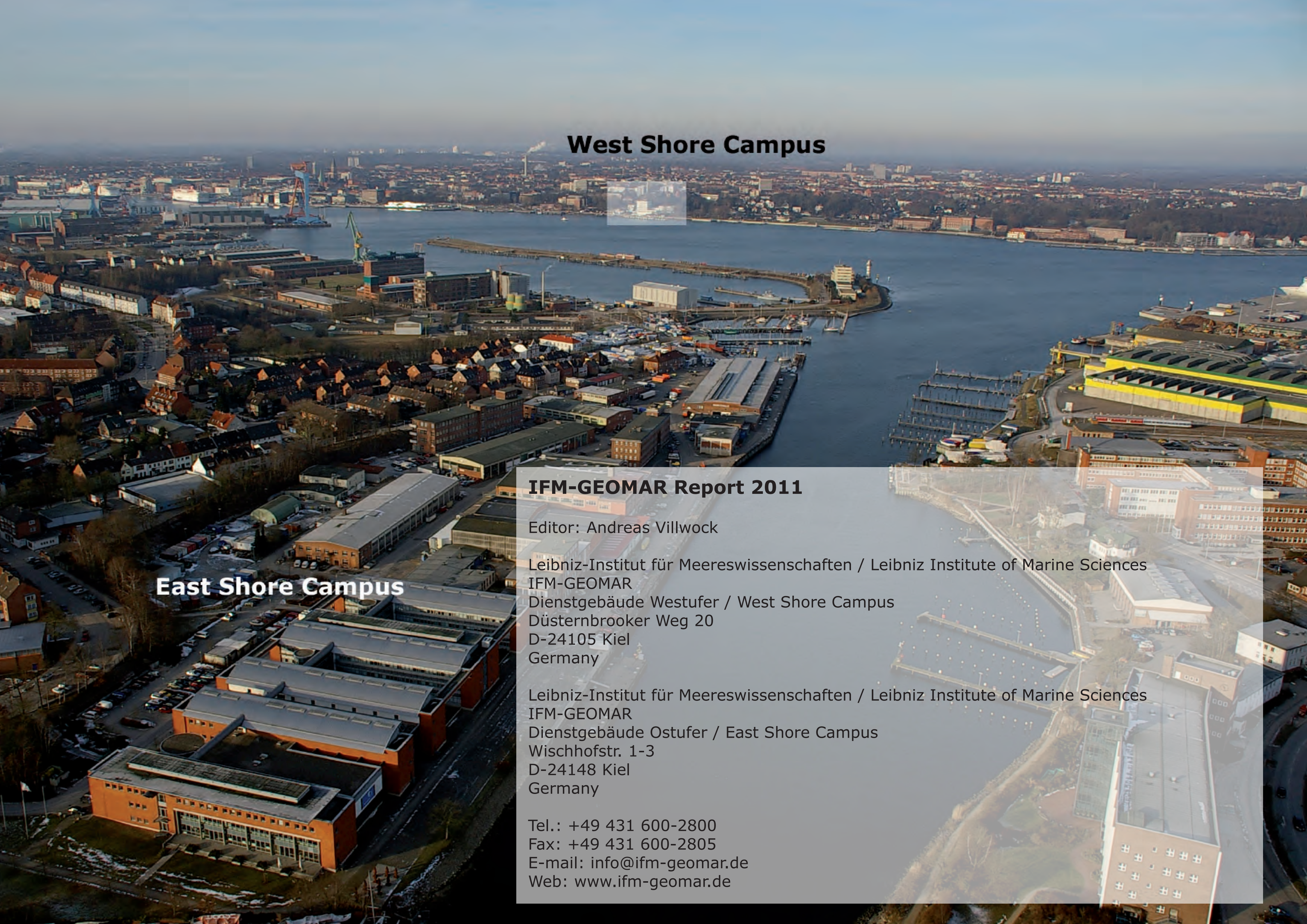
IFM-GEOMAR

IFM-GEOMAR Annual Report 2011

From the Seafloor to the Atmosphere

- Marine Sciences at IFM-GEOMAR Kiel -



IFM-GEOMAR Report 2011

Editor: Andreas Villwock

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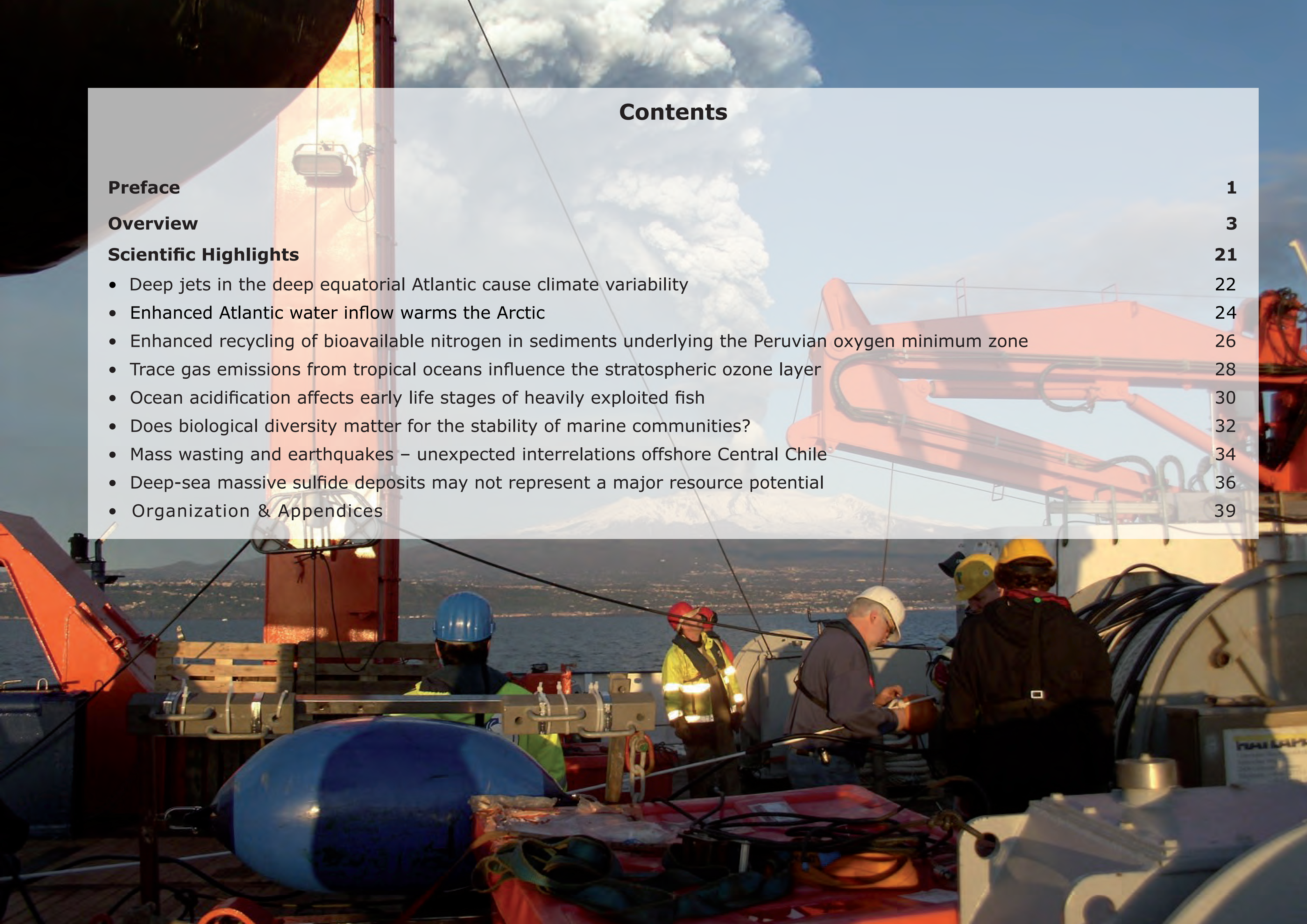

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Preface

For IFM-GEOMAR, 2011 was characterized by the preparations for the transition to the Helmholtz Association on 1 January 2012. During the first half of the year, its strategic fit was reviewed by the Senate Commission of the Helmholtz Association, the Consortium Agreement was signed by the Federal and State Ministries and preparatory work was carried out in order to apply for programme-oriented funding, all of which created important prerequisites for this transition. At the same time, the practical work required for this transition began in the spring. This included the development of a new Corporate Design and, based on this, the redesign of printed matter as well as the website of the future GEOMAR. Furthermore, in particular in the administration adaptations to different general rules within the Helmholtz Association were also necessary.

Finally, with the adoption of the Establishment Act by the State of Schleswig-Holstein and the approval by the General Assembly of the Helmholtz Association to accept the institute as a member of the Helmholtz Association on 1 January 2012, the formal prerequisites for the new GEOMAR | Helmholtz Centre for Ocean Research Kiel were created during the second half of the year.

On the scientific side, one very notable achievement was the successful approval of the follow-up application for the Collaborative Research Centre (SFB) 754: "Climate-Biogeochemistry Interactions in the Tropical Ocean", which will secure this important line of research at IFM-GEOMAR for the next four years. The successful continuation of the SFB

is also a very encouraging signal, especially with regard to our transition to the Helmholtz Association and the resulting slight changes in the general conditions for funding by the Deutsche Forschungsgemeinschaft (German Research Foundation, DFG). Furthermore, this step emphasizes our close collaboration with the University of Kiel. This is also documented in the follow-up application for the very successful cluster of excellence, "The Future Ocean", which was submitted to the German Research Foundation in September 2011. The broad interdisciplinary collaboration in the field of marine sciences that has been carried out within the scope of this cluster over the past five years, is unique worldwide and opens up many new possibilities for joint research and evaluation of results across disciplines. We are confident that, together with our colleagues at the University and our other partners, we will also be able to continue this work in the coming years.

Again during the past year, the scientists at IFM-GEOMAR took part in numerous expeditions throughout the world to find answers to socially relevant questions from among the wide range of research topics dealt with by our institute. Their findings have been documented in hundreds of reviewed publications that were published in the relevant journals. Together with the yet again large number of acquisitions of new projects funded by third parties, this shows the scientific performance of IFM-GEOMAR and the excellence of its research. We are confident that we will be able to continue this in future at the new GEOMAR | Helmholtz Centre for Ocean Research Kiel.

This Annual Report 2011 gives you an overview of the most important performance figures, events and excellent scientific findings from the past year. I hope that you will enjoy reading it!

Prof. Dr. Peter M. Herzig
Director

Overview

IFM-GEOMAR at a glance

Overview

The Leibniz Institute of Marine Sciences (IFM-GEOMAR) is one of the world's leading institutions in the field of marine sciences. The institute investigates the chemical, physical, biological and geological processes of the seafloor, the oceans and their interactions with the atmosphere. This broad spectrum makes IFM-GEOMAR unique in Germany and one of the three leading institutes in Europe. Additionally, the institute has successfully bridged the gap between basic and applied science in a number of research areas.

IFM-GEOMAR has identified four overarching research themes:

- Role of the Ocean in Climate Change
- Human Impact on Marine Ecosystems
- Living and Non-Living Marine Resources
- Plate Tectonic Processes and Geological Hazards.

In cooperation with the University of Kiel, the institute is responsible for the Excellence Cluster "The Future Ocean" and two long-term Collaborative Research Centres (SFBs) that are funded by the German Research Foundation (DFG).

Four research vessels, large-scale sea-going equipment such as the manned submersible JAGO, the unmanned deep-sea robots ROV KIEL 6000 and AUV ABYSS, as well as state-of-the-art laboratories, analytical facilities, and a hierarchy of numerical models provide a unique basis for cutting-edge marine research. With a number of curricula offered in English, the institute actively contributes to the education of young scientists in the field of marine sciences.

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

Director and CEO

Prof. Dr. Peter M. Herzig

Head of Administration

Ursula Frank-Scholz

Public Relations

Dr. Andreas Villwock

Employees

764 including 383 scientists (End of 2011)

Budget

59,4 million euros:
- 31,3 million euros institutional funding
- 28,1 million euros research funding

Contact

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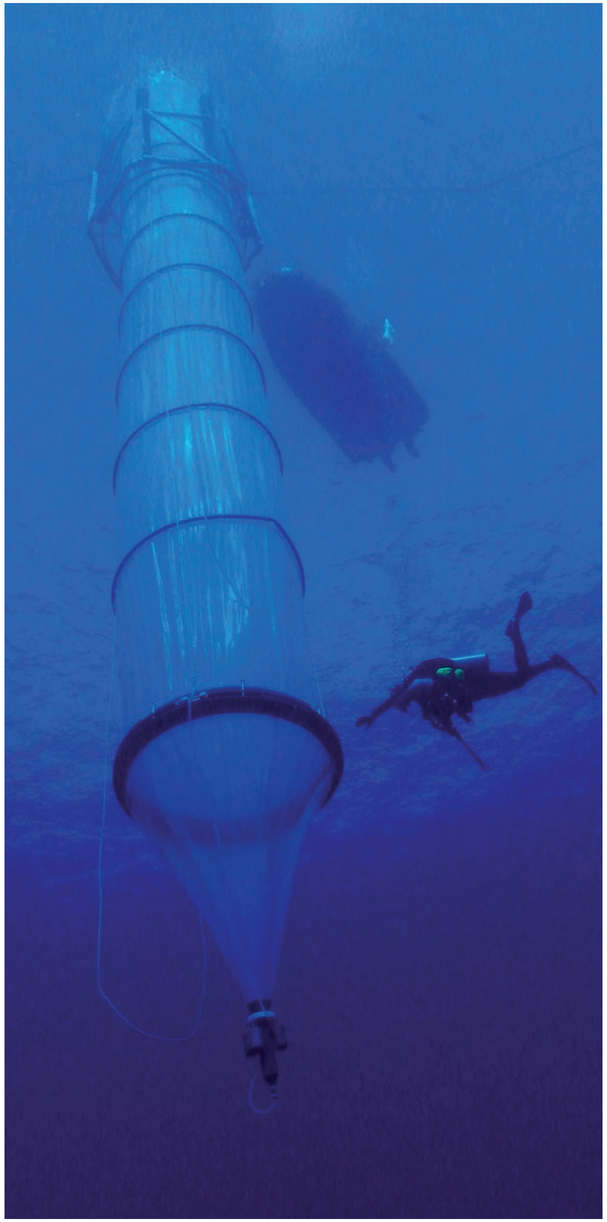


1. Transition to the Helmholtz Association

IFM-GEOMAR's transition to the Helmholtz Association was prepared at various levels throughout the year 2011. The key parameters at the administrative and political levels were:

- strategic fit reviewed by the Senate Commission of the Helmholtz Association at IFM-GEOMAR on 28 February 2011;
- preparation of the third phase of programme-oriented funding (POF-III). Drafting of a programme application: "The blue ocean - from the deep sea to the atmosphere (OCEANS)". Furthermore, participation in the programme application managed by the Alfred Wegener Institute for Polar and Marine Research (AWI) as well as in the application made by the German Research Centre for Geosciences (GFZ). The spokesperson for IFM-GEOMAR is Professor Dr. Kaj Hoernle;

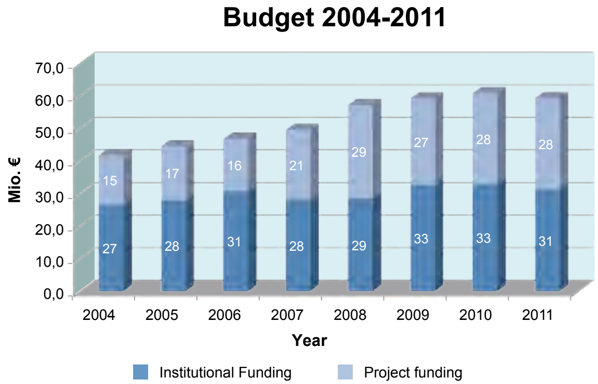
Evaluation of Helmholtz fit: left: Secretary of State of S.-H. Dr. Cordelia Andreßen, Prof. Dr. Jürgen Mlynek (President, Helmholtz- Association) and Prof. Dr. Peter Herzig (Director, IFM-GEOMAR).

