Annual Report 2010

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NIOZ Royal Netherlands Institute for Sea Research

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Introduction

In 2010 NIOZ has again been able to fulfil and strengthen its commitment as the national oceanographic institute of the Netherlands and as a major player in marine sciences in Europe and internationally. The growing international importance of our activities is driven by the fact that marine science is increasingly needed to understand System Earth and how it changes.

On the one hand there is the concern that the effects of climate change and biodiversity loss are changing the functioning of marine ecosystems, but that it is difficult to predict their consequences as they are still incompletely known, especially for the marine environment. The potential harmful effects of ocean acidification on calcifying organisms have also become a major concern. In contrast to pollution, which has more local and coastal effects, the impacts are now global and cover the entire ocean.

On the other hand, the oceans also offer new opportunities. Ocean exploration is way behind the exploration of space and new discoveries yielding new insights are made every year. Important economic activities such as maritime transport, offshore energy exploration and exploitation and exploitation of living-and non-living resources from the sea are increasing human wealth but are also affecting the global environment and have global economic and ecological consequences which affect the functioning of system earth and therefore human well-being as well. More and more human populations and economic activities are concentrating in coastal zones. The increasing use of the marine environment requires new national and international legislation and governance and this requires scientific knowledge that is often not yet available.

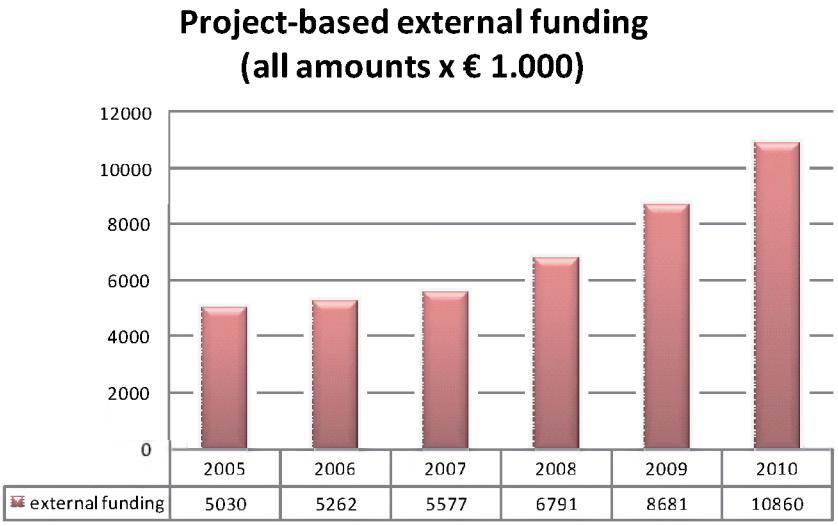
Scientific research at NIOZ has covered many of these issues, as is clear from this report. For the first time in history, NIOZ production of articles in reviewed journals passed the 200 publications mark, of which 6 articles appeared in the top journals Nature, Science or PNAS. Major papers of 2010 dealt with paleo-climate, trace metals in the ocean, invading species, cold seeps and marine viruses, migrating birds among many others. One of the strengths of NIOZ is its multi-disciplinarity, with five departments covering the major natural marine sciences and supported by dedicated and highly skilled technical and analytical departments. NIOZ is a respected partner in many EU and ESF projects and has close collaborations with major institutes and scientists in Europe and worldwide. Over sixty PhD students and post-docs are an important part of the NIOZ community. This year, 8 PhD students received their degree after a successful defence of their thesis. One of them, Rob Middag, even received a 'cum laude'. Our close connections with Dutch, German and Belgian universities have been strengthened again with now 11 NIOZ staff members also being professors. Newly appointed professors were Stefan Schouten ('Paleoceanography' at Utrecht University) and Geert-Jan Brummer ('Paleoceanography and Geochemistry' at the Vrije Universiteit Amsterdam).

The CEME building in Yerseke, Zeeland; a future part of NIOZ

Increasing the scientific core of tenured scientists of the institute will also be one of the major results of the merger between NIOZ and the Centre for Estuarine and Coastal Ecology of the Netherlands Institute of Ecology (NIOO-CEME). Much effort was devoted in 2010 to discussions in conjunction with NWO with the Royal

Netherlands Academy on this merger. After the recommendations of the Breimer Committee at the end of 2009, the intention to merge the two institutes was reconfirmed by the president of the Academy, Prof. Robbert Dijkgraaf, and the chair of the board of NWO, Prof. Jos Engelen. In practice the discussions were fraught with difficulties as the financial and personal consequences were not always resolved in a satisfactory way. This merger is essential to maintain a viable fundamental marine research community in the Netherlands in the future. Mainly for this reason, in January 2011 the boards of NWO and NIOZ accepted the offer of the Royal Netherlands Academy of Arts and Sciences (KNAW).

The overall budget of NIOZ approached 25 M€ in 2010, of which 43% was obtained through external grants. This marks an important increase of close to 20 % over the last two years, which does not include about 4,5 M€ required to cover the expense of the mid-life overhaul of R.V. Pelagia. The number of people employed by NIOZ is now close to 300, but still only 31 are tenured scientists. This is too low to support the ambitions of NIOZ to cover all the major disciplines in oceanography and marine sciences so to fulfil its mission as a multidisciplinary institute. The system of tenure track was continued and NIOZ has now 6 young scientists on tenure-track positions. The technical and analytical supporting staff of NIOZ, which also serves the whole Dutch oceanographic community, achieved a high performance level. After two years of discussion, the system of supporting labs was accepted by the Works Council and will be gradually expanded to create a more flexible and accessible support for the whole of the institute.



Development of the amounts obtained through project-based external funding 2005-2010.

Testing of ballast water treatment installations at the NIOZ harbour

The increase in the overall budget during the past years has been achieved mainly from successful applications for projects that are financed from sources outside of the regular scientific NWO and/or EU FP7 framework programmes. Examples are the EU-Interreg programme on ballast water treatment and different programmes that were funded by the 'Waddenfonds'. These projects also have a relatively large innovation component and are part of NIOZ's increasing efforts to stimulate valorisation of NIOZ knowledge on the functioning of marine ecosystems.

GENOMINEERD
BESTEWERKGEVERS2010
EFFECTORY

In December 2009, we have repeated the investigation by the 'Effectory' Company on the job satisfaction of our personnel. The results became available in the course of this year and compared to the first questionnaire in 2006, the overall NIOZ average increased from 7.6 to 8.1 (national average is 7.4). This result was apparently so good, that NIOZ received a nomination as a 'Best Employer 2010' in the category of companies with less than 1000 employees. In the final election, we ended on the 12th place; a result of which we are really proud, but of course we will strive to be in the top 5 during the next election.

A major accomplishment was the mid-life overhaul of R.V. Pelagia. In the beginning of the year, from January till March, RV Pelagia was at the Astander shipyard in Santander, Spain, for its major 20 year overhaul. The vessel was almost completely stripped. New engines were installed, all cranes were revised, the bridge was completely renewed, including the nautical equipment, and much of the accommodation was renewed. Despite the enormous amount of (partly unforeseen) work that had to been done, the overhaul was successfully finished, both within the available time and budget. An illustrated overview of what happened during the refit can be found elsewhere in this annual report.

At the start of the refit in Spain .....

