZ	Geoforschungszentrum Potsdam
GHSZ	Gas Hydrate Stability Zone
GIN Sea	Greenland, Iceland and Norwegian Sea
GKSS	Gesellschaft für Kernenergieverwertung in Schiffbau und Schiffahrt (Forschungszentrum Geesthacht)
GLOBEC	Global Ocean Ecosystems Dynamics
GODAE	Global Ocean Data Assimilation Experiment
GOOS	Global Ocean Observing System
GPI	Geologisch-Paläontologisches Institut
GSF	Forschungszentrum für Umwelt und Gesundheit (BMBF Projektträger)
HELCOM	Helsinki Commission (Baltic Marine Environment Protection Commission)
HERSUR	Herring Survey Programme (EU)
HMW	high molecular weight
HYDROARC	Hydrothermale Prozesse an flach-marinen Vulkanen der Bransfield Strasse
HYFIFLUX	Hydrothermal fluid development, material balancing and special biological activity in the North Fiji Basin
IBM	Individual-based models
IABO	International Association for Biological Oceanography
IAMAP	International Association of Meteorology and Atmospheric Physics
IAPSO	International Association for the Physical Science of the Oceans
ICARP II	International Conference on Arctic Research Planning
ICBM	Institut für Chemie und Biologie des Meeres, Universität Oldenburg
ICCM	Instituto Canario de Cencias Marinas, Las Palmas, Spain
ICES	International Council for the Exploration of the Seas
ICHCA	International Cargo Handling Co-ordination Association
IEO	Instituto Español de Oceanografía
IfM	Institut für Meereskunde
IFREMER	Institut Français de Recherche pour l'Exploitation de la Mer, Brest, France
IGBP	International Geosphere-Biosphere Programme
IGOOS	IOC-WMO-UNEP Committee for GOOS
IHF	Institut für Hydrobiologie und Fischereiwissenschaft, Hamburg
IHLS	International Herring Larvae Survey (ICES)
IMO	International Maritime Organization
INTAS	International Association (of EU)
IOC	Intergovernmental Oceanographic Commission
IODP	Integrated Ocean Drilling Program
IOW	Institut für Osteeforschung, Warnemünde
IPCC	Intergovernmental Panel on Climate Change
IPRC	International Pacific Research Institute, Honolulu, USA
IRCCM	International Research Consortium for Continental Margins
IRONAGES	Iron Resources and Oceanic Nutrients-Advancement of Global Environment Simulations
ISCCP	International Satellite Cloud Climatology Project
IUB	International University Bremen
IUGG	International Union of Geodesy and Geophysics
JGOFS	Joint Global Ocean Flux Study
KAPEX	Cape of Good Hope Experiments
K.E.R.N.	Techologie Region: Kiel-Eckernförde-Rendsburg-Neumünster e.V.
KISS	Kiel Sea-Ice Simulation
KNMI	Koninklijk Nederlands Meteorologisch Instituut, de Bilt, The Netherlands
LATFRI	Latvian Fisheries Research Institute
LIFECO	Impact of frontal activities on fish recruitment in the North Sea (EU project)
LIP	Large Igneous Provinces
LOICZ	Land Ocean Interactions in the Coastal Zone (IGBP component)
LSW	Labrador Sea Water
MACOM	Maternal effects on Atlantic cod recuitment and implications for management strategies (EU Project)
MAST	Marine Science and Technology Programme (EU)
MATER	Mediterranean Targeted Project-Mass Transfer and Ecosystem Response
MOC	Meridional Overturning Circulation
MODIS	