Signment of the Consortium Agreement: left to right: Prof. Dr. Gerhard Fouquet (President Kiel University), Prof. Dr. Karin Lochte (Chair, German Marine Research Consortium), Peter Harry Carstensen (Prime Minister Schleswig-Holstein), Prof. Dr. Annette Schavan (Federal Minister for Education and Research) and Prof. Dr. Peter Herzig (Director, IFM-GEOMAR).

- adoption of a new name for the Institute: GEOMAR | Helmholtz Centre for Ocean Research Kiel;
- signing of the Consortium Agreement by the Federal and State Ministries and the Cooperation Agreement KAIMS (CAU/ IFM-GEOMAR) at the Representation of the State of Schleswig-Holstein in Berlin on 9 May 2011;
- adoption of the Establishment Act, taking the Institute's petition as presented by the State Government on 26 August 2012 into consideration;
- advertisment of the newly created position of Administrative Director, appointment of a Selection Committee;
- approval by the General Assembly of the Helmholtz Association to accept the Institute in the Helmholtz Association as from 1 January 2012;
- first successful proposals for funding by the Helmholtz Association. This included: funding for applications within the scope of Calls for Proposals issued under the Initiative and Networking Fund: junior research group "Marine and Atmospheric Chemistry" led by Dr. Christa Marandino, financial support for equipment to ensure excellence and appointment of Professor Heidrun Kopp to a professorship (W3) for "Marine Geodesy", financial support as part of the appointment of Professor Anja Engel, Helmholtz Russia Joint Research Group "European and Russian Extreme Events: Mechanisms, Variability and Future Climate Change (EUREX)" by Professor Douglas Maraun;
- basic concept for a new Corporate Design for GEOMAR was completed and implemented;
- Administration Department and auditors for GEOMAR prepared the switch to commercial accounting (Doppik double-entry accounting system) as from 1 January 2012;
- definition of the starting values for GEOMAR in the Helmholtz Association for the years 2012 to 2014. The increase in the starting value at the beginning of the programme-oriented funding in 2014 amounts to € 7.8 mio. plus investments in the amount of € 3.9 mio.. In addition to the progressive increase in the starting values for the years 2012 and 2013, investment funds in the amount of € 3.5 mio. and € 3.7 mio. respectively were approved for the years 2012 and 2013.

2. Research funding

In 2011, basic funding (institutional funding) amounted to € 31.3 mio. Total project funding amounted to € 28.1 mio., of which more than € 10 mio. was provided by the DFG (incl. cluster and SFBs), € 7.7 mio. through BMBF projects (Federal Ministry of Education and Research) and just under € 4.2 mio. through EU funds. In addition, over



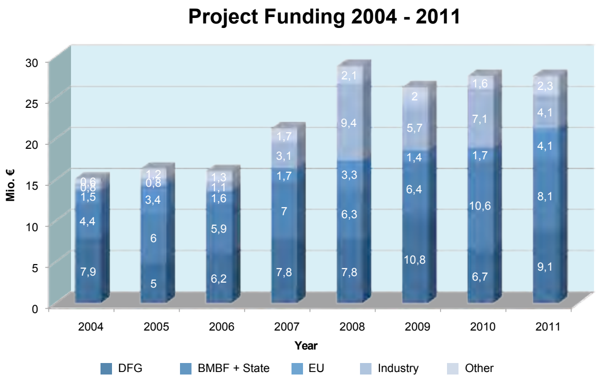


Fig. 1.1 & 1.2: Development of the total budget (top) an project funding (by sources) (below) from 2004-2011.

€ 4.4 mio. was received from funding in collaboration with various business companies. For several years now, both institutional funding as well as the acquisition of third-party funding have remained stable at the same high level (Fig. 1.1). The composition of project funding is more variable; the most important pillars here are the funds from the Deutsche Forschungsgemeinschaft (German Research Foundation, DFG) as well as funds from the Federal German Ministry of Education and Research (cf. Fig. 1.2).
Please refer to Appendix 3 for details on research funding.

Development of existing major projects:

SFB 754: "Climate-Biogeochemistry Interactions in the Tropical Ocean"

This project, which has been funded by the DFG since 2008, completed its first phase in 2011. We would like to emphasize the following events from the past year:

- March-April 2011: MARIA S. MERIAN Expedition 17/4 to the eastern Atlantic off the coast of north-west Africa, headed by Dr. Pfannkuche. Objective: investigation of the oxygen minimum zone;
- May-June 2011: MARIA S. MERIAN Expedition 18/2 to the eastern Atlantic off the Cape Verde Islands, headed by Professor Brandt. Objective: mooring recovery and data sampling along a section at 23°W;
- September 2011: on-site review by a DFG Review Panel for the 2nd funding phase (2012-2016) successfully completed. The international Review Panel evaluated the SFB as "very good" to "excellent";
- December 2011: notice awarding a grant for the 2nd phase in the amount of 11.5 mio. euros, without changes to the recommendations given by the Review Panel;
- December 2011: Election of Professor Dr. Andreas Oschlies as new spokesperson.

SFB 574: "Fluids and Volatiles in Subduction Zones"

After running for 10 years, the project is now in its final phase and will be completed in the summer of 2012. The most important events of the past year included:

- November 2010-January 2011: two MARIA S. MERIAN expeditions: Merian MSM 17/1 & 17/2 to the south-east Atlantic, headed by Professor Behrmann;
- Feb. / March: several land expeditions to different volcanoes in Chile (PIs: Professor Hoernle, Dr. Hansteen and Dr. Freundt).

Cluster of Excellence: "The Future Ocean"

The cluster of excellence "The Future Ocean", which has been running since 2006, prepared the follow-up application in 2011 for the second funding phase for 2013-2017. It was submitted on time on 1 September 2011. The review will take place on 12 January 2012. The key focus in the second phase will be on the internationalisation as well as the integration of the social sciences.

Since June 2011, the cluster has also had a small permanent exhibition at the Zoological Museum of the University of Kiel.

New research projects (extract)

Some of the projects funded by third parties that were newly approved in the past year are presented here as an example. Please refer to Appendix 3.2 for a complete list of all projects.

1. ECO2 (Sub-seabed CO_2 Storage: Impact on Marine Ecosystems)

The objective of this EU project (7th framework programme) is to investigate existing as well as potential submarine deposits for CO_2 and the impact of possible leakages on the marine environment.

The funding volume amounts to € 10.5 mio. (of which € 2.3 mio. goes to IFM-GEOMAR). The Kick-off Workshop took place in Kiel from 18-20 May 2011. ECO2 is coordinated by Professor Klaus Wallmann (IFM-GEOMAR) and runs from 2011-2014.

The first expedition on the ALKOR took place in the northern North Sea from 29 April - 14 June 2011. The objective was to investigate possible outgassing in the Sleipner field.

For more information, please visit:
www.eco2-project.eu

2. SUGAR Phase II ("Submarine Gas Hydrate Reservoirs")

In the second phase of the project on submarine gas hydrate reservoirs, jointly funded by the Federal German Ministry of Economics and Technology (BMWi) and the BMBF, the methods for producing methane while simultaneously storing carbon dioxide are to be developed further and tested. The project has a funding volume of: € 13 mio., IFM-GEOMAR's share: € 3.7 mio. for a three-year period (2011-2014). The coordinator is Professor Klaus Wallmann.

For more information, please visit:
www.sugar-projekt.de

3. CARBOCHANGE ("Changes in carbon uptake and emissions by oceans in a changing climate")

CARBOCHANGE is an EU joint research project (2011-2015). Its objective is to quantify the amount of carbon dioxide that is emitted during human activity and taken up by the ocean and determine the extent to which the rate of collection changes. The University of Bergen in Norway is the coordinating facility for this project, which has a funding volume of € 7 mio. € (of which € 675,000 goes to IFM-GEOMAR).

For more information, please visit:
http://carbochange.b.uib.no/

4. GROOM ("Gliders for Research, Ocean Observation and Management")

The objective of GROOM is the development of a European research infrastructure for the coordinated use of gliders. The project is coordinated by the Université Pierre et Marie Curie, Paris, France, within the scope of the 7th EU framework programme. The funding volume amounts to € 3.5 mio. (of which € 430,000 goes to IFM-GEOMAR). The coordinator at IFM-GEOMAR for this project, which runs from 2011-2014, is Dr. Johannes Karstensen.

For more information, please visit: http://plocan.eu/en/images/stories/project/GROOM_en.pdf

5. Otto Schmidt Laboratory for Polar and Marine Research

The Otto Schmidt Laboratory (OSL) was founded in 1999. It is operated and financed for the Russians by the Arctic and Antarctic Research Institute (AARI) in St. Petersburg, the Russian Ministry for Science and Education and the Federal Hydrometerological and Environment Service as well as, for the Germans, the Federal German Ministry of Education and Research, the Alfred Wegener Institute for Polar and Marine Research in Bremerhaven and IFM-GEOMAR. Furthermore, more than 40 universities and research facilities in Russia and Germany work together at the OSL. One of the main tasks of the OSL, apart from coordination, is the scientific qualification and promotion of young scientists.
The new project is a scholarship programme: "Climate Change in the Arctic Ocean" with a funding volume of € 990,000; it will run for three years (2012-2014). The coordinator is Dr. Heidemarie Kassens from IFM-GEOMAR.

For more information, please visit:
www.otto.nw.ru

New research projects with industrial partners

GEOHAZARD Turkmenistan

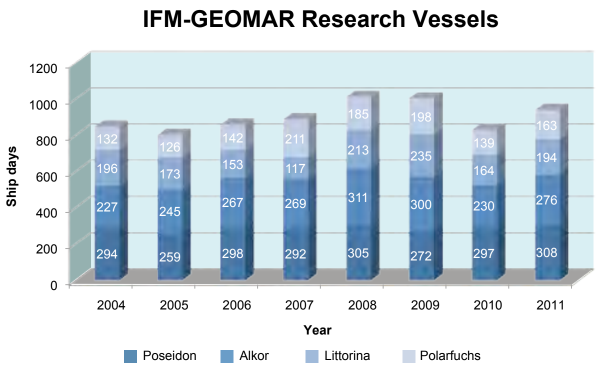
The objective of the project is to investigate natural hazards attributable to geogenic sources for offshore drilling in Turkmenistan. In particular, mud volcanoes in the southern Caspian Sea basin will be investigated. The project led by Dr. Warner Brückmann has a volume of € 1.15 mio. for the period 2011-2015. Industry partner is RWE Dea.

Please refer to Appendix 3.2 for detailed information on all projects.


Expeditions
ROV
KIEL 6000

3. Expeditions

One of the main components of a marine research facility are the expeditions on research vessels. Once again during the past year, the scientists at IFM-GEOMAR undertook a larger number of expeditions on the Institute's own research vessels as well as on other German and foreign platforms. For details, please refer to Fig. 1.3 and 1.4 as well as Appendix 4. Land-based expeditions



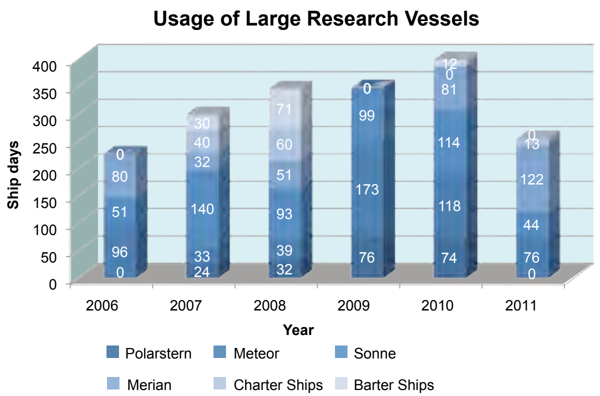


Fig. 1.3 & 1.4: Usage of IFM-GEOMAR research vessels (top) and usage of other research vessels by IFM-GEOMAR (below) from 2004-2011.

took place in Chile in the spring of 2011 (SFB574) and along the Saudi Arabian coast (JEDDAH Project) as well as in the north Siberian Laptev Sea in the autumn. The most important ship-based voyages included:

3.1 RV CHAKRTONG TONGYAI

6 - 26 January 2011, off the coast of Thailand, TRIAS /MASS ; objective: bathymetric and seismic data sampling; taking samples for estimating the possibility of landslides; chief scientist: Professor Krastel

3.2 MERIAN MSM 17/1-2

two expeditions (23 November 2010 - 27 January 2011) in the south-east Atlantic off the coast of Namibia with the scope of SFB 574; objective: to investigate the crustal and lithospheric structure of the southern African plate and the formation of the South Atlantic; chief scientist: Professor Behrmann

3.3 POSEIDON POS 408/1-3

three expeditions to the Red Sea within the scope of the cooperation with the King-Abdul-Aziz University, Jeddah, Saudi Arabia:

- 13 - 31 January 2011; objective: rifting processes in the Red Sea; chief scientist: Professor Devey;
- 3 - 20 February 2011; objective: investigation of volcanism, hydrothermalism and ore deposits in the Atlantis II Deep; chief scientist: Dr. Schmidt;
- 23 February - 3 March 2011; objective: investigation of nutrients, algae and coral in the central and northern Red Sea; chief scientist: Professor Sommer.

3.4 SONNE SO 214

9 March - 22 April 2011, Wellington - Auckland, NEMESYS; objective: variability of submarine gas leaks in structure and chemistry and their impact on the climate; chief scientist: Dr. Bialas.

3.5. MERIAN MSM 17/4

10 March - 12 April 2011, eastern Atlantic off the coast of Senegal and Mauritania;

Jeddah Project: Sampling of a coral in the Red Sea.

Unusual for marine scientists: SFB 574 land expedition with horses in den Chilean Andes.

Rare view: the sister ships ALKOR (right) and Heincke (left) joint returning into the Kiel Fjord.

objective: investigation of the oxygen minimum zone (OMZ) within the scope of the Collaborative Research Centre (SFB) 754; chief scientist: Dr. Pfannkuche.

3.6 METEOR 84/3

5 - 28 April 2011, Istanbul-Vigo, Mediterranean; objective: investigation of the large-scale distribution of water mass properties as a result of an observed shift of the deep water formation from the Adriatic to the Aegean Sea; chief scientist: Dr. Tanhua.

3.7 ALKOR AL 371

8 - 21 April 2011, Kiel-Kiel, Baltic Sea; objective: investigations within the scope of various projects in the field of evolutionary ecology of marine fish, incl. Aquashift, EPOCA; chief scientist: Professor Reusch.

3.8 POSEIDON POS 412

19 April - 7 May 2011, Thyrrhenian Sea, north of Sicily; objective: geological, chemical and biological characterisation of ecosystems in geological formations such as the Palinuro volcanic complex, the Panarea hydrothermal field and the Marsili seamount; chief scientist: Professor Imhoff.

3.9 MERIAN MSM 18/2-3

Two expeditions to the eastern equatorial Atlantic. Objective: current systems, characteristics of water masses, oxygen minimum zones in the eastern equatorial Atlantic.

- 11 May - 19 June 2011, Mindelo-Mindelo, BMBF North Atlantic, SOPRAN and SFB 754; chief scientist: Professor Brandt.
- 22 June - 21 July 2011, Mindelo-Libreville, BMBF North Atlantic, SOPRAN and SFB 754; chief scientist: Professor Körtzinger.

3.10 METEOR 84/5

31 May - 21 June 2011, Vigo-Brest, Bay of Biscay, TransBiscay; objective: palaeo-oceanographic work in the Bay of Biscay; chief scientist: Dr. Flögel.