.....and back in the Marsdiep thereafter!

The renovation of the NIOZ buildings, an ongoing process that started more than five years ago, became much more visible by the renovation of the entry of NIOZ, which included also a renovation of our main hall where colloquia and symposia are organized. An important improvement was the replacement of part of the solid facade by large windows. This made the NIOZ entry much brighter. Moreover, new separate rooms could be created that are ideally suited for meetings of groups of 30-50 persons. These will serve mainly for courses that are held at the institute.

Our renovated hall and auditorium 'Ocean hall' were also the location where the national North Sea Days took place on 7 and 8 October. This event is organised annually at a different location, and is meant to bring together scientists, policy makers and professional users of the North Sea. It was attended by no less than 175 people.

Impression of the North Sea Days

Another major outreach event was the Open Day at NIOZ in which also our colleagues from IMARES and SOVON which inhabit our building participated. More than 1300 visitors came to NIOZ to be informed about all our activities.

On a regional scale, the plans of our management to widen the scope for use of the NIOZ harbour drew considerable media attention. The NIOZ harbour is increasingly used for certification trials of ballast water treatment installations and cultivation experiments with algae, seaweeds, shellfish and fish. This research is often done together with commercial firms and represents the valorisation of science which is considered to become more important in the near future. This was underlined by the visits paid by the Secretary-General Rijkswaterstaat Ir. S. Riedstra and the Queen's Commissioner of the Province North-Holland Mr. J.W. Remkes.

NIOZ scientist Marcel Veldhuis explains his research on ballast water treatment installations to Secretary-General S. Riedstra, D. Brus of the Ministry V&W, and the Major of Texel, Mrs. F. Giskes.

NIOZ deputy director Herman Ridderinkhof explains the plans with the NIOZ harbour to Commissioner of the Queen of North-Holland Mr. J. Remkes, Mrs. F. Giskes and E. Hercules.

Our former NIOZ PhD student Isabel Smallegange won the prize for the best PhD thesis between 2005 and 2009 of the Wadden Academy of the Royal Netherlands Academy of Arts and Sciences (KNAW) for her thesis (of 2007) on the feeding behaviour of shore crabs.

Overall, 2010 was a busy and very successful year for our institute and we look forward to 2011, which will be a historic year in the sense that the fusion with CEME will cause that NIOZ will get two locations and about 80 extra employees.

Carlo Heip
Herman Ridderinkhof

New external projects

- Consequences of Ocean Acidification for phytoplankton production and losses (Double Trouble, Darwin Center for Biogeosciences).
  C.P.D. Brussaard. Iin cooperation with Utrecht University and Alfred-Wegener Institute.
- Joint Doctorate Programmes of ERASMUS MUNDUS doctoral school in Marine Ecosystem Health and Conservation (MARES).
  M.J.W. Veldhuis.
- Wadden Sea ecosystem data assimilation and integrated modelling (NWO-ZKO).
  P. Ruardij, T. Gerkema. In cooperation with IMARES, NIOO.
- Multi-scale modelling of calcification in scleractinian corals, (MultiCalc), NWO.
  J.D.L. van Bleijswijk. In cooperation with University of Amsterdam.
- North Sea Ballast Water Opportunity project, Interreg IVb (ESRF). Extension of the project.
  M.J.W. Veldhuis.
- Age determination in bivalves: validation of the seasonality of shell growth bands along the European coast.
  J.F.M.F. Cardoso, H.W. van der Veer, in cooperation with CIIMAR/CIMAR (Porto, Portugal).
- Local eel management (LNV).
  J. van der Meer.
- Pilot project Local eel management in Friesland (LNV).
  J. van der Meer.
- Science-Policy Interfaces for Biodiversity: Research, Action, and Learning (SPIRAL, EU 7th FP).
  C.H.R. Heip, C.J.M. Philippart, E. van Haastrecht.
- Wadden Sea Long-Term Ecosystem Research (WaLTER) (Waddenacademie)
  C.J.M. Philippart and T. De Bruin. In cooperation with IMARES, SOVON Vogelonderzoek Nederland, Radboud University Nijmegen,University of Groningen and Common Wadden Sea Secretariat.
- Integration of European marine research networks of excellence (Euromarine, EU 7th FP).
  C.H.R. Heip.
- Developing a knowledge network for European expertise on biodiversity and ecosystem services to inform policy making economic sectors (KNEU, EU 7th FP)
  C.H.R. Heip.
- Joint European Research Infrastructure network for Coastal Observatories (JERICO, EU 7th FP).
  C.H.R. Heip.
- Climate Change and European Marine Ecosystem Research (CLAMER, EU 7th FP).
  C.H.R. Heip, C.J.M. Philippart.
- Climatic and anthropogenic shifts in seasonal river runoff into the Indian Ocean over the past Millennium resolved by coral geochemistry and photoluminescence (CLIMATCH, NWO-ALW).
  J. Zinke, G.J.A Brummer, in cooperation with VU Unisversity Amsterdam.
- Coral Reefs and Global Change – a historical perspective spanning the western Indian Ocean. (Western Indian Ocean Marine Science Association-Marine Science for Management; WIOMSA-MASMA).
  J. Zinke, in cooperation with University of Cape Town (South Africa).
- Natural monitors benchmark environmental change: valorization of the NIOZ-Core Scanner (NWO).
  G.J.A. Brummer, R. Tjallingii, J. Zinke, B. Koster.
- Darwin revisited: Atolls and climate change in Keeling Island corals since the voyage of the Beagle (VPRO and NIOZ/NWO).
  G.J.A. Brummer, R. Nagtegaal, in cooperation with University of Wollongong (Australia) and Dutch and Belgian national television.

- Hydroacoustic seafloor and water column mapping: New tools for multibeam backscatter analyses and 3D/4D visualization (NWO Valorization).
  J. Greinert, H. de Haas.
- Spatial methane and CO_2 flux quantification from a pockmark area in the Black Sea: SPUX. (ESF Eurofleets).
  J. Greinert, in cooperation with IFM-GEOMAR, Kiel (Germany), Ghent University, Ghent (Belgium), IOBAS, Varna (Bulgaria).
- Permafrost and gas hydrate related methane release in the Arctic and impact on climate change: European cooperation for long-term monitoring (PERGAMON, ESF/COST).
  J. Greinert, A. Stadnistkaia.
- Development large-scale application offshore tidal energy, funded by the European Regional Development Fund (ERDF)
  H.M. van Aken, J. Nauw.
- Bornholm basin ILWAO.
  H. van Haren, NIOZ-participant IOW-Warnemunde project.
- Budget modeling of fines in the Dutch coastal zone, Building With Nature/ Ecoshape.
  T. Gerkema. In cooperation with MEE and Deltares.
- Development, validation and application of compound specific hydrogen isotope analysis as a tool for reconstructing Agulhas Current paleo sea surface salinity variability (EU Marie Curie Initial Training Network GATEWAYS).
  S. Kasper, M.T.J. van der Meer, S. Schouten.
- Waddensleutels (Waddenfonds).
  J.S. Sinninghe Damsté, S. Schouten, in cooperation with MEE, Groningen University and Utrecht University.
- Developing new methods to estimate paleosalinity; understanding the past as key to future climate change (NWO Innovational Research Incentives Scheme VIDI).
  M.T.J. van der Meer.