MOVE	Meridional Overturning Variability Experiment
MPI	Max-Planck Institut für Meteorologie
MRI	Marine Research Institute, Reykjavik, Iceland
MUNF	Ministerium für Umwelt, Natur und Forsten
NAC	North Atlantic Current
NADW	North Atlantic Deep Water
NAFO	Northwest Atlantic Fisheries Organization
NAO	North Atlantic Oscillation
NATO	North Atlantic Treaty Organization
NBUC	North Brazil Undercurrent
NCAR	National Center for Atmospheric Research, Boulder, USA
NCEP	National Center for Environmental Prediction (NOAA)
NERC	National Environmental Research Council
NIOZ	Royal Netherlands Institute for Sea Research, The Netherlands
NOAA	National Ocean Atmosphere Administration
NOCES	Northern Ocean-Atmosphere Carbon Exchange Study
NOPEX	Northern Hemisphere Climate-Processes Land-Surface Experiment (BAHC comp.)
NSERC	National Science and Engineering Research Council (CDN)
NSF	National Science Foundation (US)
OBH	Ocean Bottom Hydrophones
OBIS	Ocean Biogeographic Information System
OBS	Oean-Bottom-Seismometers
OCTOPUS	Ocean Tomography Operational Pakkage and Utilization Support
ODP	Ocean Drilling Program
OMEX	Ocean Margin Exchange
OPAC	Online Public Access Catalogue
ORNL	Oak Ridge National Laboratory, Oak Ridge, USA
OPRAN	Surface Ocean Processes in the Anthropocene
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic (Oslo-Paris)
QUEEN	Quaternary Environment of the Eurasian North, PAGES component
PAH	Polycyclic Aromatic Hydrocarbons
PARS	Precision and accuracy of tools in recruitment studies (Eu-Project)
PDF	Probability Density Function
PEP	Pilot Study of Evaporation and Precipitation (BALTEX)
PESCA	Fisheries Programme (EU)
PCB	Polychlorinated biphenyl
PCR	Polymerasekettenreaktion
PIK	Potsdam Institute für Klimafolgenforschung, Potsdam
PJTT	Paleo-JGOFS Task Team
POC	Particulate Organic Carbon
POGO	Partnership for Observations of the Global Oceans
PON	Particulate Organic Nitrogen
PR	Public Relations
PTJ	Projektträger Jülich (BMBF)
RAFOS	Profiling Float
RD	Research Division
RIVO	Nederlands Instituut voor Visserijonderzoek, Ijmuiden, The Netherlands
ROV	Remotely Operated Vehicle
RSMAS	Rosenstiel School of Marine and Atmospheric Sciences, Miami, USA
RSP	Red Sea Programme
SAB	Scientific Advisory Board
SAP	Sustainable Fisheries: Assessment and Prediction (EU project)
SCAR	Scientific Committee on Antarctic Research
SCOR	Scientific Committee on Oceanic Research
SDN	Schutzgemeinschaft Deutsche Nordseeküste
SETAC	Society of Environmental Toxicology and Chemistry
SFB	Sonderforschungsbereich
SIL	Societas Internationalis Limnologiae
SimCoast	Interdisciplinary methodologies for the sustainable use and management coastal resource systems: EU and ASEAN Coastal transect applications (EU Project)
SIO	Scripps Institution of Oceanography, La Jolla, USA
SMHI	Swedish Meteorological and Hydrological Institute
SOC	Southampton Oceanography Centre, UK
SOIREE	Southern Ocean Iron RElease Experiment
SOLAS	Surface Ocean Lower Atmosphere Study
SOMARE	Sampling, Observations & Modelling of Atlantic Regional Ecosystems
SPACC	Small Pelagic Fishes and Climate Changes
SPP	Special Priority Program (DFG)
SSB	spawning stock biomass
STC	Shallow Subtropical Cell
STORE	Fish stock recruitment in the Baltic (EU project)
SV	Sverdrup (10^6 km^3/s)
TAR	Third Assessment Report (IPCC)
TAV	Tropical Atlantic Variability
TIEFBAK	Distribution pattern, geochemical and biological characterization of hydrothermal and cold seep communities (BMBF)
TIEFBIT	BMBF Tiefseeforschungsprogramm
TIMS	Thermal Ionisation Mass Spectrometers
TIV	Tropical Instability Waves
TLZ	Technology and Logistic Center
TTO	Transient Tracers in the Ocean
UBA	Umweltbundesamt
VAAM	Vereinigung für Allgemeine und Angewandte Mikrobiologie e.V.
VOS	Voluntary Observing Ships
VW	Volkswagen
WCRP	World Climate Research Programme
WDC-MARE	World Data Center for Marine Environmental Data
WGL	Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz
WGNE	Working Group on Numerical Experimentation
WGOMD	Working Group on Ocean Modelling Development
WHOI	Woods Hole Oceanographic Institution, Woods Hole, USA

Appendix 4: Acronmys

WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment
WTZ	Wissenschaftl.-Technische Zusammenarbeit (BMBF)
ZAM	Zentrum für Angewandte Meereswissenschaften
ZMK	Zentrum für Meeres- und Klimaforschung der Universität Hamburg
XBT	Expendable Bathythermograph