3.11 ALKOR AL 374

29 April - 14 June 2011, Kiel-Kiel, northern North Sea, ECO2; objective: investigation of possible CO_2 emissions in the Sleipner field; chief scientist: Dr. Linke.

3.12 MERIAN MSM 18/4

5 - 25 August 2011, St. John's-Reykjavik, BMBF North Atlantic, THOR, EuroSITES; objective: variability of current systems in time in the North Atlantic; chief scientist: Dr. Karstensen.

3.13 POSEIDON POS 419/1

10 August - 2 September 2011, Tromsö-Tromsö, HERMIONE & cluster of excellence: "The Future Ocean"; objective: biological and biogeochemical processes by releasing methane from melting gas hydrates west of Svalbard; chief scientist: Dr. Pfannkuche.

3.14 POSEIDON POS 420/1 and the submersible "JAGO"

5 - 30 September 2011, Tromsö-Kiel, shelf west of Norway, BIOACID; objective: investigation of cold water corals; chief scientist: Professor Riebesell.

Research submersible JAGO and RV POSEIDON in Trondheim Fjord, Norway.

3.15 SONNE SO 218

15 - 29 November 2011, Singapore-Manila, West Pacific / South China Sea, SHIVA Project; objective: processes for transporting bromine from the ocean into the stratosphere; chief scientists: Dr. Krüger / Dr. Quack.

3.16 MERIAN MSM 19/3

2 - 22 December 2011, Cape Town-Cape Town, AGULHAS Project; objective: mapping the sea floor and taking samples of hard rock from volcanic structures in the area around the Agulhas Ridge and the Discovery hotspot in the South Atlantic; chief scientist: Dr. Werner.

4. Large-scale equipment and infrastructure

Apart from the research vessels, IFM-GEOMAR maintains large equipment that allows it to take samples and carry out experiments in parts of the world's oceans that would otherwise be difficult to access, in particular in the deep sea. In 2011, in addition to the deep sea robots ROV Kiel6000 and AUV ABYSS, a further remote-controlled vehicle, PHOCA, was put into service. This device can dive up to 3,000 meters deep and used even on medium-sized vessels such as the RV POSEIDON. It was procured within the scope of the MoLab Project. Initial operation planned for 2012.
The so-called "benthocosms" were procured as a further experimental facility, to be used in particular for exploring the effect of changed environmental conditions on organisms that live on the seabed (benthic flora and fauna). In 2011, IFM-GEOMAR operated this large equipment as follows:

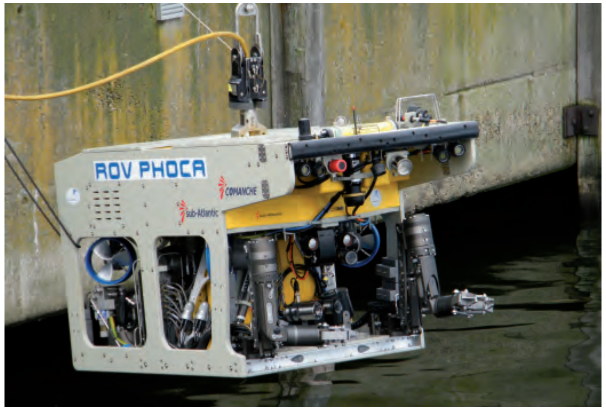
4.1 ROV Kiel 6000

13 July - 3 August 2011: RV POLARSTERN expedition ARK XXVI/2, Framstrasse, HAUSGARTEN Observatory in cooperation with the Alfred Wegener Institute for Polar and Marine Research, Bremerhaven

November 2011, used on the RV JAMES COOK for an expedition to the southern Indian Ocean together with British Antarctic Survey, Cambridge in cooperation with the National Oceanography Centre (NOC), Southampton, UK.

4.2 ROV PHOCA

March-April 2011: first test with the support of the German Bundeswehr Technical Centre 71 in Eckernförde. Plans for initial operation off the coast of Norway within the scope of the MoLab Project 2012.



PHOCA test in Eckernförde.

4.3 AUV „ABYSS"

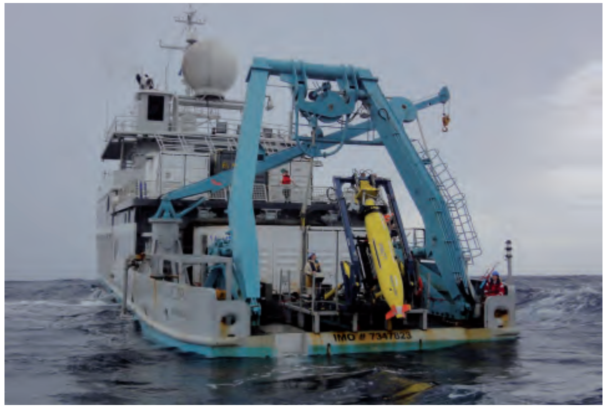
March-April 2011: operated on the RV ALUCIA for a new search for the missing Air France Airbus; wreck found on 3 April 2011.

November 2011, expedition on the RV KILO MOANA in the western Pacific (Lau Basin) in cooperation with Nautilus Minerals Inc.


Part of wreck of Air France airbus in the Atlantic.

4.4 Research Submersible "JAGO"

April 2011: operated on the RV GARCIA DEL CID off the coast of the Balearic Islands together with scientists from Institut de Ciènces del Mar in Barcelona within the scope of the EU Project LIFE+INDEMARES/Natura 2000.

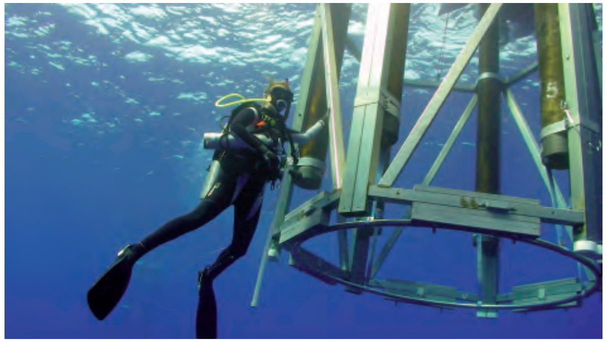

AUV ABYSS launched from RV KILO MOANA.

September 2011, operated on RV POSEIDON off the coast of Norway for investigating ocean acidification and cold water corals; chief scientists: Dr. Form / Professor Riebesell.

4.5 Kiel Mesocosm System

May-June 2011: experiment in the fjord off Bergen, Norway;

November-December 2011, experiment off the coast of Hawaii; chief scientist: Professor Riebesell.


Installation of the mesocosm off Hawaii.

5. Scientific achievements and publications

More than 350 reviewed scientific articles in the year 2011 document IFM-GEOMAR's ongoing high level of scientific performance. The publication output of the individual fields of research (measured according to so-called "Journal Impact Factor" points) has remained stable at a very high level for a number of years (Fig. 1.5).

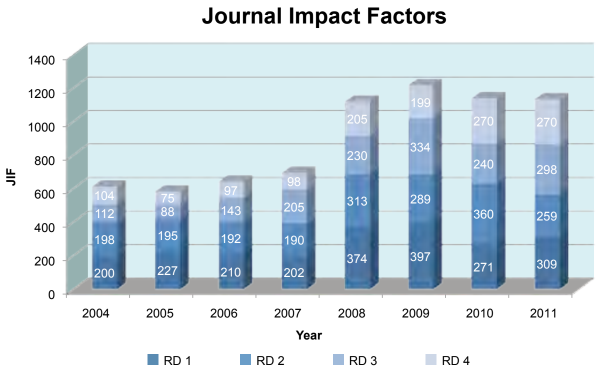


Fig. 1.5: Scientific publications (accounted by journal impact factors) by research divisions from 2004-2011.

Amongst those, the following publications appear in the high-level international journals *Science* and *Nature*:

Beal, L. M., De Ruijter, W. P. M., Biastoch, A., Zahn, R., Cronin, M., Hermes, J., Lutjeharms, J., Quartly, G., Tozuka, T., Baker-Yeboah, S., Bornman, T., Cipollini, P., Dijkstra, H., Hall, I., Park, W., Peeters, F., Penven, P., Ridderinkhof, H. and Zinke, J., 2011: On the role of the Agulhas system in ocean circulation and climate. *Nature*, **472** (7344), 429-436, DOI 10.1038/nature09983.

Brandt, P., Funk, A., Hormann, V., Dengler, M., Greatbatch, R. J. and Toole, J. M., 2011: Interannual atmospheric variability forced by the deep equatorial Atlantic Ocean. *Nature*, **473** (7348), 497-500, DOI 10.1038/nature10013.

Frank, M., 2011: Chemical twins, separated. Nature Geoscience, **4** (4), 220-221, DOI 10.1038/ngeo1125.

Hoernle, K., Hauff, F., Werner, R., van den Bogaard, P., Gibbons, A. D., Conrad, S. and Müller, R. D., 2011: Origin of Indian Ocean Seamount Province by shallow recycling of continental lithosphere. *Nature Geoscience*, **4** (12), 883-887, DOI 10.1038/ngeo1331

Joye, S. B., Leifer, I., MacDonald, I. R., Chanton, J. P., Meile, C. D., Teske, A. P., Kostka, J. E., Chistoserdova, L., Coffin, R., Hollander, D., Kastner, M., Montoya, J. P., Rehder, G., Solomon, E., Treude, T. and Villareal, T. A., 2011: Comment on "A Persistent Oxygen Anomaly Reveals the Fate of Spilled Methane in the Deep Gulf of Mexico". *Science*, **332** (6033), 1033, DOI 10.1126/science.1203307.

Spielhagen, R.F., K. Werner, S. Aagaard Sørensen, K. Zamelczyk, E. Kandiano, G. Budeus, K. Husum, T. M. Marchitto, M. Hald, 2011: Enhanced Modern Heat Transfer to the Arctic by Warm Atlantic Water. Science, **331**, 450-453, DOI 10.1126/science.1197397.

Stroncik, N. A. and Devey, C. W., 2011: Recycled gabbro signature in hotspot magmas unveiled by plume–ridge interactions. *Nature Geoscience*, **4**, 393-397, DOI 10.1038/NGEO1121.

Worzewski, T., Jegen, M., Kopp, H., Brasse, H. and Taylor, W. T., 2011: Magnetotelluric image of the fluid cycle in the Costa Rican subduction zone. *Nature Geoscience*, **4**, 108-111, DOI 10.1038/ngeo1041.

Wu, L., Jing, Z., Riser, S. and Visbeck, M., 2011: Seasonal and spatial variations of Southern Ocean diapycnal mixing from Argo profiling floats. *Nature Geoscience*, **4** (6), 363-366, DOI 10.1038/ngeo1156.

Front page of the intl. journal Geology, December 2011: Hannington, M., J. Jamieson, T. Monecke, S. Petersen, and S. Beaulieu, 2011: The abundance of seafloor massive sulfide deposits. Geology, 39, 1155-1158, doi: doi:10.1130/G32328.1.

Please refer to Appendix 6 for a detailed list of all publications.

A selection of some of the scientific highlights of the past year is presented in Chapter 2. These include, among others, investigations on equatorial current systems, climate changes in the Arctic, oxygen minimum zones off the coast of Peru, impact of ocean acidification on fish stocks or the value of mineral resources as a source of raw materials for the future.

6. Personnel

At the end of 2011, 764 members of staff were employed at IFM-GEOMAR. This means that the overall number of employees was almost the same as in the previous year. 50% of the employees work in the scientific field. Women represent 46% of the total number of staff and approx. 40% of the scientists. The percentage of women among the professors is still rather low, but was increased in the course of new appointments (see below). 72% of the employment contracts have a fixed period; about 80% in the scientific field. Personnel development, subdivided into organisational units, is depicted in Fig. 1.6.

For further details, please refer to Appendix 2.

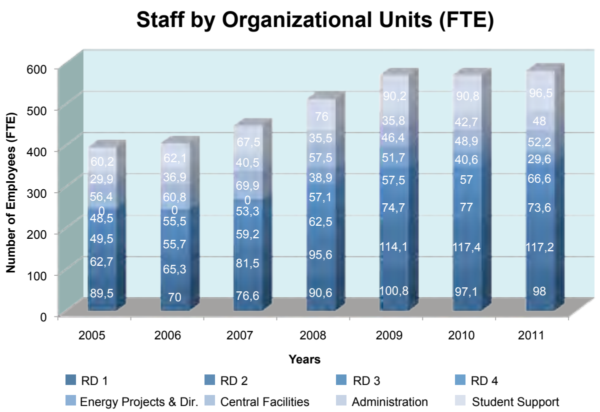


Fig. 1.6: Development of personell by organizational units 2004-2011.

6.1 Changes in management staff

The following changes were carried out at the Professorial level in 2011:

- Biological Oceanography (W3, successor for Professor Lochte): Professor Anja Engel, AWI; commencement of duties: 1 September 2011.

Prof. Dr. Anja Engel.

- Marine Meteorology (W3, successor for Professor Macke): Professor Katja Matthes, GFZ and FU Berlin; commencement of duties August 2012.

Prof. Dr. Katja Matthes

- Marine Meteorology (W1, successor for Professor Dommenget): Professor Douglas Maraun, Justus Liebig University of Gießen.

Prof. Dr. Douglas Maraun.

- Seafloor Resources (W3, permanent adoption of a junior professorship from the cluster of excellence): Professor Lars Rüpke.

Prof. Dr. Lars Rüpke.

Overview

- Marine Geobiology (W3, permanent adoption of a junior professorship from the cluster of excellence): Professor Tina Treude.

Top: Prof. Dr. Tina Treude.
Below: Prof. Dr. Andreas Oschlies.

Negotiations with Professor Andreas Oschlies (Biogeochemical Modelling) were successfully concluded and he will remain in office. The vacancy to refill the W3 Chair for Chemical Oceanography (successor for Professor Wallace) has been published.

6.2 Honors and Awards (selection)

During the past year, the following members of staff received awards or distinctions for special scientific achievements:

- **Prof. Dr. Wolf-Christian Dullo**: Werner Heisenberg-Medal from the Alexander von Humboldt Foundation

Prof. Dr. Wolf-Christian Dullo.

Prof. Dr. Ulf Riebesell, Prof. Dr. Heidrun Kopp and Prof. Dr. Andreas Oschlies at EGU in Vienna, Austria.

- **Prof. Dr. Heidrun Kopp**: C.F.Gauß Lecture of the German Geophysical Society (DGG) at the European Geosciences Union
- **Prof. Dr. Andreas Oschlies**: Georg-Wüst Prize 2011, German Society for Marine Research (DGM)
- **Prof. Dr. Ulf Riebesell**: Vladimir Ivanovich Vernadsky Medal of the European Geosciences Union
- **IFM-GEOMAR Publication Award 2011** (1,000 euros each, sponsored by the Deutsche Bank):
  - **Dr. Sascha Flögel**, Palaeo-Oceanography
  - **Dr. Jutta Wiese**, Active Marine Substances Research
  - **Dr. Folkmar Hauff**, Geochemistry

  as well as 500.00 euros each for their excellent first publications:
  - **Lisa Bohlen**, Marine Biogeochemistry
  - **Jan Taucher**, Biogeochemical Modelling

For a complete list of all awards, please refer to Appendix 7.

Winners of the publication award 2011 with IFM-GEOMAR mangement. From left: Prof. Dr. Peter Herzig, Jan Taucher, Dr. Sascha Flögel, Lisa Bohlen, Dr. Jutta Wiese and Ursula Frank-Scholz. Not of the photo: Dr. Folkmar Hauff.