Multidisciplinary Themes

InPlace

Geotraces

An Integrated Network for Production and Loss Assessment in the Coastal Environment (IN PLACE)

Katja Philippart, Hendrik van Aken, Mark van Dijk, Eric Epping, Margriet Hiehle, Jacco Kromkamp[1], Anna Noordeloos, Lars Okel, Anneke van den Oever, Herman Ridderinkhof, Suhyb Salama[2], Eric Wagemaakers, Thalia Watmough, Marcel Wernand, Hans van der Woerd[3]*

In shallow seas, such as the Wadden Sea, algae in the water column (phytoplankton) and algae attached to the surface of tidal flats (microphytobenthos) form the base of the food web and are the source of food for many marine organisms such as bivalves. Statistical analyses of more than 30 years of field observations show changes in phytoplankton biomass, in phytoplankton composition, and in the productivity, that are likely caused by changes in nutrient input in the Wadden Sea.
These observations are, however, scattered in time and place and consistent measurements of primary production in the water column are limited to a single station only, while data on the production of microphytobenthos are virtually lacking. The NWO-funded 'IN PLACE' project simultaneously studies the growth and loss processes of phytoplankton and microphytobenthos at the appropriate scales in time and space for the first time in this coastal region. This mechanistic approach is carried out by a multidisciplinary team consisting of physical oceanographers, chemists, microbiologists, ecologists and mathematical modellers from NIOZ, the Centre of Estuarine and Marine Ecology (NIOO-CEME), the Institute for Environmental Studies of the Vrije Universiteit (VU-IVM), and the Faculty of Geo-Information Science and Earth Observation of the University of Twente (UT-ITC).

We exploit a monitoring network of two permanent stations in the western Wadden Sea (Balgzand and NIOZ jetty), and in the Marsdiep tidal inlet using equipment mounted under two TESO ferries sailing between Den Helder and Texel. This network monitors the western-most basin of the Dutch Wadden Sea, the only basin for which long-term records on hydrography, nutrients like nitrogen and phosphate, phytoplankton production and large invertebrate animals living in and on the sea floor (macrozoobenthos) are available. A selection of meteorological, hydrological, physical, chemical and biological variables are monitored, using sensor packages that have been already successful in existing long-term monitoring programs deployed in other coastal environments. On site fluorometric techniques are used to monitor the concentration of the pigment chlorophyll of the microalgae.
In 2010, we have designed and built the sensor package for the permanent station at the tidal flat 'Balgzand' in the western Wadden Sea. The platform carries sensors for monitoring weather conditions, light intensity above and underwater, water height and waves. On this platform, we also placed several instruments to assess the biomass, species composition and production of phytoplankton and microphytobenthos, and the grazing behaviour of filter-feeding bivalves such as mussels. In addition, we built a system to supply power to the sensors and logging devices, and a system to transfer the data from the platform to the database at NIOZ. Due to the shallowness of the Balgzand area, the large research vessels of NIOZ are not capable of reaching the platform. Thanks to additional funding by Rijkswaterstaat, we were able to design and build the small research vessel 'Zeevonk' in 2010. This 7m aluminium vessel is fully dedicated to the high-frequency maintenance of the platform.
To increase the spatial resolution of our studies, we organize seasonal surveys with RV 'Navicula' to measure phytoplankton and microphytobenthos primary production and to map characteristics of the water column and the sediment. In addition, we obtain basin-wide information on algal biomass and sediment characteristics from satellite observations and airborne images.
The 'IN PLACE' project is closely linked with parallel research on the consequences of phosphorus reduction for the dynamic transfer of organic matter between algae and their primary consumers. This NWO-funded 'P REDUCE' project allows us to focus in depth on phosphate as the main factor limiting primary production in the Wadden Sea and controlling the species composition of algae.
The most innovative aspect of 'IN PLACE' concerns the inter-calibration of methodologies to measure the rate of primary production. This information is a prerequisite to examine the different options for management strategies related to the carrying capacity of the western Wadden Sea. In December 2010, our proposal to develop a multidisciplinary strategy to monitor abiotic, biotic and socio-economic development in the Dutch Wadden Sea was granted. The 'Wadden Sea Long-Term Ecosystem Research' (WaLTER) monitoring plan includes new measurements with optimal sampling techniques, conceptual models, and rigorous statistical designs derived from analyses of existing data. Insights and expertise from 'IN PLACE' will directly contribute to the aims of 'WaLTER'.

[1] NIOO-Centre for Estuarine and Marine Ecology; [2] UT – Faculty of Geo-Information Science and Earth Observation; [3] VU – Institute for Environmental Studies

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Sampling at the NIOZ jetty. Gerhard Cadée (left) and Katja Philippart (right) from the department of Marine Ecology at NIOZ, are the scientists responsible for the long-term field observations on phytoplankton dynamics that started in 1974. The coinciding changes that were observed between environmental conditions and phytoplankton biomass, production and species composition at the end of the 1970s and during the 1980s, form the basis of the working hypothesis underlying the 'IN PLACE' project.

The Balgzand platform is almost ready to be launched. Lars Okel and his colleagues at the department of Marine Technology at NIOZ designed and built the platform in close collaboration with the 'IN PLACE' research group. The pole on which the platform is mounted was formerly used by GKKS in the German Wadden Sea, and has kindly been loaned to NIOZ for the 'IN PLACE' project. The underwater sensors are positioned at the base of the pole and are hoisted up to the platform for weekly maintenance.

Extensive testing of the sensor package before it got launched. After selection of the most appropriate sensors by the 'IN PLACE' Sensor Group, Eric Wagemaakers and his colleagues of the NIOZ departments of Physical Oceanography and Marine Technology developed and built the automated monitoring station that is located at the Balgzand tidal flat. In addition to the sensors, this intertidal station accommodates systems to supply power to the sensors and logging devices and to transfer the data from the platform to the database at NIOZ.

Our new research vessel 'Zeevonk', specially designed to navigate in shallow areas of the Wadden Sea, where one of the automated monitoring stations is located.

The RV 'Navicula' at sea during the 'IN PLACE' cruise in September 2010. During the four research cruises in 2010, changes in abiotic and biotic conditions were followed over a full tidal cycle (13 hours) at subtidal stations in the main gullies of the western Wadden Sea and, weather permitting, in the North Sea coastal zone. The participants were divided into two groups, i.e. a pelagic team that was responsible for the sampling and analysis of the water samples, and a benthic team that collected and processed sediment cores.

Pelagic sampling on board the RV 'Navicula'. Together with one of the crew members, Margriet Hiehle took hourly water samples at three different depths for the duration of a full tidal cycle at each station sampled during the 2010 'IN PLACE' cruises. The water samples were subsequently distributed over the various participants of 'IN PLACE' and 'P REDUCE' who analysed them for a suite of parameters, e.g. concentrations of nutrients and total suspended matter, and biomass, primary production and species composition of phytoplankton. Additional water samples were taken to quantify the rates of incorporation of ^{13}C into phospholipids and zooplankton grazing.

Benthic sampling on board of the RV 'Navicula': Eric Epping checks if the sediment samples are of sufficient quality to take them to the NIOZ laboratories for further treatment. Subsequent analysis of the nutrient concentrations at various sediment depths enables a calculation of the rates of exchange of nutrients between the sediment and the water column.
Photo: Meint Brookman

GEOTRACES West Atlantic

Hein de Baar, Micha Rijkenberg, Loes Gerringa, Hendrik van Aken*

The goal of the GEOTRACES project is to produce complete ocean sections of classic hydrographic tracers like temperature and salinity, trace elements and several isotopes, tracers of global change, microbial biodiversity and metabolism, and interpretation of the data by ocean modeling. Six trace metals, iron, aluminum, zinc, manganese, cadmium and copper are the key tracers in this project since they are essential for life in the oceans. The NIOZ developed a unique all-titanium frame with 24 plastic sample bottles of 27 liters each enabled us to do the extensive ultra clean metal sampling. Because the natural concentrations of metals in sea water are extremely low, an ultra clean sampling system is essential since it reduces the danger of metal contamination from the sampling equipment itself. Many of the GEOTRACES tracer sections are first-ever ocean sections, while others will allow unraveling of transient global changes over the past 35 years by comparison with other cruises. The invasion of human derived transient tracers such as CFCs and 3H/3He happens mainly in the North Atlantic Ocean and partly overlaps with warming of upper ocean waters, and with the increase of CO_2, hence ocean acidification.

The North Atlantic GEOTRACES survey in 2010 consisted of two legs with a test station on the way (Fig. 1). The latter was to check the performance of the new titanium frame with the PVDF plastic sample bottles, on our way to the desolate embarkation port of Scrabster in the most northern part of Scotland. After results showed that the system was clean enough for trace metal work and worked excellent as a large seawater volume collector system, the Pelagia started its first Atlantic GEOTRACES cruise. The Pelagia first sailed to a location between Iceland and Greenland where we were very interested in sampling the Denmark Strait Overflow Water (DSOW). Preliminary results show high concentrations of manganese in the DSOW water, whereas iron was similar in DSOW and surrounding waters.

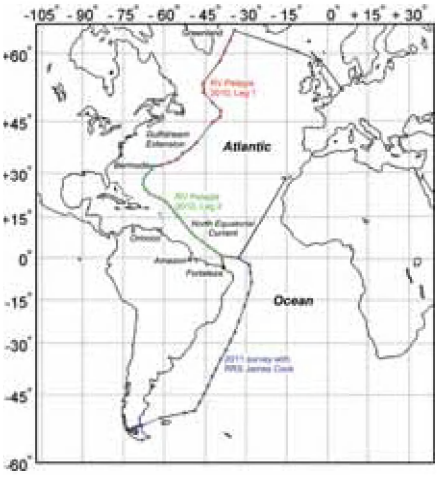

Fig. 1. Cruise tracks of the three GEOTRACES cruises. The two northern cruises took place in 2010 with RV Pelagia, the southern will take place in 2011 with RV James Cook

Sailing south following the deep sections along the Greenland coast we sampled another 4 stations. Encountering one storm after the other we followed our route doing stations where and when weather permitted until we arrived at Bermuda.

The second leg of the Atlantic GEOTRACES cruise started two weeks later from Bermuda and covered 22 stations between Bermuda and Fortaleza in Brazil. Aluminum concentrations increased going south which was attributed to dust input from the Sahara dessert. At this moment it is still unclear whether these high Al concentrations are the result of direct local Saharan dust input or the result of transport with water masses that were originally underlying the Saharan dust plume.

Between Denmark Strait and the equator, the distribution of tracer concentrations shows relations with the wind-driven surface circulation, with the thermohaline circulation, and with occasional large river plumes. E.g. the iron concentrations show subsurface maxima in the lower thermo cline (250 to 1000 m), centered in the Gulfstream Extension (~45°N) and the North Equatorial Current (~10°N), with lower values in the centre of the wind-driven gyre (Fig. 2). The iron maximum in the North Equatorial Current coincides with a minimum in the oxygen concentration. This negative correlation between iron and oxygen is a well documented effect of remineralization of organic matter by heterotrophic bacteria leading to the release of iron from dead organisms back into the seawater. Also here it is the question whether we look at a local phenomenon which is the result of local biological production or whether we deal with water masses originating from a well known oxygen minimum zone in

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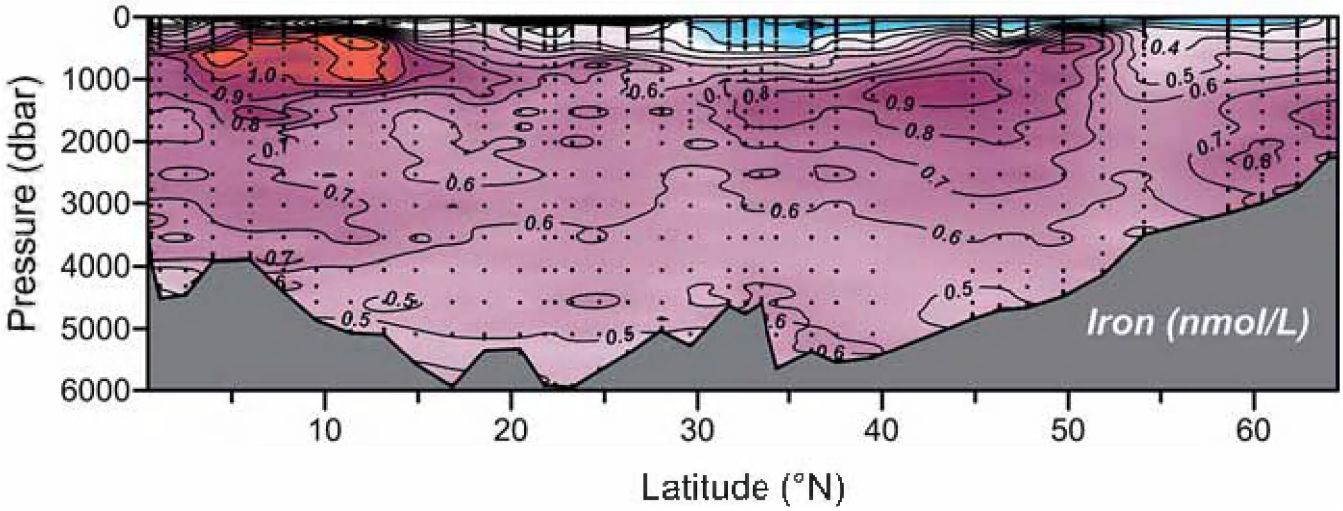

Fig. 2. Results of dissolved Iron concentrations at different depths from South to North. Sampling 24 times per station was possible due to the titanium frame with 24 special plastic bottles, made at NIOZ

the Equatorial East Atlantic Ocean around the Cape Verde Islands. Analyses of all sorts of isotopes in the different water masses will reveal their origin. An interesting aspect of the Geotraces leg 2 was the encounter of water masses consisting of seawater mixed with Amazon and Orinoco river water. The low salinity surface waters encountered at a latitude between 17°N and 13°N, probably originated from the Orinoco river and was characterized by a green-black color (Fig. 3A). A second patch of low-salinity surface waters, at latitudes between 6°N and 4°N, was caused by Amazon River input (Fig. 3B). In both river plumes the surface water was enriched in dissolved silicate and iron.