7. Teaching

The professors at IFM-GEOMAR continue to contribute in numerous ways to education in the field of marine science study programmes. Apart from lectures, exercises, seminars and workshops within the scope of the reduced teaching load for non-university research facilities (four credit hours per week), final thesis (for Bachelor's and Master's degrees as well as German diplomas and doctorates) are supervised and evaluated. The development of academic qualification work, subdivided into fields of research, is depicted in Fig. 1.7. This figure, which has increased enormously, also results from the conversion to courses finishing with a Bachelor's or Master's degree, because theses must now be written for both of these courses (previously only for a German diploma). For further details, please refer to Appendix 5.7 (Academic Qualification Work) and Appendix 8 (Lectures). For the period of transition before IFM-GEOMAR became part of the Helmholtz Association, the Cooperation Agreement KAIMS laid an important foundation for the future collaboration with the University of Kiel. This includes joint search procedures for professors; in addition, the existing scope of commitment to teaching will be continued.

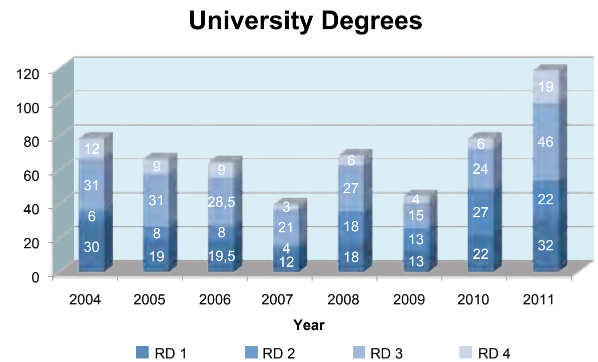


Fig. 1.7: University degrees (bachelor, master, PhD, habilitation) by research divisions from 2004-2011.

Beside lectures, pratical excerises are of particular importance for the next generation of marine scientists. Sampling of a sediment core in Marine Geology.

8. European and international cooperations

Apart from the individual cooperations that exist at the scientific level with a large number of facilities worldwide, which are impressively substantiated by numerous joint publications, and the research association projects at the European level, there are also many cooperations at an institutional level that focus, in particular, on strategic aspects. Events and developments occurred during 2011 in the following sectors, which should receive special mention:

G3-Cooperation (National Oceanography Centre (UK), Ifremer (F), IFM-GEOMAR (D))

- Lunch Briefing at the European Parliament on 2 February 2011 at the initiative of the German Marine Consortium and at the invitation of MEP Reimer Böge (topic: Resources from the Sea);
- 8th G3 Workshop on 28 November 2011 in Southampton, UK.

Cooperation with China

- Foundation of a Chinese-German Centre for Cooperation in Marine Sciences in Qingdao on 24 February 2011 to support the scientific exchange between Kiel, Bremen and Qingdao;
- 5 - 17 September 2011, Chinese-German Workshop and Summer School, organized by the "Chinese-German Centre for Collaboration in Marine Sciences" (SGMS) in Qingdao, China. The key focus of the events, which approx. 50 people from China and Germany attended, was on

Opening ceremony of the Sino-German Center for Cooperation in Marine Sciences in Qingdao, China.

investigating seas with regard to changes in the environment;

- since October 2011: supporting the exchange programme for educating graduates and doctoral students from the Integrated School of Ocean Sciences (ISOS). Co-financing of the coordinating position by IFM-GEOMAR.

Cooperation with Canada

- German-Canadian Conference, approx. 100 participants, in Halifax, Canada, from 2-4 June 2011 during Oceans Week at Dalhousie University. Intensifying contacts after Professor Dr. Douglas Wallace began working at the newly founded Halifax Marine Research Institute.

From left: Prof. Doug Wallace, scientific director of the new Halifax Marine Research Institute, Dr. Martha Crago, Vice-President Research, Dalhousie University, Prof. Peter Herzig, Director, IFM-GEOMAR.

Cooperation with Saudi Arabia

- Kick-off Meeting for the Poseidon Expedition within the scope of the Jeddah-Transect Project at the King Abdullah Aziz University in Jeddah (11 January 2011)

Prof. Dr. Peter Herzig (2.v.l.) with representatives of the King Abdullah Aziz University in front of the research vessel POSEIDON in Jeddah.

Further infomation: www.jeddah-projekt.de

Cooperation with Cape Verde

- Professor Dr. Peter Herzig attended consultations with representatives from the Government of the Republic of Cape Verde in Praia from 16 - 18 June 2011 regarding

A loggerhead turtle (Caretta caretta) equipped with a transmitter from IFM-GEOMAR on her way back into the ocean.

the further expansion of the Ocean Observatory;

- August 2011: Start of a new, interdisciplinary research project to investigate the migration of the world's third largest turtle population, the endangered species ‚loggerhead turtle' (*Caretta caretta*) as well as their mechanisms and the genetics of their reproduction.

Cooperation with Taiwan

- 2nd German-Taiwanese Gas Hydrate Workshop at IFM-GEOMAR from 12 - 13 July 2011, with 21 participating scientists from Taiwan and Germany.

Cooperation with Russia

Participants of the German-Taiwanese Workshop on Gas Hydrates.

- Otto Schmidt Laboratory Scholarship Programme, coordinated by: Dr. H. Kassens (IFM-GEOMAR) (see p. 5);
- Helmholtz-Russian Joint Research Group "European and Russian Extreme Events: Mechanisms, Variability and Future Climate Change (EUREX)" (see p. 3).

9. Institutional matters, notable events, visitors and public relations

9.1 Extension building

The transition to the Helmholtz Association resulted in several modifications to the planning process for the new extension. Consequently, there was a slight delay in planning; the project as a whole was not, however, called into question. The most important milestones in 2011 were:

- discussion regarding building coordination, which was also attended by the BMBF, BMVBS, MWV, FM and IFM-GEOMAR, during the first half of July 2011;
- appointment of a building engineer until the end of 2011;
- appointment of a Technical Project Manager from January 2012 to prepare the competition for the realisation of the building in the summer of 2012.

Planned building phase: 2013- 2015.

9.2 Deutsche Bank – IFM-GEOMAR Marine Award

The Deutsche Bank – IFM-GEOMAR Marine Award was awarded for the third time in 2011. The winner of this award, endowed with 10,000 euros, was best-selling author Frank Schätzing ("The Swarm"). The congratulatory speech was held by the scientific journalist Karsten Schwanke (television programme: Abenteuer Wissen, ZDF). The award was presented during a ceremony in Kiel on 23 May 2011.

From left: Till Keulen (Deutsche Bank) with Frank Schätzing and Prof. Dr. Peter Herzig.

9.3 Excellence Programme of the "Professor Dr. Werner Petersen Foundation"

Each of the visiting professor positions have been set up with a grant of 20,000 euros. During a research visit lasting several weeks, these excellent scientists hold a course for students; in addition, they give a public lecture one evening. In 2011, this once again took place at the Art Gallery in Kiel; each lecture was well attended by more than 100 guests.

Prof. Dr. Mark Hannington.

The following scientists were honoured in 2011:

- Dr. Sinéad Collins (University of Edinburgh, UK), Marine Biology
- Professor Dr. Mark D. Hannington (University of Ottawa, Canada), Economic Geology
- Professor Dr. Uwe Send (University of San Diego, USA), Physical Oceanography

9.4. Visitors

Once again last year, a number of distinguished guests were welcomed to IFM-GEOMAR. Among them were:

- Mrs. Bettina Wulff, wife of the Federal President, and Mrs. Sandra Carstensen, wife of the State Prime Minister of Schleswig-Holstein (9 March 2011);
- the Brazilian Delegation, with 20 representatives from the Universidade Estadual Paulista Julio des Mesquita Filho (UNESP) in São Paulo and Petrobras (28 March

Bettina Wulf signing in the IFM-GEOMAR guest book.

German prime ministers welcomed on board of RV ALKOR.

2011);

- an international group of young diplomats (11 May 2011);
- a group of science counsellors from foreign embassies (8 June 2011);
- Dr. Juliane Rumpf, Minister of Agriculture, Environment and Rural Areas in Schleswig-Holstein (9 August 2011);
- members of the working group on education from the Christian Democratic Union Party of the Schleswig-Holstein Parliament (11 August 2011);
- Personnel Committee of the Helmholtz Association (26-27 September 2011);
- 27 October 2011: Reception and informal chat during the State Prime Ministers' Conference on the ALKOR in Lübeck.

Left col: top: "young diplomats"
Middle: Science counsellors from foreign embassies in Germany
Bottom: Minister Dr. Juliane Rumpf with Prof. Dr. Martin Wahl (left) at the benthoscosm facility.

Further international guests who spent a longer period of time at IFM-GEOMAR: Professor Theophilus Davis (Humboldt Fellow, U. Venda, South Africa), Professor James B. Gill (Humboldt Research Award, U. California, Santa Cruz, USA), Professor Uwe Send (Petersen award, SIO, La Jolla, USA), Professor Mark Hannington (Petersen award, U. Ottawa, Canada), Dr. Sinead Collins (Petersen award, U. Edinburgh, UK).

Guided tours / Visits to the Institute: A visitor's programme lasting about two hours is available for registered groups, during which it is possible to have a presentation of the Institute's work and to visit parts of the facility during a guided tour. To the extent possible, individual topical requests are taken into consideration. About 60 groups with a total of almost 2,000 participants took advantage of this offer in 2011.

9.5 Public relations and other events

Please refer to Appendix 7 for an overview of the many scientific events that took place at IFM-GEOMAR in 2011 or were organized by the members of the Institute. The Institute held numerous further activities as a means of presenting itself at an international level. These included:

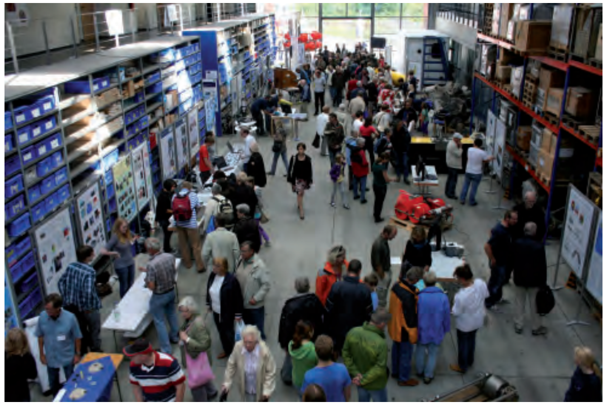
- 26-29 April 2011: 1st "Easter School" onMarine Biology for pupils;
- May to October 2011: Contribution to an exhibition on the subject of active marine substances research on board of the ‚science ship' during the official Year of Health;
- 7-8 May 2011: "Hands-on Marine Animals" at the Kids' Festival;

Kids-festival: touching a living crab for the first time.

- 19 May 2011: Opening event of the national German competition “Jugend forscht” (young scientists‘ competition) with about 200 participants;
- 26 May 2011: Participation in the scientific event: “Stadt der jungen Forscher” (city of young scientists) in Kiel: presentations by pupils and presentation of the Institute on board the RV LITTORINA;
- 20-24 June 2011: Kiel Week activities: traditional “Kiel Week Lectures” in collaboration with the cluster of excellence “Futzre Ocean” (key focus: “Year of Health”) and Open Ship on board the RV ALKOR (24 June 2011), visit from the President of the International Sailing Association at IFM-GEOMAR (23 June 2011);
- 11-14 July 2011: 3rd Summer School: “Marine Biotechnology” of the Kieler Wirkstoff-Zentrum (Centrer for Marine Substances) at IFM-GEOMAR;
- 16-22 July 2011: 5th Summer School on Marine Geosciences for pupils;
- 21 July 2011: Opening of the permanent exhibition “Exploration and Use of the Seas” of the German Marine Consortium (KDM) at the OZEANEUM, Stralsund, with the support of IFM-GEOMAR;
- 28 August 2011: Open House, together with the Zentrum für Technologie und Seefischmarkt GmbH and the summer festival in the suburb of Wellingdorf. Approximately 3,000 visitors on the ALKOR, more than 10,000 at the Institute;
- 7 September 2011: Symposium commemorating the 20th anniversary of the North Pole Expedition ARCTIC-91;
- 30 September 2011: Participation in the Open Ship event in connection with the 25th anniversary of the RV METEOR in Hamburg;

“Subduction experiment” presented by pupils during Open Ship on RV ALKOR.

Lab practical with scientific advice during the 5. Summer School on Marine Geosciences.



Numerous visitors during the Open House at IFM-GEOMAR.

Dr. Gerd Hoffmann-Wieck (Coordinator for exhibits) welcomed the Prime Minister of North Rhine-Westphalia, Hannelore Krafft in the exhibition in Bonn.

- 1-3 October 2011: Day of German Unity 2011 in Bonn: exhibition on marine research in Kiel together with the cluster of excellence "Future Ocean";
- 14 October 2011: Opening of the German-Russian exhibition on marine and polar research in St. Petersburg as part of the German-Russian Year of Education, Science and Innovation 2011/2012. Further exhibitions will be held in 2012 in Moscow, Bonn and Berlin;
- Preparation of contributions for exhibitions for the German Marine Consortium (Brussels, January 2012) as well as for the deep sea exhibition at the „Lokschuppen" in Rosenheim (March to November 2012);
- Short film project: two new films: Subduction Zone off the Coast of Chile (SFB574) and on the topic of Black Smokers / Hydrothermal Systems were completed. Available via the IFM-GEOMAR website.

The German-Russian exhibition on marine and polar research in St. Petersburg.

Scientific Highlights

A selection of short scientific reports in this section provides an overview on IFM-GEOMAR research activities and results throughout 2011. This encompasses summaries from major expeditions, interdisciplinary activities, technology development and scientific results. These are just a few highlights from the broad scope of marine research at IFM-GEOMAR.

- Deep jets in the deep equatorial Atlantic cause climate variability
- Enhanced Atlantic water inflow warms the Arctic
- Enhanced recycling of bioavailable nitrogen in sediments underlying the Peruvian oxygen minimum zone
- Trace gas emissions from tropical oceans influence the stratospheric ozone layer
- Ocean acidification affects early life stages of heavily exploited fish
- Does biological diversity matter for the stability of marine communities?
- Mass wasting and earthquakes – unexpected interrelations offshore Central Chile
- Deep-sea massive sulfide deposits may not represent a major resource potential

Deep jets in the deep equatorial Atlantic cause climate variability

Peter Brandt, Ocean Circulation and Climate Dynamics - Physical Oceanography
Richard Greatbatch, Ocean Circulation and Climate Dynamics - Theory and Modelling

Climate variability in the tropical Atlantic is affected by the ocean in many ways. Besides large-scale ocean-atmosphere interactions, it was found that the deep equatorial Atlantic also plays an important role in tropical climate. Equatorial deep jets that are generated in the deep ocean (perhaps as deep as several thousand meters) and propagate their energy toward the sea surface are found to affect sea surface temperature, wind, and rainfall in the tropical Atlantic region and constitute a 4 ½ -year climate cycle.

The dominant climate phenomenon in the tropical Atlantic is a north/south movement of the tropical rain belt, which on average extends from equatorial South America across the Atlantic to the southern part of West Africa. This rain band is caused by the convergence of the northeast and southeast trades and is commonly referred to as the Inter Tropical Convergence Zone. It moves with the sun to the north in early boreal summer and reaches its northernmost position in August. Then it moves back south as the season progresses. The associated rain areas are displaced not only over the ocean but also over continental Africa where they are referred to as the African monsoon. It is characterized by a two-time reversal of winds during the course of a year, leading to the formation of rainy and dry seasons. Despite the dominant annual cycle in the Atlantic, sub-Saharan Africa experiences strong multi-year to multi-decadal climate variability with great impact on water supply, agriculture, tropical diseases, and infrastructure of the respective countries.

While long-term, decadal and multi-decadal fluctuations may be associated with the general temperature gradient between the North and South Atlantic, for example due to changes in the meridional overturning circulation, year-to-year fluctuations may depend more on the surface temperature of the adjacent seas particularly the central and eastern equatorial Atlantic. With the appropriate prediction of sea surface temperatures, it would thus be possible, in principle, to forecast the rainfall, its starting date and strength, not only for the next rainy season but for the next few years as well – a tremendous benefit for the people living in these regions. The atmospheric and oceanic processes responsible for the change in sea surface temperature, however, are still not understood well enough to be implemented correctly in models to allow an accurate prediction of the African monsoon.