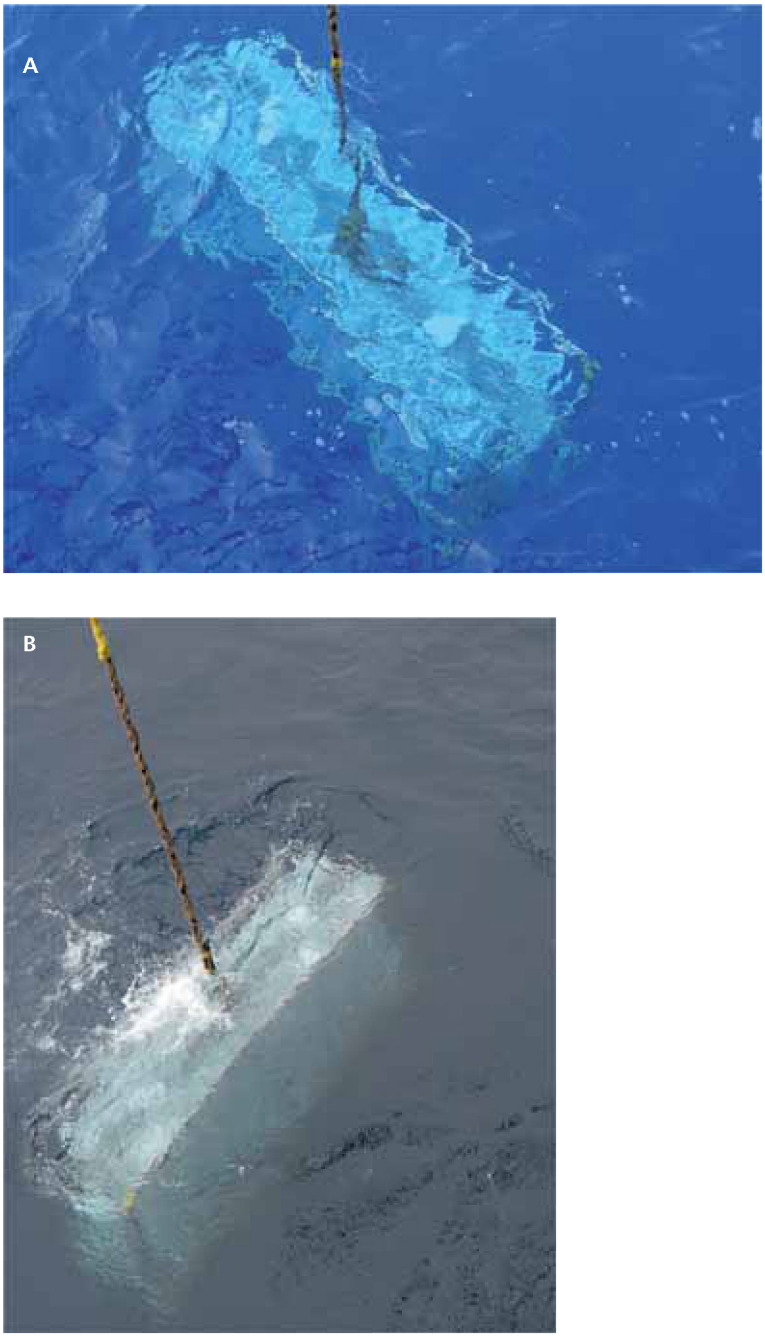

Fig. 3. (A) Picture of the clear blue surface seawater at 28°05'N, 67°30'W and (B) Picture of the green black surface seawater affected by Amazon river outflow at 05°55'N, 46°25'W.

Physical Oceanography

In 2010 the department of Physical Oceanography (FYS) carried out research in the research areas 'Oceanography of Shelf Seas and Estuaries', 'Deep Ocean Processes', and 'Regional Oceanography' of the NIOZ science plan. FYS is also involved in multi-disciplinary research. The number of PostDocs and PhD students is rising again, while at the end of 2010 a Tenure Track vacancy was filled. The number of publications by FYS authors (30) is the largest since 2000.

Oceanography of Shelf Seas and Estuaries.

This year much effort of the FYS department was spent on the preparatory phases of the setup of an automatic monitoring network for the multi-disciplinary INPLACE programme. This programme aims to determine the primary production in the western Wadden Sea, both pelagic and benthic, as the food basis for the ecosystem. Over half of the technical staff of FYS is involved in the preparation of the physical sensors (light, thermodynamics, and hydrodynamics), the data transmission and the data storage and processing for INPLACE, while in the running monitoring system of FYS in the Wadden Sea also required attention.

Progress was made in adaptation of an existing ocean circulation model (GETM/GOTM) to the western Wadden Sea. Test runs with a realistic topography and boundary conditions were conducted successfully, and also a 1-dimensional turbulence and silt model functioned as required. A number of observational cruises with the RV Navicula were performed to determine realistic parameters for the model.

Observations for a programme on the tidal current variability in the Wadden Sea were started in 2010. A PhD student for this programme will be hired in 2011. This programme, funded by the European Regional Development Fund (ERDF) aims to support the development of a test plant to generate energy from the tidal currents. Knowledge on the natural spatial and temporal variability is required to assess the anthropogenic consequences of such power plants on the water and silt transport in an estuary.

FYS was also involved in a number of research cruises with RV Navicula in the coastal zone of the North Sea as part of the Building with Nature (BwN) project. With different observational methods (optical and acoustic) the variation of the sediment load was determined on sections perpendicular to the coast. Earlier results were confirmed that a silt maximum in the bottom layer is encountered near the 10 m isobath. The GETM/GOTM model, implemented for the Wadden Sea, will also be used in this study.

Observations were carried out on the existence of non-linear Helmholtz oscillations in the Mok Bay, a small embayment in Texel, on a short distance from NIOZ. The existence of such oscillations was confirmed. These oscillations have characteristic frequencies which differed with the tidal phase, and typical amplitudes of about 20 cm/s near the outlet of the embayment to the Marsdiep.

The research on internal waves in the Wadden Sea was finished with the master's thesis.

Deep Ocean Processes

Research on the internal wave field in the deep ocean was continued in 2010. The observational part of this research is connected with the development of a European underwater neutrino telescope in the Mediterranean Sea. For this purposes moorings were deployed at different locations near Greece and Italy. Also the develop-

ment of fast thermistor strings is connected with this programme. The FYS department was also invited to participate in internal wave research programmes in the Mediterranean, the Polar Ocean, and the Baltic.
A PhD project on the theory of internal waves and supporting model experiments was finished successfully with an academic promotion. A newly started PhD project on near-equatorial internal waves, involving theory, observations and model experiments, was continued. The laboratory models for internal wave research are also used for the training of master's students from Utrecht University. For 2 periods of several months a PhD student from Spain worked at the NIOZ FYS department.
The mooring in the centre of the Irminger Sea was recovered, serviced, and redeployed with the German RV Meteor, as part of the EU project THOR. The mooring contained a profiling CTD, two acoustic Doppler current profilers and the self-contained CTD. Now a total of 7 year of daily observations of the stratification in this sub-Arctic sea are available, which can be extended with similar observations by foreign research institutes.

Regional Oceanography

While in December 2009 a mooring array was re-deployed in the Mozambique Channel between the island of Madagascar and the African mainland, in 2010 a current meter array was deployed east of Madagascar with the South African RV Algoa, as part of the NWO-ZKO INATEX programme. This is the first time that both parts of the fast western boundary current in the southern Indian Ocean are monitored simultaneously, the Mozambique Current and the East Madagascar Current. An analysis of the array data from the Mozambique Current between 2004 and 2009 has shown that next to large inter-annual variations in the volume transport, also considerable variations in the temperature and salinity field occur in the Mozambique Channel.
The international INSTANT project on the Indonesian throughflow was finished in 2010 with the publication of a special issue of the journal Atmospheres and Oceans. Three of the papers had NIOZ (co)authors.
Research on the variable hydrography of the Irminger Sea was continued in 2010 as part of the EU THOR project with an academic PhD promotion. also several papers on this subject are in preparation, in cooperation with scientists from abroad. A few CTD casts were measured along the AR7E section in the Irminger Sea during a cruise with RV Meteor. The data from this section, collected in October 2009 with RV Pelagia, were submitted to the ICES data centre.
In the summer of 2010 RV Pelagia surveyed a meridional section in the Western Atlantic Ocean from Denmark Strait to the Equator. This survey is part of the international multidisciplinary GEOTRACES programme which aims at the determination of the spatial distribution of trace elements. GEOTRACES is also follow-up of the similar GEOSECS programme from the early 1970's. The FYS department has taken care of the data processing for both GEOTRACES cruises, and has supplied a first hydrographic description of the data to all cruise participants.

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Hydrographic variability in the north-western North Atlantic Ocean

Femke de Jong, Hendrik van Aken*

The north-western North Atlantic Ocean has several functions in the ocean circulation and climate system. The relatively warm surface water, supplied by the Gulf Stream and North Atlantic Current, relinquishes large quantities of heat to the colder atmosphere. This is one of the reasons why the climate in western Europe is relatively mild for its latitude. It is also one of the few locations where surface waters are transformed into deep water, thus forming a vertical link in the overturning circulation. Therefore it is important to describe and understand the variability of this part of the ocean.

Ocean variability can be compared with the variability of the atmosphere. Where the atmosphere has high and low pressure areas the ocean has warm and cold eddies. Where the air varies in temperature and moisture, the water varies in temperature and salinity. Changes are smaller in the ocean because of the higher density and viscosity of water. Therefore ocean currents will never be as fast or chance as fast as the wind.

Although the North Atlantic Ocean is relatively well observed compared to other ocean areas, observations are still scarce compared to the atmosphere. That is why the variability of the north-western North Atlantic, especially the variability on seasonal and shorter time scales, is still poorly known. From 1950 observations by ships where made in this area nearly annually, but the stations, sample depths and measured parameters were relatively unorganized. Regular surveys of hydrographic sections did not start until the international World Ocean Circulation Experiment (WOCE), which began in 1990. Since then, two sections in the North Atlantic, one from Labrador, Canada to western Greenland (the AR7W) and one from southeast Greenland to Ireland (the AR7E, Fig. 1), have been surveyed nearly annually. NIOZ cooperates with the National Oceanography Centre, Southampton (NOC) and the Institut für Meereskunde, Hamburg (IfMH) in the surveys of the AR7E line (Fig. 2). The NIOZ R.V. Pelagia surveys this line every other year.

The north-western North Atlantic can be a hostile environment in winter, with strong winds and sea-ice. Therefore, shipboard observations are often made in summer or early autumn. This leaves the winter and spring, the period most interesting for deep water formation, unobserved. Two moored observing systems were deployed in this area to obtain detailed observations throughout the year. These moorings, part of the LOCO (Long-term Ocean Circulation Observation) program, were deployed since September 2003 in the Irminger Sea, a deep ocean basin east of Greenland (Fig. 1). The last of these moorings was deployed in July 2010 to record its 8th year of data. The moorings are fitted with an autonomous CTD (conductivity, temperature, depth) profiler, which records daily hydrographic profiles between 200 and 2400 m depth. Acoustic Doppler Current Profiles, which measure the near-surface and near-bottom currents, are also included.

The data from the moored instruments show that the hydrography of the Irminger Sea is highly variable. An example for the near-bottom waters is shown in Fig. 3. Changes that exceed the range of the variability (determined from annual shipboard observations) can occur within a few months. Thus, this fast variability is often missed or unintentionally wrongly interpreted in the record of shipboard observations. The sharp drops

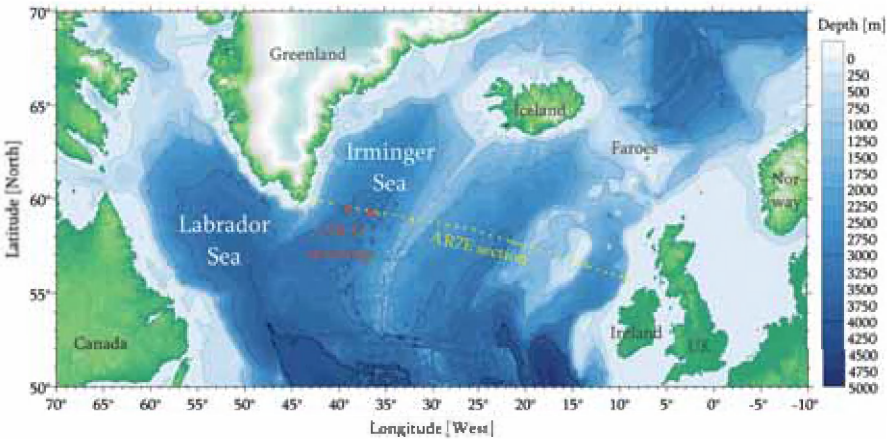

Fig. 1. Map of the northern North Atlantic. The two LOCO moorings (red crosses) were deployed in the center of the Irminger Sea at a depth of 3000 m. They are close to the AR7E section, which is surveyed by the R.V. Pelagia every other year. The yellow dots are examples of CTD stations along this line.

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in salinity shown in the example (Figure 3) originate from the overflow of cold and therefore dense Nordic water in Denmark Strait, the narrow shallow passage between Greenland and Iceland. Similar, but larger, drops in salinity were observed by moorings in this source area.

The upper water column is subject to strong seasonal variability. There is a constant import of relatively warm, southern waters through the Irminger Current, the extension of the Gulf Stream. These warm waters are cooled in winter by the dry cold air coming from Canada and Greenland. The atmospheric cooling increases the density of the surface water, rendering the water column unstable. Thus, in very cold winters the colder surface waters sink and deep water rises, inducing deep turbulent mixing. This was observed by the LOCO moorings during two cold winters. Mixing of the water column reached down to 1 km depth in one of these winters. Such deep mixing in the Irminger Sea had not been observed in this detail before.

On top of the seasonal variations, there are long-term variations in temperature and salinity which extent over the upper 2 km of the water column. This was found in the record of shipboard deep CTD stations since 1950 and verified against independent surface temperature observations by voluntary ships and satellites. The variations are characterized by a warm, saline period in the 1970s, a cool, fresh period in the 1980s followed again by an increase in temperature and salinity. They are strongly correlated with changes in the atmosphere, especially the wind forcing and the related changes in the heat exchange between the ocean and atmosphere. Whether the warming observed during the last 20 years will continue will depend on these parameters.