Oceanographers from IFM-GEOMAR, in collaboration with their colleagues from the Woods Hole Oceanographic Institution (WHOI, USA), are now able to demonstrate the existence

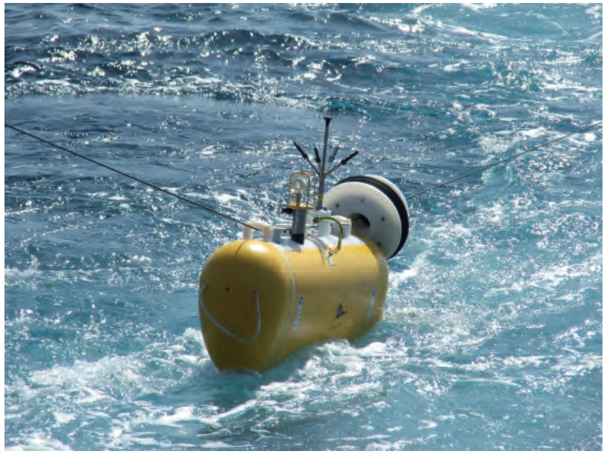


Figure 1: A "Profiler" is an instrument moored to the ocean floor by steel wire several km in length. The Profiler autonomously moves up and down the mooring wire between 1000 and 3500m depth, measuring currents, temperature, salinity and pressure along the way. Higher up on the mooring wire are additional instruments, such as acoustic current meters, temperature and salinity recorders. This entire platform allows us to continuously monitor the Atlantic at depth.

of regular interannual temperature fluctuations which have an effect on the rainfall of the region but cannot be traced back to previously known sources related to the large-scale ocean-atmosphere interactions.

As part of a multi-year international research programme, scientists involved in the Tropical Atlantic Climate Experiment (TACE) have attempted for many years to track the causes, effects and potential periodicities of

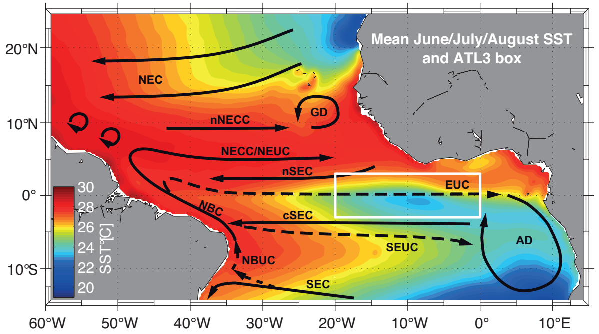


Figure 2: Sea surface temperature is one of the determining factors for rainfall fluctuations over West Africa. For example, if the equatorial cold water tongue in the Gulf of Guinea forms particularly early during the boreal summer months, the likelihood of early rainfall over West Africa is high. If the cold water tongue remains relatively warm, the onset of rainfall over land is delayed, but the rainfall itself will be heavier. After Brandt et al., 2011.

climate fluctuations in the tropical Atlantic. The German contribution to this programme, supported by the Federal Ministry of Education and Research ("Nordatlantik" project) and the German Science Foundation (as part of the Kiel Special Research Project SFB754 "Climate - Biogeochemical Interactions of the Tropical Oceans") includes deep-sea moorings along the equator. These moorings consist of several km of mooring wire held upright in the water column by flotation and buoys. Instruments are mounted along the wire to continuously record current speed and direction, salinity and temperature, thereby allowing the observation of long-term changes in the deep ocean. Furthermore, data on ocean currents is also available from freely drifting deep-sea buoys (the so-called Argo floats) and on the sea surface and the atmosphere from various satellite-based sensors. The time series obtained over the past ten to twenty years have revealed previously unknown fluctuations of currents and temperatures at the surface of the tropical Atlantic which have a regular cycle of 54 months, or 4 ½ years. The 4½ cycle at the surface is connected to fluctuations in ocean currents that are observed throughout the water column down to 3000 m depth with speeds of 10-20 cm/sec known as the "Equatorial Deep Jets". These jets flow along the equator, crossing the entire Atlantic, with flow reversals every few hundred meters in depth. The jets are generated in the deep ocean, and their energy apparently propagates upwards through the water column. Once near the surface, their energy affects currents and temperatures leading to the 4 ½ year cycle that influences the atmosphere.

Up to now, state-of-the-art high-resolution ocean models are not able to simulate the generation and propagation of equatorial deep jets in a realistic way. Ongoing research at GEOMAR includes continuing the measurements in the equatorial Atlantic that are required to describe the long time scales involved, as well as process modelling designed to develop understanding of the dynamical nature of these peculiar features of the equatorial ocean. The goal of this research is to include the effect of equatorial deep jets in climate models, either by parameterizing or direct simulation, in order to facilitate more reliable predictions of tropical climate variability in the future.

References

Brandt, P., Funk, A., Hormann, V., Dengler, M., Greatbatch, R.J., and Toole, J.M., 2011: Interannual atmospheric variability forced by the deep equatorial Atlantic Ocean. *Nature*, **473** (7348), 497-500. DOI 10.1038/nature10013.

Enhanced Atlantic water inflow warms the Arctic

Robert Spielhagen, Kirstin Werner and Evguenia Kandiano,
Ocean Circulation and Climate - Paleoceanography

Never in the last 2,000 years was the Atlantic Water entering the Arctic in the Fram Strait between Greenland and Svalbard as warm as today. This was revealed by a study of marine sediments from the western Svalbard continental margin which was led by researchers from IFM-GEOMAR.

The Arctic region is responding to global warming more rapidly than other areas on earth. The only ca. 2 m thick sea ice cover has shown a dramatic decrease in areal extent in the last three decades of satellite observations. It is expected to disappear in summer in the second half of the 21st century, provided continuous warming. Compilations of circum-Arctic terrestrial climate data series from tree rings, ice cores etc. have shown that modern atmospheric temperatures in the Arctic are unprecedented in the last 2000 years and have reversed a long-term cooling trend (Kaufman et al., 2009). The variability of oceanic heat flux to the Arctic on such times scales, however, had remained unknown due to the lack of available high-resolution marine sedimentary archives from the Arctic.

Suitable sedimentary archives which truthfully record oceanic changes on times scales of decades can be found only in areas of unusually high deposition rates, e.g., near the mouths of large rivers. Similar conditions can be found on Arctic continental margins where fine-grained sediments are exported from partly glaciated fjords. In August 2007, an international geoscientific working group led by scientists from IFM-GEOMAR surveyed the western continental margin off Svalbard (Spitsbergen) with the German research vessel Maria S. Merian. Here, in the eastern part of the >2,500 m deep Fram Strait between Greenland and Svalbard, relatively warm (6-7°C in summer) and saline water masses from the North Atlantic enter the Arctic (Fig. 1). This current, the northernmost extension of the so-called "Gulf Stream", provides ice-free conditions in the waters west of Svalbard even in winter. The working group found sheltered places on the sea floor where fine-grained material from Svalbard fjords could settle due to diminished bottom currents. Long and short sediment cores were obtained in such places and analyzed later in the laboratories of IFM-GEOMAR and institutions in Tromsö (Norway) and Boulder (USA) for various paleoclimatic proxies. Ages of the sediment layers could be assigned based on radiocarbon datings of calcareous microfossils found in the sediments.

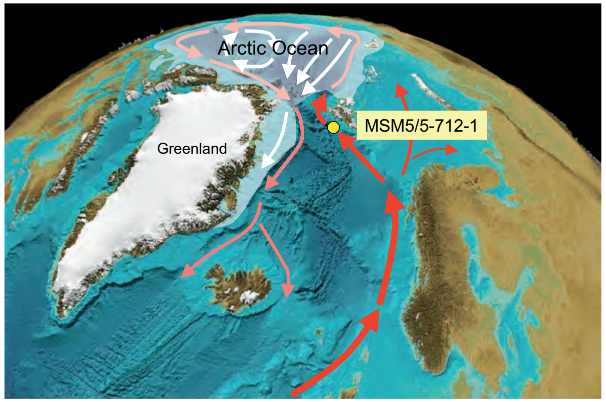


Fig. 1: Atlantic Water flow (red arrows) from the North Atlantic to the Arctic Ocean and ice drift (white arrows) in the Arctic. Pink arrows show subsurface recirculation of Atlantic Water. The yellow circle marks the site where the analyzed sediment core was obtained.

A major success of the work was the reconstruction of summer water temperatures for the last 2,000 years of the Atlantic Water entering the Arctic Ocean (Spielhagen et al., 2011; Fig. 2). The team used specific foraminifers from a sediment core as a paleothermometer. These protozoans live in water depths of 50 to 200 m and build calcareous shells. When they die, the shells sink and accumulate on the sea floor together with other particles. Because specific foraminiferal species prefer specific water temperatures, the species associations in sediment samples of a known age can be used to determine past oceanic and climatic conditions. In addition, the group analyzed the Magnesium/Calcium ratio of the calcareous shells which also allows reconstructing the water temperature

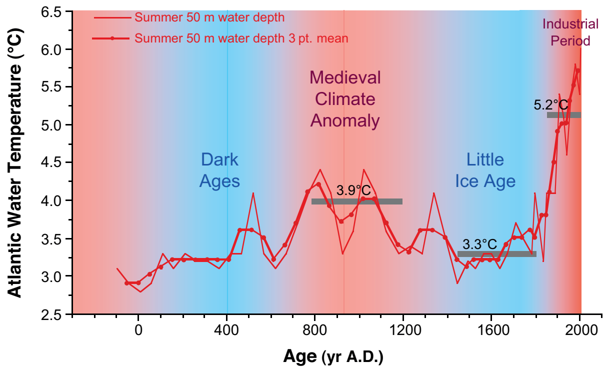


Fig. 2: Temperature reconstruction of Atlantic Water entering the Arctic Ocean over the last ca. 2,000 years. Bluish and reddish background colors mark cool and warm climatic periods, respectively.

in which the foraminifers lived. Using these two independent methods, it was found that there were several warmer and cooler intervals in the Fram Strait during the past 2,000 years. Temperatures of the northward inflowing Atlantic Water had varied several tenths of a degree Celsius in the past 2,000 years (Fig. 2). It was especially cold during the ‚Little Ice Age' from the mid-15th to the late 19th century, followed by a dramatic temperature increase of approximately 2°C, which was unprecedented in the past 2,000 years. This warming of the Atlantic Water significantly differed from all climate variations in the past 2,000 years. As a result, modern temperatures of the Atlantic Water in the Fram Strait are approximately 1.5 degrees Celsius higher than even during the climatically warm Medieval Period.

To obtain further information about the impact of variable water temperatures on the sea ice cover in the Fram Strait, the isotopic composition of the calcareous foraminifer shells was analyzed at IFM-GEOMAR. The results indicate that the perennially ice-free conditions off Svalbard are a relatively young feature (Werner et al., 2011). During most of the last 2,000 years the study area has been covered by sea ice at least in winter.

The results from the Fram Strait indicate that the accelerated decrease of the Arctic sea ice cover and the warming of ocean and atmosphere in the Arctic, as measured during the past decades, are in part related to an increased heat transfer from the Atlantic. A lack of sea ice amplifies climate change in the Arctic because sunlight is no more reflected by the ice. Instead, solar energy is absorbed by the ocean water ("ice-albedo effect") and in part released as heat to the atmosphere. The new findings support results from another study performed by IFM-GEOMAR scientists, together with Russian colleagues within the project "Laptev Sea System" in the Russian Arctic (Dmitrenko et al., 2010). Their data suggest that the warm Atlantic Water layer on the Siberian shelf of the Laptev Sea is found in significantly shallower waters than in the 80 years before. A further warming and extension of the Atlantic Water layer in the Arctic can have dramatic consequences for the sea ice formation and sea ice coverage in the Arctic Ocean.

References

Dmitrenko, I.A., Kirillov, S.A., Tremblay, L.B., Bauch, D., Hölemann, J.A., Krumpen, T., Kassens, H., Wegner, C., Heinemann, G., and Schröder. D., 2010: Impact of the Arctic Ocean Atlantic water layer on Siberian shelf hydrography. *J. Geophys. Res.*, **115**, C08010.

Kaufman, D.S., Schneider, D.O., McKay, N.P., Ammann, C.M., Bradley, R.S., Briffa, K.R., Miller, G.H., Otto-Bliesner, B.L., Overpeck, J.T., Vinther, B.M., and Arctic Lakes 2k Project Members, 2009: Recent warming reverses long-term Arctic cooling. *Science*, **325**, 1236-1239.

Spielhagen, R.F., Werner, K., Sørensen, S.A., Zamelczyk, K., Kandiano, E., Budeus, G., Husum, K., Marchitto, T.M., and Hald, M., 2011: Enhanced modern heat transfer to the Arctic by warm Atlantic Water. *Science*, **331**, 450-453.

Werner, K., Spielhagen, R.F., Bauch, D., Hass, H.C., Kandiano, E., and Zamelczyk, K., 2011: Atlantic Water advection to the eastern Fram Strait - multiproxy evidence for late Holocene variability. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, **308**, 264–276.

Enhanced recycling of bioavailable nitrogen in sediments underlying the Peruvian oxygen minimum zone

Lisa Bohlen, Stefan Sommer - Marine Biogeochemistry - Marine Geosystems

Oxygen minimum zones (OMZ) are key regions for pelagic and benthic nitrogen turnover. During Meteor cruise M77-1/2, conducted within the SFB 754, the shelf and upper slope sediments off Peru were identified as major recycling sites for bioavailable nitrogen. This is in strong contrast to the common perception that continental margin sediments in upwelling regions generally represent a major sink for bioavailable nitrogen releasing dinitrogen gas, N_2, into the environment.

As part of the SFB 754 "Climate - Biogeochemistry Interactions in the Tropical Ocean", redox-sensitive sedimentary nitrogen (N) cycling was extensively studied along a transect traversing the Peruvian oxygen minimum zone (OMZ) at 11° S. This transect covered the transition from anoxic bottom water conditions to low oxygen concentration of around 40 µM (Fig. 1). As a limiting element for biological productivity, the availability of dissolved inorganic nitrogen, DIN, (nitrate, NO_3^-; nitrite, NO_2^- and ammonium, NH_4^+) occupies a central role in ocean biogeochemistry, exerting a significant influence on cycles of many other elements, in particular carbon. While DIN, also known as fixed nitrogen, can generally be taken up by phytoplankton, dinitrogen gas (N_2) is only accessible for a small group of nitrogen fixing organisms called diazotrophs. Hence, the balance of DIN removal and production is linked to primary production and carbon cycling with its availability controlling not only the productivity of the oceans but also the sequestration of carbon dioxide from the atmosphere. Due to the redox–sensitivity of many processes involved in the marine N cycle a globally significant proportion of N turnover proceeds in the relatively restricted areas of the world ocean OMZs.

Marine sediments have been perceived to represent a main sink for DIN (e.g. Gruber, 2004) with denitrification and anammox representing the main processes. During denitrification organic matter is decomposed using nitrate as electron acceptor instead of oxygen (O_2), during the recently discovered anammox pathway NH_4^+ is oxidized using NO_2^-. Both processes convert DIN into N_2 and thus lead to a loss of bioavailable N. Denitrification and anammox are generally inhibited by O_2. Hence, these processes are restricted to areas where O_2 concentrations are very low such as in OMZs or reactive sediments where O_2 only penetrates a few millimeters deep into the sediment.