Fig. 2. The CTD ready for deployment just off the east coast of Greenland. This photo was taken on board the RRS Discovery in 2008.

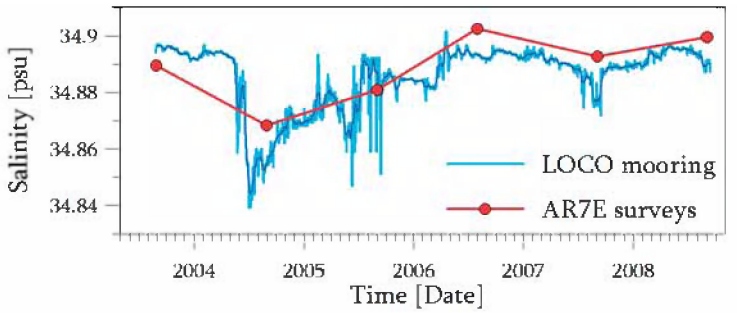

Fig. 3. Observations of the salinity of the near-bottom water. The high resolution observations from the moored instruments (blue line) show strong variability. Part of this variability is missed by the annual shipboard observations (red circles).

Unique measurements of ocean currents east of Africa

Jenny Ullgren, Hendrik van Aken, Herman Ridderinkhof*

The ocean currents in the Mozambique Channel, between continental Africa and Madagascar, are an important part of the global ocean circulation. The water that passes southward through the Mozambique Channel 'feeds' the Agulhas Current one of the strongest ocean currents in the world. By transporting warm and salty Indian Ocean water towards the southern tip of Africa, where some of it enters the Atlantic, the currents east of Africa may even play a role in global climate because of their influence on the amount of heat and salt in the Atlantic. Still, the strength of the flow in the Mozambique Channel was not well known until the beginning of the Dutch monitoring programme Long-term Ocean Climate Observations (LOCO). Thanks to our unique time-series of measurements we now know how large this flow is, and also how much it varies from year to year and even from week to week.

Because 'blobs' of salty water exported from the Indian Ocean may have an impact on the saltiness of the Atlantic, they may be important for the part of the ocean circulation which is driven by differences in heat and salt (the thermohaline circulation). To better understand the role of the oceans in the climate system, we need detailed information about the currents of the south-western Indian Ocean. In 1873, Thompson Maury wrote about 'the hot Mozambique Current' as 'the Gulf Stream of the Indian Ocean', but later work has shown that the flow in the Mozambique Channel is not so much a steady current as a train of southward-moving whirls or eddies. Apart from being part of the water transport chain feeding the Agulhas, eddies from the Channel can also affect the Agulhas Current by causing it to wobble in such a way that it is more likely to in turn send a warm, salty Indian Ocean eddy onwards into the Atlantic.

We have collected detailed information about the flow of water through the Mozambique Channel continually since 2003, using measuring instruments placed on long moorings in the ocean (Fig. 1, 2). Seven deep-sea moorings are placed across the narrowest part of the Channel, with instruments at different depths measuring the current speed and direction about every half-hour, and water temperature and salinity every five or six minutes. The six years' worth of current velocity data from these measurements have now been processed and analysed. By measuring at several locations across the Channel and at different depths, we have formed a good picture of the spatial pattern of the currents, and by measuring at short, regular intervals for an extended period we have learned how the flow varies in time.

Fig. 1. Acoustic Doppler Current Profiler (ADCP) mounted inside a buoy being recovered on board the FRS Algoa in the Mozambique Channel. Facing upwards (as shown) the ADCP gathers information about the direction and speed of currents over a range of several hundred metres.

The water in the centre of characteristic Mozambique Channel eddies is warmer than the surrounding waters. As these eddies are found in the Southern Hemisphere, this means they spin anticlockwise, while cold-core eddies spin clockwise (in the Northern Hemisphere it is the other way around). When the anticlockwise eddies move southward through the Channel, the net result is that the average southward flow is enhanced on the western side of the Channel and reduced on the eastern side, where the northward part of the rotating eddy current passes. Along the continental slope on the western side of the Channel, a deep undercurrent is flowing northward, underneath the southward mean flow and eddies.

The total volume of water transported through the Channel was estimated to be on average 17 million cubic metres per second (17 Sverdrup (Sv); compare with the transport of the Gulf Stream through the Straits of Florida, which is about 30 Sv). The value of the transport varies strongly from day to day, between 45 Sv northward and 65 Sv southward. Because upper ocean currents are driven by wind and the winds over the Indian Ocean change with the seasons, the currents show a seasonal cycle. The seasonal cycle adds to transport variations in the Channel, but with a range of about 4-5 Sv it is only a small part of the total variability. The amplitude of the seasonal part of the transport variability in our observations is similar to the estimate from

Fig. 2. Recording Current Meter (RCM) being deployed as part of one of the East Madagascar Current moorings.

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computer models. A much larger contribution to the observed fluctuations both in current velocity and water properties comes from the passage of eddies. On average, about four or five eddies per year pass through the Mozambique Channel, and they strongly influence the strength of the volume transport, contributing to the high short-term variation. However, the effect of eddies on the transport has so far not been well represented in model results. The strength of the transport through the Mozambique Channel also varies strongly from year to year, which seems to be connected to the large-scale recurring climate pattern known as the Indian Ocean Dipole, the Indian Ocean counterpart to the Pacific's El Niño/La Niña.

Records of continuous temperature, salinity, and velocity measurements in the open ocean as long as our time series are very rare, especially from such a comprehensive observational array, covering the full width of a current and measuring both current and water properties. The gridding and analysis of the current velocity data and the estimate of volume transport done to date have improved our knowledge of the current system in the Mozambique Channel and its variability on different time scales. Our results provide a benchmark for comparison with results of numerical modelling, and are also important for studies of marine biology, paleoceanography and paleoclimatology in the region.

Now, a closer study of the long-term temperature and salinity data set from the Mozambique Channel mooring array is underway. We are addressing questions about what water is moving through the Channel, where it comes from, and what determines the variability of water properties in the Channel. Furthermore, we have recently expanded the study area geographically with a new mooring array off southeast Madagascar. Five moorings were deployed in the East Madagascar Current in early October 2010 (Fig. 3). The new moorings will be used to monitor the East Madagascar Current, another important source for the Agulhas Current.