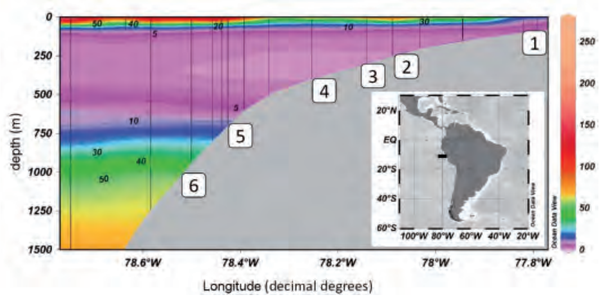


Fig. 1: Cross–section of oxygen concentrations (µM) on the shelf and slope of the Peruvian OMZ at 11 °S. The vertical lines denote the CTD casts where O_2 measurements were made during cruise M77 leg 1. Station locations 1 to 6 for benthic studies are indicated.

In order to determine to what extent the sediments underlying the Peruvian OMZ serve as a sink for bioavailable N, DIN fluxes across the sediment water interface were measured *in situ* at six stations along the transect using benthic landers (Fig. 1). With regards to the net flux of DIN the transect can be separated into two sections. At the slope stations 3 to 6 the uptake of NO_3^- + NO_2^- was higher than the release of NH_4^+ and the sediments represented a net sink for DIN. However, at the shelf and the upper slope (station 1 and 2) uptake of NO_3^- + NO_2^- almost balanced release of NH_4^+ indicating strong recycling of bioavailable N. This finding is in great contrast to the common belief that OMZ sediments represent major sinks (e.g. Middelburg et al., 1996; Devol and Christensen, 1993). At the shelf

Fig. 2: Bacterial mats (white) on the sediment surface at the Peruvian shelf. The length of the ground-weight is 20 cm.

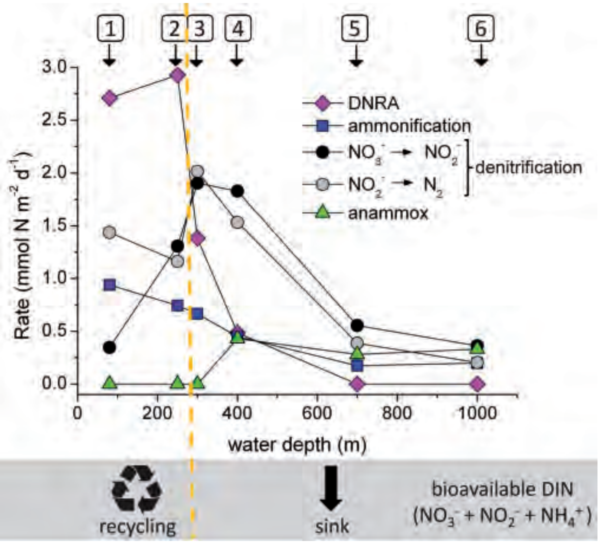


Fig. 3: Model-predicted depth-integrated rates of nitrogen turnover along the 11°S transect. Station numbers are indicated by the arrows at the top. The dashed line denotes the shift from DNRA to denitrification as the major N-turnover process.

and upper slope extended mats of giant sulfur bacteria such as *Beggiatoa* and *Thioploca* were observed (Fig. 2). These organisms can store high amounts of NO_3^- in their cells to oxidize sulfide and thereby release NH_4^+. This process is termed dissimilatory nitrate reduction to ammonium (DNRA). In contrast to denitrification and anammox, DNRA retains bioavailable N in the ecosystem and opposes the "self-cleaning" effect of denitrification and anammox.

To resolve the different N turnover processes the *in situ* DIN fluxes as well as measured porewater concentration profiles were used to constrain a 1-D reaction-transport model (Bohlen et al., 2011). The model allows a detailed simulation of the N cycle including simultaneous two-step denitrification and nitrification, DNRA, and anammox. Results show that the relative importance of the different N turnover processes distinctively changes along the transect (Fig. 3). At stations 1 and 2, DNRA indeed governed N turnover and accounted for more than half of the benthic NO_3^- + NO_2^- uptake. At greater water depth, denitrification became dominant and the sediments turn into a sink for DIN. Anammox was of minor importance on the shelf and upper slope yet contributed up to 62% to total N_2 production at the deepest station.

These new findings illustrate that OMZ sediments do probably not remove as much bioavailable N as previously thought. High rates of DIN recycling by DNRA counteract the overall loss of bioavailable N from the system. Consequently, the role of OMZ sediments as strong sinks for DIN need to be revised. Moreover, strong NH_4^+ release potentially stimulates primary production and O_2 consumption in the water column. Such a positive feedback mechanism maintains or even promotes further expansion of OMZs (Stramma et al., 2008).

References

Bohlen, L., Dale, A.W., Sommer, S., Mosch, T., Hensen, C., Noffke, A., Scholz, F. and Wallmann, K., 2011: Benthic nitrogen cycling traversing the Peruvian oxygen minimum zone. *Geochim. Cosmochim. Ac.*, **75**, 6094-6111.

Devol A.H., and Christensen, J.P., 1993: Benthic Fluxes And Nitrogen Cycling In Sediments Of The Continental–Margin Of The Eastern North Pacific. *J. Mar. Res.*, **51**, 345–372.

Gruber N., 2004: The dynamics of the marine nitrogen cycle and its influence on the atmospheric CO_2 variations. In *The Ocean Carbon Cycle and Climate* (eds. Follows M. and Oguz T.). NATO ASI Series, 97–148.

Middelburg, J.J., Soetaert, K., Herman, P.M.J. and Heip C. H.R., 1996: Denitrification in marine sediments: A model study. *Global Biogeochem. Cy.*, **10**, 661–673.

Stramma, L., Johnson, G.C., Sprintall, J. and Mohrholz, V., 2008: Expanding oxygen–minimum zones in the tropical oceans. *Science*, **320**, 655–658.

Trace gas emissions from tropical oceans influence the stratospheric ozone layer

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The halogens chlorine, bromine and iodine are highly efficient at destroying atmospheric ozone. Rising concentrations of these compounds from human activities have led to depletion of global stratospheric ozone over the last decades, and formation of the Antarctic "ozone hole". Whereas the chlorine supply is dominated by anthropogenic emissions, a major part of the bromine and iodine is supplied by short-lived organic trace gases with oceanic sources, entering the stratosphere principally in the tropics. The Western Pacific is a projected hot spot area for both oceanic sources and stratospheric entrance region of the trace gases. In order to reduce uncertainties in the amount of naturally emitted halogen-containing compounds reaching the stratosphere and the resulting ozone depletion, a large campaign was performed in the western Pacific, combining measurements from the German research vessel SONNE, the German research aircraft DLR-FALCON as well as land and space-based platforms.

Since the 1970s it is known that gases containing chlorine and bromine emitted by human activities deplete stratospheric ozone. 200 nations committed themselves to limit and abandon the emissions of the industrially produced chlorofluorocarbons (CFC) in the Montreal Protocol in 1989. Their goal to protect the ozone layer, close the existing ozone hole and therewith decrease UV radiation at the surface is underway, although the ozone hole and durable CFCs still exist in the stratosphere. In concert with climate change the future development of the ozone layer is very uncertain, not least because the contribution of natural halogenated compounds to the destruction of ozone is hardly known. Strong sources of brominated and iodinated organic compounds for the atmosphere are found in the oceans. Regionally enhanced phytoplankton and photochemical reactions in the open ocean and macro algae as well as anthropogenic sources in coastal regions are known contributors to the highly variable marine and atmospheric concentrations of substances such as bromoform ($CHBr_3$), dibromomethane (CH_2Br_2) and methyl iodide (CH_3I).

Their highly variable oceanic emissions cause major uncertainties in the contribution of the natural sources to stratospheric halogens and therewith ozone depletion. A good spatial and temporal resolution of emissions and the understanding of their variability are needed for an accurate climate-ozone-interaction modeling. This includes the resolution of gradients between coastal, near-shore and open ocean emissions, the revelation of the diversity of emissions in variable environments and their controls, as well as the magnitude of global air sea fluxes and the possible effects of climate change on the fluxes.

Figure 1: The research aircraft FALCON from the DLR measures and follows air masses that have been investigated on the SONNE (21. November 2011).

The tropical oceans have been identified as potentially important source regions for various halogenated trace gases, where marine emissions have the potential to enter the stratosphere due to rapid uplift of surface air to the tropical tropopause layer in form of deep convection. Especially the tropical western Pacific is a largely uncharacterized region for the oceanic compounds, where the research cruise SO218 of the German research vessel SONNE was conducted by the Chemical Oceanography in cooperation with the Marine Meteorology research unit. From 15 to 29 November 2011 an international crew of European, Malaysian and Philippine scientists investigated the South China and Sulu Sea within the frame work of the EU-

Figure 2: Local Malaysian research boats meet RV Sonne for the exchange of water and air samples off the coast of Borneo (19./21. November 2011).

project SHIVA (Stratospheric ozone: Halogen Impacts in a Varying Atmosphere; http://shiva.iup.uni-heidelberg.de).

The instruments on board made quasi-continuous measurements of a suite of trace gases in both seawater and air to determine actual sea to air fluxes. The atmospheric structure was determined by intense radio and ozone sounding and in situ and satellite measurements of phytoplankton groups informed about biogeochemical conditions during the ship expedition.

The research during the cruise was coordinated with research flights of the Falcon Aircraft (Figure 1) from the German Aerospace Center's (DLR) which was stationed in Miri on Borneo for this project. The air craft over passed the ship several times and its atmospheric sampling started at the same height as the ship measurements and followed the same air masses up to an altitude of 13 km. In order to obtain near-coastal samples, which were analyzed on board the SONNE for their trace gas and plankton content, meetings with coastal research cruises from our Malaysian partners were organized and successfully conducted in the open ocean (Figure 2),

First results show generally enhanced concentrations of brominated and iodinated trace gases in the water, being very high in some shallow shelf-regimes and close to the coasts (Figure 3), while the atmospheric abundances were generally rather low. Strong oceanic emissions with rapid dilution in the atmosphere indicate that the cruise region comprises major source areas of biogenic halogen compounds capable of damaging the stratospheric ozone layer. Measurements and models indicate that the vertical transport in

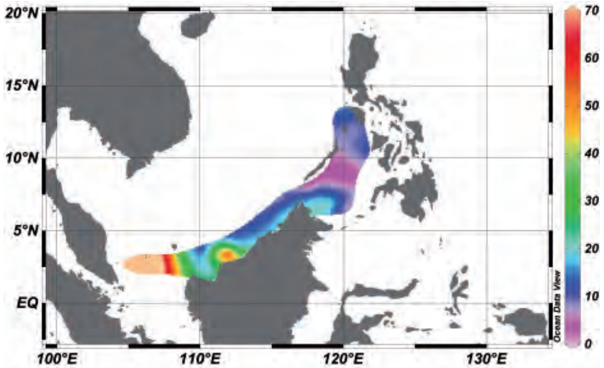

Figure 3: Concentrations (pmol/L) of Bromoform ($CHBr_3$) in surface water of the South China and Sulu Sea.

large tropical thunderstorms is a very important factor for the transport of the ozone relevant gases into the upper tropical troposphere, from where these gases may reach the lowermost stratosphere.

The results of the SHIVA-SONNE campaign about the natural and oceanic sources of ozone depleting substances will help to better predict the rate, timing and climate sensitivity of ozone-layer recovery in response to the decline of the industrial "ozone killers" like chlorofluorocarbons (CFC) which interact with the oceanic halogenated organic trace gases. Further spatial and temporal wide measurements of the biogenic compounds containing chlorine, bromine and iodine are needed in order to provide a profound surface forcing for simulations of the future development of the ozone layer incorporating these natural sources of halogens under the influence of anthropogenic change.

Ocean acidification affects early life stages of heavily exploited fish

Catriona Clemmesen, Andrea Frommel, Rommel Maneja, Andrea Franke, Uwe Piatkowski, Thorsten Reusch – Marine Ecology - Evolutionary Ecology of Marine Fishes

Ocean acidification (OA) and its effects on fish have recently come into focus. Early developmental stages, in particular, are sensitive to OA because they lack efficient osmoregulation. Our experiments indicate severe damages in major organs in Atlantic cod during the transition from the larval to the juvenile stage, and showed differences in sensitivities of different populations of Atlantic cod (Baltic vs. Northeast Atlantic). OA may constitute an additional bottleneck in the life cycle of fish potentially causing mortality and affecting the recruitment to fisheries.

Ocean acidification the "other CO_2 problem" is presently considered to be one of the most complex and critical anthropogenic threats to marine life. It is caused by the uptake of excess atmospheric CO_2 by the oceans, reducing not only the pH of surface seawater but also the mid and bottom waters due to CO_2-remineralization by decomposition of primary plankton production. Ocean acidification has been found to affect a wide array of organisms from single-celled algae to complex invertebrates. While calcifying organisms are particularly challenged by acidified waters, fish are considered less vulnerable as they have a well developed acid-base regulatory system in the gills. However, early life stages that hatch without functional gills may be more vulnerable to high CO_2 concentrations. Ocean acidification data on marine fish remain limited, negative effects so far have been identified in the behavior of coral reef fishes and in an estuarine fish species, the Atlantic silversides with reduced growth and increased mortality in the early larval stages (Baumann et al. 2012). In coral reef fish realistic CO_2 levels predicted by global climate models for the near future impaired their olfactory ability for homing, while predator and prey detection was also compromised. In contrast, no significant effects on embryonic duration, egg survival and size at hatch for these reef fish, but on the size of the otoliths, the earstones of the fish, were found (f.e. Munday et al., 2009).

Hence, we intended to address ocean acidification effects in Atlantic cod, a key fish species which is heavily exploited in the entire northern Atlantic. Experiments were performed in large land-based outdoor mesocosms (Fig. 1) under natural temperature, salinity and light conditions near Bergen, Norway using natural plankton from the nearby fjord as food for the larvae. The Atlantic cod is widely distributed along the entire North Atlantic coast. It matures at 3 – 5 years. Its reproduction is characterized by high fecundity with an average of 1 million eggs per female and fluctuations in recruitment (stage were fish enter the fisheries) are mainly caused by high mortality during the early life stages. Cod are external fertilizers and their sperm is activated by changes in ionic composition and osmolality as it is expelled into the open ocean during a spawning event. Therefore reduction in seawater pH has the potential to influence sperm behavior and fertilization success. By examining the effect of elevated CO_2 concentrations over the entire early life-history range from gametes to the juvenile stage, vulnerable stages could be defined. While gametes and yolk-sac larvae seem to be robust to very high levels of CO_2, (Frommel et al., 2010, 2012a) the transition from larvae to juveniles was heavily impacted by CO_2 (Frommel et al., 2012b). At this developmental stage, severe damage to internal organs (liver, pancreas, kidney and gut) in larvae raised under ocean acidification scenarios was found based on histological sectioning (Fig. 2). This transi-

Fig.1: Mesocosm set up at Espegrend, Norway.

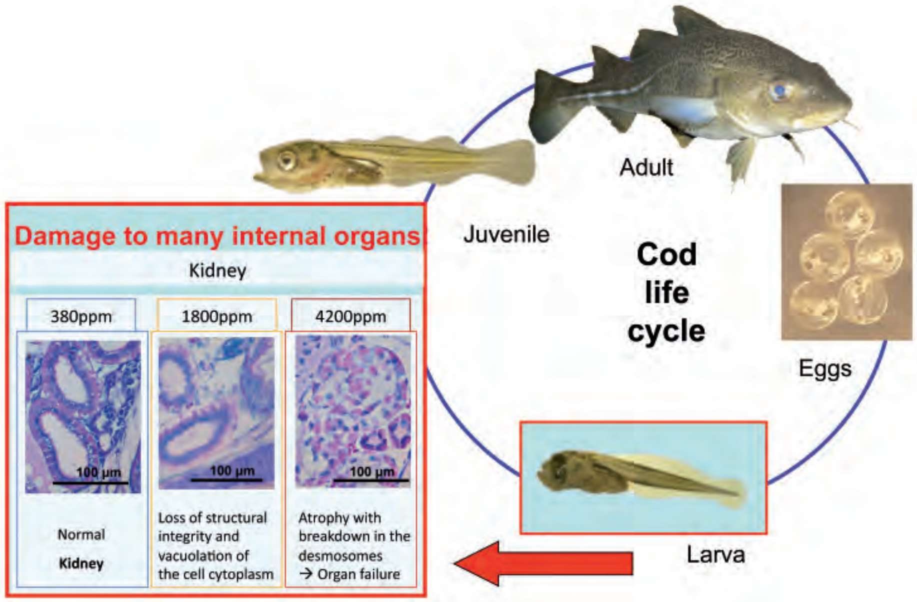

Fig. 2: The life cycle of cod showing an example of damage to one of the organs (kidney) occurring in the transition phase between larval and juvenile stage.

tion marks a particularly vulnerable phase in which structural reorganization like the development of functional gills takes place, lowering the chance of larval survival considerably. Additionally, changes in lipid metabolism were observed (Frommel et al., 2012b).

One has to be very careful when extrapolating results from our findings, measured in one population at one time point, to the species or even genus level. Different cod populations may experience very different environmental conditions rendering them more or less sensitive to climate change. Atlantic cod populations along the Norwegian coast live in full saline and well oxygenated water. In contrast, Baltic cod spawn in oxygen depleted water layers and naturally experience CO_2 levels predicted for the year 2100 in other areas (global, open ocean average). Therefore Baltic cod may be adapted to chronically elevated CO_2 levels, since the non-feeding stages of Baltic cod larvae were insensitive to elevated CO_2 levels (Frommel et al., 2012a). Similar results were obtained for herring larvae from the western Baltic Sea which showed no effect of ocean acidification on the embryonic development, hatch rate and size, and weight at hatch. The RNA concentration, as a proxy for protein biosynthesis, was reduced at higher CO_2 levels possibly indicating an energy deficiency (Franke & Clemmesen, 2011). An evolutionary ecology perspective is thus indispensible to understand biological effects of global warming and acidification on fish populations. Multiple hydrographical stressors in the Baltic Sea may also lead to a higher sensitivity in later stages, which so far have not been studied. Effects of ocean acidification on the survival of these stages, as indicated by the results from our working group, must be further analysed in combination with other relevant climate change variables to ensure a better projection of the effects of ocean acidification on fish populations. Furthermore, species that already experience strong pressure via fisheries exploitation have a reduced buffering capacity towards climate change aspects.

References

Baumann, H., Talmage, S.C., Gobler, C.J., 2012: Reduced early life growth and survival in a fish in direct response to increased carbon dioxide. *Nature Climate Change*, **2**, 38-41.

Franke, A., Clemmesen, C., 2011: Effect of ocean acidification on early life stages of Atlantic herring (*Clupea harengus* L.). *Biogeosciences*, **8**, 3697-3707.

Frommel, A.Y., Schubert, A., Piatkowski, U., Clemmesen, C., 2012a: Egg and early larval stages of Baltic cod, *Gadus morhua* are robust to high levels of ocean acidification. *Mar. Biol.*, DOI 10.1007/s00227-011-1876-3

Frommel, A.Y., Maneja, R., Lowe, D., Malzahn, M., Geffen, A.J., Folkvord, A., Piatkowski, U., Reusch, T.B.H., Clemmesen, C., 2012b: Severe tissue damage in Atlantic cod larvae under increasing ocean acidification. *Nature Climate change*, **2**, 42-46, DOI: 10.1038/NCLIMATE 1324

Frommel, A., Stiebens, V., Clemmesen, C., Havenhand, J., 2010: Effect of ocean acidification on marine fish sperm (Baltic cod: *Gadus morhua*). *Biogeosciences*, **7**,1-5.

Munday, P.L., Dixson, D.L., Donelson, J.M., Jones, G.P., Pratchett, M.S., Devitsina, G.V., Doving, K.B., 2009: Ocean acidification impairs olfactory discrimination and homing ability of a marine fish. *PNAS*, **106**, 1848-1852

Does biological diversity matter for the stability of marine communities?

Martin Wahl, Marine Ecology - Experimental Ecology

Species are being irreversibly lost at an unprecedented pace. Will this de-stabilize communities, i.e. make them more vulnerable to stress and global change? In a global-scale approach involving more than 500 benthic communities in 8 biogeographic regions we show that species richness stabilizes communities when functional diversity is low, but tends to destabilize communities when functional richness is high. Given the decrease of functional richness in benthic hard bottom communities from the tropics towards the poles, we expect a more severe impact of species loss at higher latitudes.

A variety of metrics have been used when assessing "biodiversity". Species richness is certainly the most commonly used metric but also one of the most controversial ones. Thus, despite intense biodiversity research over the past decades, the role of species richness for the performance and stability of communities is still highly controversial. Recent reviews have shown that richness may stabilize or destabilize communities, and enhance or decrease their susceptibility to abiotic stress or biotic invasions (Balvanera et al., 2006, Romanuk et al., 2009, Valdivia & Molis, 2009).

Likely causes for the contradictory findings about the role of diversity are the use of different diversity metrics, differences in the biological and geographical properties of the systems investigated, in the pressures applied and responses measured, in the number of trophic levels considered, and in the duration of the experiments (Wahl et al., 2011). To avoid the weaknesses of previous studies we decided to work on "standardized" (same size, same age) natural communities, expose them to a natural environmental shift, allow sufficient time for a community level response (compositional stability), assess two important aspects of diversity simultaneously (species richness and functional diversity), and replicate the experiments at an unprecedented scale (500 communities in 8 biogeographic regions world-wide, Fig. 1).

Shortly, communities of sessile invertebrates and algae (Fig. 2) which had assembled on artificial substrata were transplanted between two moderately different sites within each region simulating environmental shift. As a response to this pressure, some species decreased, others increased in abundance, and new species invaded the community. The rate of this re-organization was used as a measure for the structural instability of communities under stress.

Fig. 1: The biogeographic regions covered in this investigation were (1) South East Pacific (Chile), (2) South West Atlantic (Brazil), (3) North Sea (England), (4) Baltic Sea (Finland), (5) West Pacific (Malaysia), (6) North West Pacific (Japan), (7) South West Pacific (New Zealand) , and (8) Tasman Sea (Australia).

The substantial effort invested into this study was rewarded by a consistent and interesting response pattern which explains a major part of the past controversy. Briefly, (i) at a global scale, more diverse ecosystems are not more stable at the community level than less diverse regions; at the regional scale (ii) functional diversity has important indirect effects on stability while (iii) species richness has important direct effects which, however, may be stabilizing or de-stabilizing. (Functional diversity in this context is defined as the number of "ecologically different" groups in the communities, i.e. species which differ in regard to body size, growth form, feeding type or coloniality, each of which represents

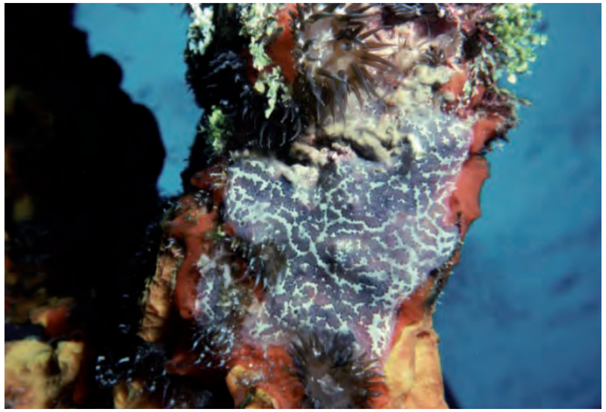

Fig. 2: Examples for tropical (A) and temperate (B) hardbottom communities.

a compound trait including other properties such as longevity or mode of reproduction.)

Community stability increased with species richness when functional diversity was low, but tended to decrease with species richness when functional diversity was high (Fig. 3). For a better understanding let us look at the two extremes of this gradient: Many

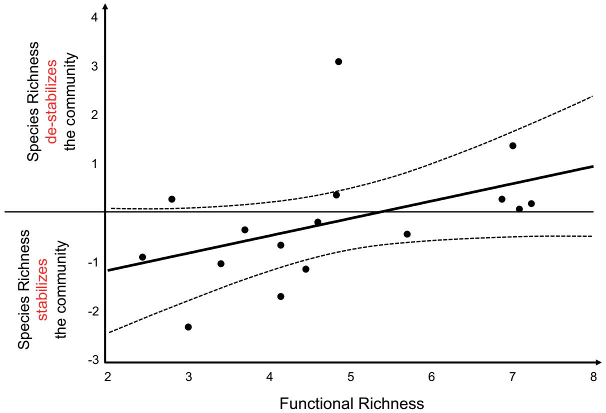

Fig. 3: Gradual change of the species diversity-stability–relationship from communities with low functional richness to communities with high functional richness. Values on the y-axis give the slope of the relationship between structural change and species richness. When values are negative, the rate of change driven by mortality and invasions decreases with species richness, i.e. structural stability increases with species richness.

species in communities with few functional groups leads to high functional redundancy: given ecological functions are represented by several species. Few species in communities with many functional groups leads to high complementarity: most species differ from each other ecologically. The two drivers of the re-organization process were mortality and bioinvasion. High functional diversity is considered an insurance against invasions because the invader is unlikely to find an unoccupied niche. Consequently, high redundancy in communities with reduced functional diversity warrants that the (few) functional groups are preserved even when single species are lost. At high functional diversity this important role of species richness is less crucial.

Our data show further that communities are functionally richer at low latitudes. Thus, the ongoing loss of species may have more severe consequences for community stability in temperate or polar regions than in tropical regions.

References

Balvanera, P., Pfisterer, A.B., Buchmann, N., He, J.S., Nakashizuka, T., Raffaelli, D., Schmid, B., 2006: Quantifying the evidence for biodiversity effects on ecosystem functioning and services. *Ecol. Lett.*, **9**, 1146–1156.

Romanuk, T.N., Vogt, R.J., and Kolasa, J., 2009: Ecological realism and mechanisms by which diversity begets stability. *Oikos*, **118**, 819–828.

Valdivia, N. and Molis, M., 2009: Observational evidence of a negative biodiversitystability relationship in intertidal epibenthic communities. *Aquat. Biol.*, **4**, 263–271.

Wahl, M., Link, H., Alexandridis, N., Thomason, J.C., Cifuentes, M.J., Costello, M., da Gama, B.A.P., Hillock, K., Hobday, A.J., Kaufmann, M.J., Keller, S., Kraufvelin, P., Krüger, I., Lauterbach, L., Antunes, B.L., Molis, M., Nakaoka, M., Nyström, J., bin Radzi, Z., Stockhausen, B., Thiel, M., Vance, T., Weseloh, A., Whittle, M., Wiesmann, L. Wunderer, L., Yamakita, T., Lenz, M., 2011: Re-structuring of marine communities exposed to environmental change: a global study on the interactive effects of species and functional richness. *PLoS ONE*, **6**(5), e19514, DOI:10.1371/journal.pone.0019514.

Deep-sea massive sulfide deposits may not represent a major resource potential

Sven Petersen, Dynamics of the Ocean Floor - Magmatic and Hydrothermal Systems

The ocean floor, covering 70 % of our planet, is increasingly seen as a valuable potential resource for mineral and energy supply. Gravel, sand and hydrocarbons have been exploited from the ocean floor for many years. In addition, diamonds, gold, tin, and other minerals that were transported to the coastal ocean from the continents are being mined from shallow-water and beach areas. Efforts to expand ocean mining into deep-ocean areas have recently begun and we will likely see exploitation of massive sulfides formed at black smokers by the year 2014. However, fundamental data on the distribution, size, and grade of these deep-ocean massive sulfide deposits is still lacking and therefore the resource potential of this commodity is largely unknown.

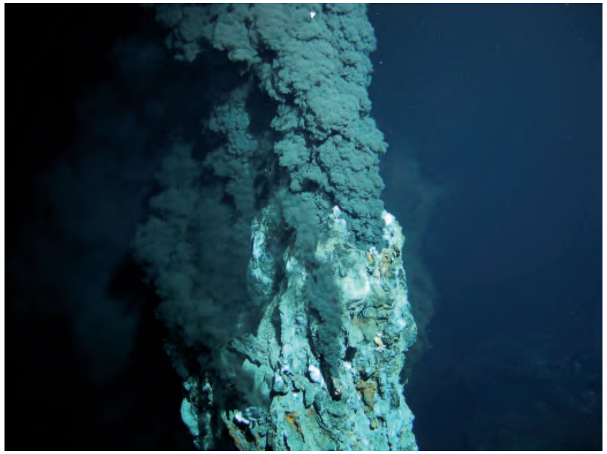

Fig. 1: Black smoker at the slow-spreading Mid-Atlantic Ridge, an important exploration target for the future.

The discovery of submarine hydrothermal venting in 1977 started a period of intensive seafloor exploration for hydrothermal activity and related mineral deposits. Because the ocean floor covers more than 70% of the Earth's surface, many expect the oceans to contain a proportionate amount of the world's mineral resources, comparing the resource potential of seafloor massive sulfide deposits to that of ancient deposits that are now mined on land and are important producers for zinc, copper, and gold. The rising metal prices enhance the possibility of mining seafloor massive sulfides, which has stirred debate about the sustainable use of this resource and whether its development is worth the risk. While currently only a few commercial companies are exploring the exclusive economic zones throughout the world's oceans, an increasing number of countries such as Russia, China, Korea, USA, but also France, Portugal and Germany are becoming more and more interested in this resource and are actively exploring at sea. Recently, China and Russia acquired large sulfide exploration license areas from the International Seabed Authority in the open ocean. Among the outstanding questions are, however, how many deposits might actually be there and what is their resource potential.

Since large parts of the worlds spreading centers are not explored at all, geologists from the University of Ottawa (Canada), the Colorado School of Mines (USA), GEOMAR, and Woods Hole Oceanographic Institution (WHOI, USA) have used a growing global database of seafloor hydrothermal systems and gathered detailed information on the number, distribution, and size of known sulfide deposits in order to extrapolate the abundance of seafloor massive sulfides in the neovolcanic zones of the global oceans and their resource potential.

More than 300 sites of high-temperature More than 300 sites of high-temperature hydrothermal venting have so far been identified since the discovery of black smokers. Previous estimates of the total number of active vent fields in the global oceans are based on the heat budget of young oceanic crust and by analyzing water column evidence for hydrothermal activity. This approach, however, is only considering active hydrothermal venting along the spreading axis and is not accounting for old, inactive deposits that might be accessible for mining. At the same time this method provides no information on the size of the deposits or whether sulfides are, at all, formed at the seafloor. To better constrain the abundance of sulfide deposits and their resource potential, the current study used geological information of a number of well known control areas containing active and inactive deposits and calculated an average density of one sulfide deposit

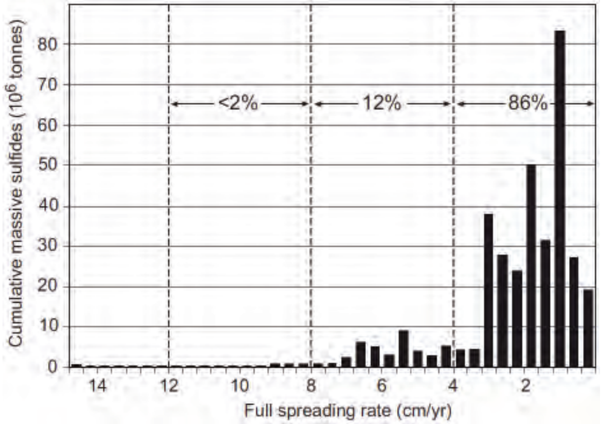

Fig. 2: Estimated size distribution of seafloor massive sulfide deposits as a function of spreading rate showing the resource potential of slow-spreading ridges.

every ~100 km for this dataset. Based on the cumulative strike length of the oceanic plate boundaries (89,000 km) the total number of deposits expected in the global neovolcanic zones is therefore ~900. Taking into account the actual range of deposit densities, the expected number of such seafloor deposits could range from 500 to 5,000.

The abundance of sulfide deposits at the seafloor is, in itself, not a measure of its resource potential. Only deposits with a certain metal content and size will be commercially attractive. Since copper and zinc are the main metals of interest in these deposits, the study focuses on these metals. Most seafloor hydrothermal deposits are not characterized well enough to quantify their true potential, but using a statistical approach the study suggests that most deposits are very small (median 70.000 tonnes) and that only few large deposits exist. These estimates are hampered by the poor knowledge of the vertical extent of the seafloor deposits and the lack of information on inactive deposits or buried deposits that are difficult to identify with current exploration methods.

However, extrapolation of the number and size of the known seafloor systems and comparison to land-based sulfide deposits that formed by similar processes throughout Earth's history allow the first calculation of the total tonnage of seafloor massive sulfide in the global neovolcanic zones and to place this resource potential into a global framework.

Taking the calculated existence of ~ 1000 deposits with a size distribution comparable to land-based deposits and a grade of 5 % of combined copper and zinc, the total sulfide tonnage within the neovolcanic zone is estimated to be on the order of 600 million tonnes, containing ~30 million tonnes of copper and zinc. Most of this metal is suggested to occur at slow-spreading centers, which account for ~60% of the total ridge length and have been shown to host the largest deposits. From a global resource perspective the total combined copper and zinc content in the neovolcanic zones of all oceans is comparable to the annual production of copper and zinc from land-based deposits, insufficient to contribute significantly to an ever growing global demand for these metals.

It is important to understand that the predicted amount of metal within seafloor massive sulfide deposits calculated in this study is far short of the amount of metal that is actually delivered to the seafloor by black smoker vents (~106 tonnes per year). At this rate the calculated metal content in massive sulfides could be produced in only 600 years while the neovolcanic zone comprises rocks that are several thousand or several ten thousand years old. The fate of the missing metal is unclear, but can only be addressed by a better understanding of the true regional distribution and vertical extent of such deposits. Development of technologies to investigate the third dimension and to search for buried deposits, either under volcanic rocks or sediments, is a key component to understand the fate of the missing metal. Additionally, the metal content of the seafloor deposits is poorly defined due to the lack of information from the interior of the deposits and more research is needed about the processes affecting metal distribution within the deposits. On the other hand, sulfide exploitation from the seafloor will have a large impact on the marine environment with concerns about complete destruction of entire ecosystems on a local, regional and global scale. Investigations of the environmental impact of mining activities in the deep-sea are necessary and need to address reaction of faunal communities to and recovery from such activities.

References

Hannington, M.D., Jamieson, J., Monecke, T., Petersen, S., Beaulieu, S., 2011: The abundance of seafloor massive sulfide deposits. *Geology*, **39**, 1155-1158.

Mass wasting and earthquakes – unexpected interrelations offshore Central Chile

David Völker, Jacob Geersen, Jan H. Behrmann, Wilhelm Reimer Weinrebe -
Dynamics of the Ocean Floor - Marine Geodynamics

Submarine landslides are an important but underestimated geological hazard that can generate destructive tsunamis and devastate populated shorelines. Based on a unique bathymetric dataset that covers ~ 90% of the Chilean continental margin between 33°S and 42°S, more than 60 submarine landslides were identified. The obtained database encompasses a wide spectrum of events, different in terms of failure mechanism, shape and size. The largest failure occurred in Pleistocene and mobilized 472 km³ of slope material, enough to cover Schleswig-Holstein with ~30 meters of debris. Rock material was dumped in the Chile Trench, where it forms a body of 1-2 km thickness. A fraction of this material has been subducted and now is sandwiched between the down-going Nazca, and the overriding South American Plates. The inhomogeneous nature of the subducted slide material changes the frictional properties of the plate interface, apparently generating a mechanical barrier for the propagation of earthquake rupture. This is the first indication of how mass wasting processes affect the seismological behavior of a convergent margin. The reverse causal relation, the triggering of mass wasting by earthquakes is often suspected. The Maule Earthquake of 2010 gave us the opportunity to investigate the impact of a megathrust earthquake on continental slope stability. We re-mapped the rupture area to investigate changes in the slope morphology quantitatively. Contrary to our expectations, this large seismic trigger did not result in major submarine slope failure.

Detailed acoustic scans of the seafloor have been acquired during 16 successive cruises led by scientist from the IFM-Geomar. This effort resulted in one of the best high-resolution bathymetric datasets of a continental margin worldwide. We used the dataset to create seafllor maps, determine gradients and spatial extent of submarine landslides and calculate displaced rock volumes. One of the highlights of the dataset is the availability of bathymetric data acquired prior to and shortly after the Maule earthquake of the 27 February 2010, the sixth largest ever recorded earthquake (Magnitude 8.8), allowing to investigate seafloor deformation related to the event.

In total, 62 submarine landslides were mapped with extents between 1 and 1,285 km². Roughly, 5.7% of the continental slope is affected, but within certain slope sectors this value increases significantly; in particular the zone off Arauco Peninsula (between 37°S and 38°S) stands out with 31% of failed slope (Figure 1). Based on type of morphology and area of occurrence, we distinguish four basic

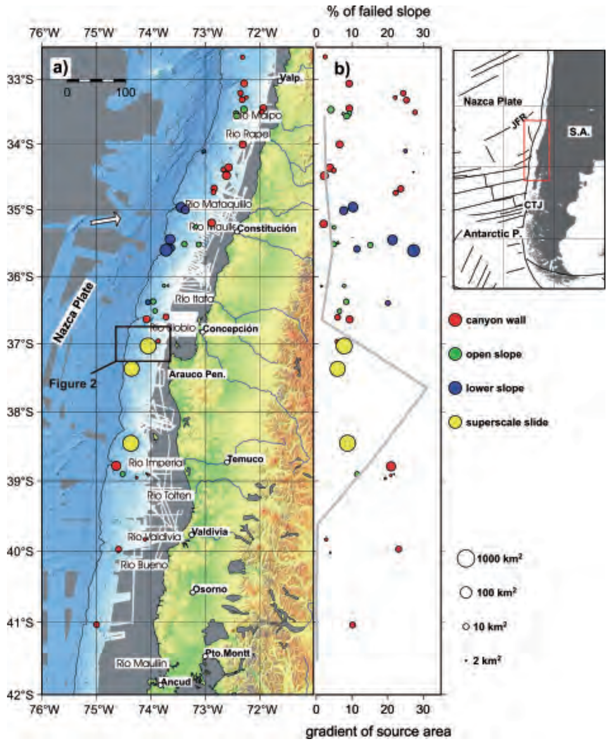

Figure 1: Bathymetric map of the working area, from a compilation of bathymetric cruises. The centers of submarine landslides are indicated as points (red = canyon wall collapses, blue = failures of lowermost slope, green = open slope failures, yellow = superscale failures) The outline of Fig. 2 is indicated as a box. (b) Spatial distribution of submarine landslides along the continental slope of Central Chile and distribution with slope gradient. Size of symbols is log-scaled to the total affected area. The percentage of areas affected by slides in latitudinal segments of 1° is given as curve

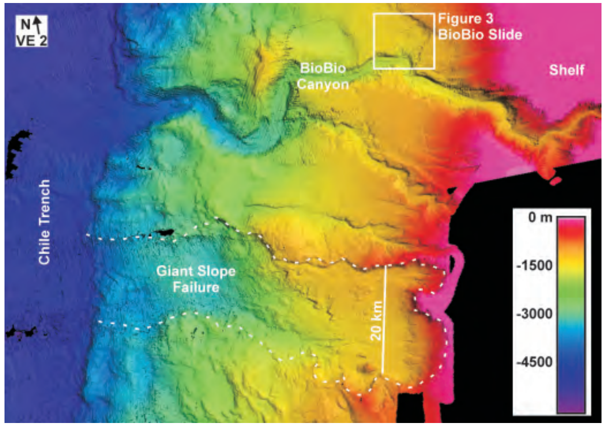

Figure 2: Giant submarine slide offshore Arauco Peninsula, stretching from the Chile Trench at 4800 m water depth to the shelf edge at 400 m water depth. Sidewalls are up to 500 m high. The BioBio Canyon, like all major submarine canyon systems is bordered by translational slides like the BioBio Slide, shown in Figure 3.

groups of sediment failure: (1) failure related to submarine canyons, (2) failure on open slopes, (3) failure affecting the lowermost continental margin and (4) failure at the scale of the entire slope (Völker et al., 2012). The spatial occurrence of lower slope collapses and failures that affect the entire slope are related to the tectonic segmentation of the forearc.

Half of the slope failures are related to seven major submarine canyons that incise the continental slope. Parasound data collected during R/V Sonne Cruise 210 in 2011 demonstrated that the canyon incision destabilizes large adjoining areas (Völker et al., 2012).

Among the lowermost slope collapse features, the Reloca Slide is the most noticeable because of its size and spectacular bathymetric expression. The displaced rocks are preserved as prominent blocks in the Chile Trench. The lower continental slope facing Reloca Slide is steep (20–30°), and forms a straight ramp of 2,000 m elevation. The blocks are angular, and together make up roughly 90% of the material that is missing at the slope scar. This completeness of the cohesive blocks as well as the drop height and the short runout distance are indicative of a fast event which makes Reloca Slide a tsunamogenic slide in spite of the large water depth (Völker et al., 2011).

Offshore Arauco Peninsula (Fig. 1), three very large slope indentations ranging in areal extent between 924 – 1285 km^2 shape the continental slope down to the abyssal plain and change the seismic reflection pattern of the sedimentary trench fill (Geersen et al. 2011a). Seismic images of the trench fill show chaotic deposits, commonly attributed to rapid deposition by mass wasting in front of the slope embayments. This is in marked contrast to the well-stratified trench fill elsewhere. Two of the failures define a significant landward retreat of the shelf break (Figure 2). The volume of material missing at the slope is in the order of 300–500 km^3 for each of the three slides.. Submarine mass wasting in this area is linked to the local tectonic regime, where continuous uplift of the forearc results in steep slope gradients. The recurrence time of the three giant slides is about 200,000 years.

Apart from their geohazard, the large submarine slides are interesting as they appear to affect the seismotectonic regime of Southern Chile. Deep underthrusting of the inhomogeneous slide deposits along with the downgoing Nazca Plate may play an instrumental role in arresting earthquake ruptures. One of the subducted giant slides is located at the boundary of the coseismic ruptures of the 1960 Great Chile and the 2010 Maule earthquakes (Geersen et al., 2011b). The slip zone of megathrust earthquakes must be thin and continuous to allow the fast propagation of coseismic slip over distances of hundreds of kilometers. This condition is likely given within the rupture areas of the 2010 Maule and the 1960 Great Chile earthquakes, because there the underthrust trench sediment is well stratified. In contrast, the underthrust slide material is highly inhomogeneous in terms of structure and physical properties. This results in the absence of continuous weak layers parallel to the plate boundary megathrust, and prevents development of a continuous slip zone that is required for earthquake rupture propagation.

No newly formed slides were found in the rupture area of the 2010 Maule Earthquake, the 6th largest ever instrumentally recorded earthquake, although a number of older failures were identified (Völker et al., 2011, Figure 3). The absence of new mass wasting is particularly remarkable, as the slope gradient is steeper than 20°. Among the few cases, where mass wasting was studied after an earthquake, we find tsunamogenic landslides (like the Papua New-Guinea event of 1998), as well as the absence of landslides, just like in Chile. Obviously the impact of a

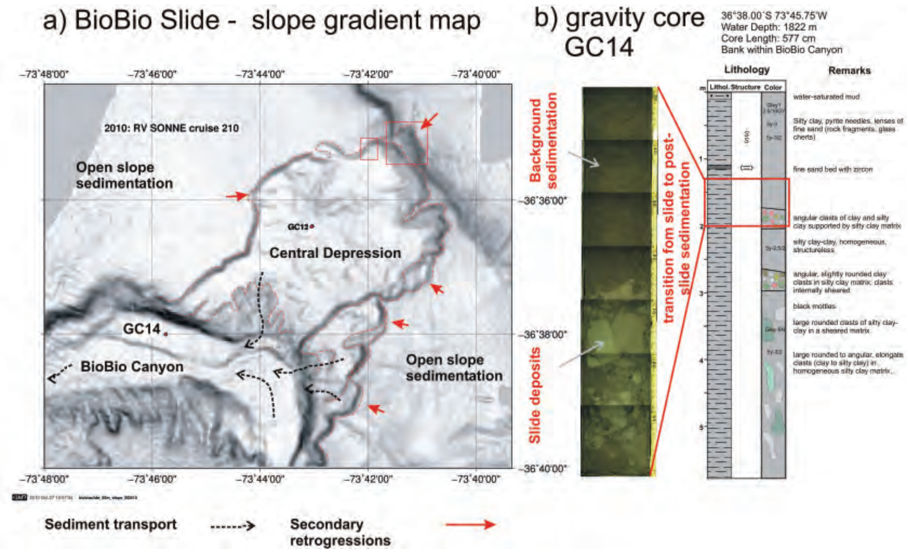

Figure 3: a) Detail gradient map of BioBio Slide and adjacent BioBio Canyon with coring locations of SONNE cruise SO210. BioBio Slide is a depression of 29 km² extent that is 55–160 m deep in relation to the surrounding sea floor, opening to the deeply incised BioBio Canyon.The steep head- and sidewalls indented by smaller and less deep, partly overlapping retrogressions. Within the canyon, a flat-topped terrace forms a depositional feature on top of which gravity core GC14 was taken. b) Core photo mosaic and description for GC14 , showing the transition from the youngest, ~7000 year old mass wasting deposit from the BioBio Slide area to background sedimentation.

seismic source on the slope stability is limited by factors such as sediment supply, distribution and rheology. In contrast to popular hypotheses, we contend that the frequent recurrence of earthquakes at convergent continental margins does not necessarily pose a particular risk of landslide-generated tsunamis. As landslides of much larger volume and tsunamogenic potential are observed at seismically more stable passive margins, it seems that the frequent shaking at active margins shifts the size spectrum of submarine slide events towards smaller scales.

References

Geersen, J., Völker, D., Behrmann, J.H., Reichert, C. and Krastel, S. 2011(a); Pleistocene giant slope failures offshore Arauco Peninsula, Southern Chile. *Journal of the Geological Society London*, **168**, 1237-1248, DOI: 10.1144/0016-76492011-027.

Geersen, J., Behrmann, J. H., Völker, D., Weinrebe, W., Krastel, S. and Reichert, C., 2011(b): Upper plate control on segmentation of the 1960 Great Chile and the 2010 Maule earthquakes [Talk]. In: *AGU Fall Meeting 2011*, 05.-09.12.2011, San Francisco, USA.

Völker, D., Geersen, J., Weinrebe, W. and Behrmann, J. 2012: Submarine mass wasting off Southern Central Chile: Distribution and possible mechanisms of slope failure at an active continental margin. In: *Submarine Mass Movements and their Consequences,* (Eds. Y. Yamada et al.), *Advances in Natural and Technological Hazards Series*, **5**, 379-390. Springer, Dordrecht.

Völker, D., Scholz, F. and Geersen, J. 2011: Analysis of submarine landsliding in the rupture area of the 27 February 2010 Maule earthquake, Central Chile. *Marine Geology*, **288**, 79-89, doi: 10.1016/j.margeo.2011.08.003.

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From IFM-GEOMAR to GEOMAR

- The transition -

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At the time this report is published, the Leibniz Institute of Marine Sciences (IFM-GEOMAR) has been transformed into the Helmholtz Centre for Ocean Reseach (GEOMAR).

Some important changes due to this transition can be found below.

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