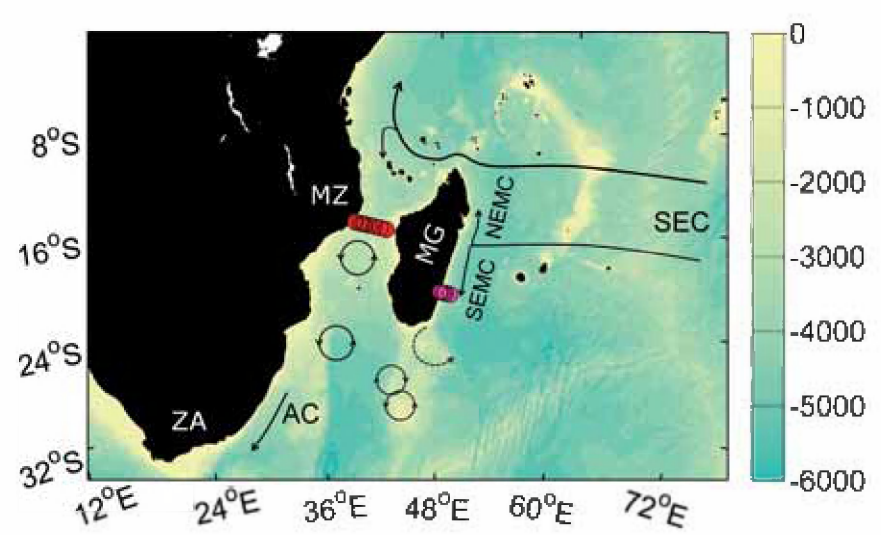

Fig. 3. Overview of the study area with some ocean circulation features: the South Equatorial Current (SEC), South and North East Madagascar Current (SEMC, NEMC), and the Agulhas Current (AC) off the coast of South Africa (ZA). Some eddies are shown in and south of the Mozambique Channel, between Madagascar (MG) and Mozambique (MZ). The Mozambique Channel mooring array is marked in red, and the new East Madagascar Current array in pink.

Laboratory experiments on local generation of internal solitary waves

Theo Gerkema, Louis Gostiaux[1], Matthieu Mercier[2], Manikandan Mathur[3], Jorge Magalhães[4], Thiery Dauxois[2], Jose da Silva[4]*

Within the 6th EC Framework Programme Hydralab III, experiments on internal solitons (i.e. solitary waves of large amplitude) were carried out on the rotating platform in the Coriolis Laboratory, Grenoble (France), inspired by recent observations in the Bay of Biscay and Mozambique Channel. They have revealed a hitherto unknown mechanism for the generation of these waves: by an internal tidal beam impinging on the seasonal thermocline from below, creating a large disturbance, which subsequently evolves nonlinearly in a train of internal solitons. To identify the key parameters in this process, a series of 30 experiments was carried out for different settings in terms of vertical density stratification, forcing frequency and rotation rate (mimicking the effect of the Earth's diurnal rotation).

In the ocean, internal solitons are among the most spectacular waves, with vertical amplitudes of up to 100 m and periods of tens of minutes. They usually appear as a wave of depression in the seasonal thermocline, which means that the isotherms are momentarily bended downward as the wave passes. The propagation of the wave is such that the horizontal currents accompanying it are directionally opposed above and below the thermocline. This strong shear, in turn, can lead to instabilities and mixing. Thus, internal solitons can act as an agent for vertical redistribution of nutrients, and they have been aptly referred to as a 'nutrient pump'.

Compared to their huge amplitudes in the interior of the ocean, their surface manifestation is modest, yet visible from satellites due to changes in seasurface roughness, which modifies the reflection of light. They can even be observed directly from spacecraft (Fig.1), the long stripes at the surface indicating the passage of a group of internal solitons.

For many years, internal solitons were thought to be created by tidal flow over strong bottom topography, such as the continental slope. They are, indeed, predominant in the vicinity of slopes, or can be traced back to one. Since the early 1990s, however, several observations, notably in the Bay of Biscay, have demonstrated that internal solitons may as well appear in the central basin, 'out of nothing' as it were. The agent generating them turned out to be an internal tidal beam that propagates in a zigzag way through the ocean: originating from the shelf edge, it propagates forward and downward into the abyss, then, after reflection from the ocean floor, forward and upward, eventually hitting the seasonal thermocline from below. This spot of impact, in the central Bay of Biscay, turned out to coincide with the location from which the internal solitons emerge. It is now understood that they evolve from the large disturbance created by the impinging internal tidal beam. Theoretically, a simple criterion for effective generation was derived in terms of phase speeds: the horizontal speed of the beam should be of similar magnitude as that of thermocline waves.

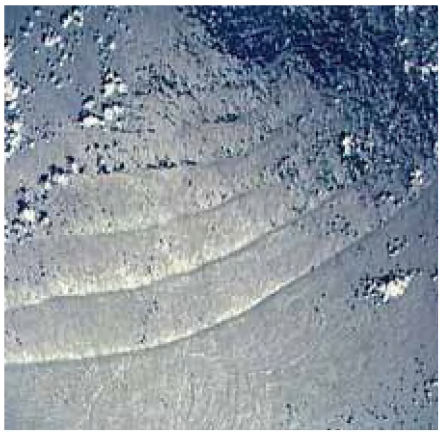

Fig. 1. Surface manifestation of internal solitons observed from the Space-Shuttle, open sea near Borneo. Source: NASA, JSC digital image collection.

To test such a criterion in the ocean is difficult, since the number of observations is limited, and only a small part of the parameter space is covered. Therefore, one has to resort to laboratory (or numerical) experiments to test the validity.

In the experiments carried out on the Coriolis platform (the largest such device in the world, 14 m in diameter), the ocean's vertical density stratification was modelled by creating a lower layer with a linear salinity gradient, and adding a thin fresh layer on top. The halocline thus formed plays the role of the thermocline in the ocean. A recently developed wave generator was used to create an internal wave beam, whose energy propagates diagonally towards the halocline. The angle of the diagonal orientation was varied by using different forcing frequencies. The fluid was filled with small particles of different densities, which stay on the depth level of their own density. Lightened by a laser sheet, the movement of the particles, which move along with the currents accompanying the passage of waves, can be traced using cameras and a technique called Particle Image Velocimetry. Thus, the current velocities over a large section of the basin can be measured. (This, by itself, already literally widens our view of the

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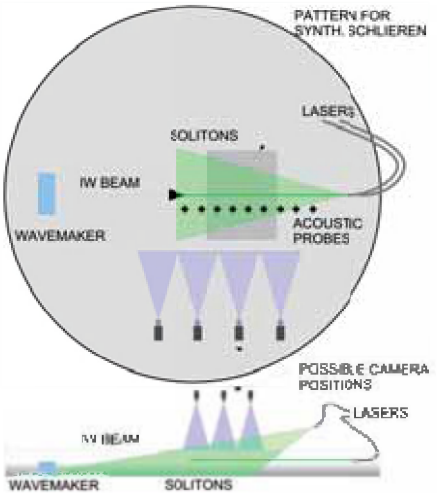

Fig. 2. Set-up of the experiments (top view and side view).

process, compared to point measurements in the ocean.) Furthermore, acoustic probes were used to measure vertical displacements (Fig. 2).

The effect of the presence of a halocline is clearly seen in Fig. 3. In the upper panel, no halocline is present, whereas in the lower panel, there is one, close to the surface. In both panels the internal wave beam, generated at the left end, propagates rightward; the red and blue areas indicate where its energy is concentrated. In the upper panel, the beam retains its form after reflection from the surface. In the lower panel, by contrast, the beam is much broadened after its passage through the halocline.

To see the effect on the halocline itself, we turn to the acoustic probes, which measure the vertical movement of the halocline. An example is shown in Fig. 4, in which (nearly) five periods of wave-forcing are present. The departure from a sinusoidal form signals the importance of nonlinearity. In particular, we see that every period starts with a steep decline followed by a number of peaked waves. This is the same phenomenon as observed in the ocean, the group of peaks being a train of solitons, which are, as is typical, amplitude-ordered (the largest coming first).

In these experiments, the process of local generation of internal solitons was demonstrated for the first time in a laboratory setting. Analysis of the different

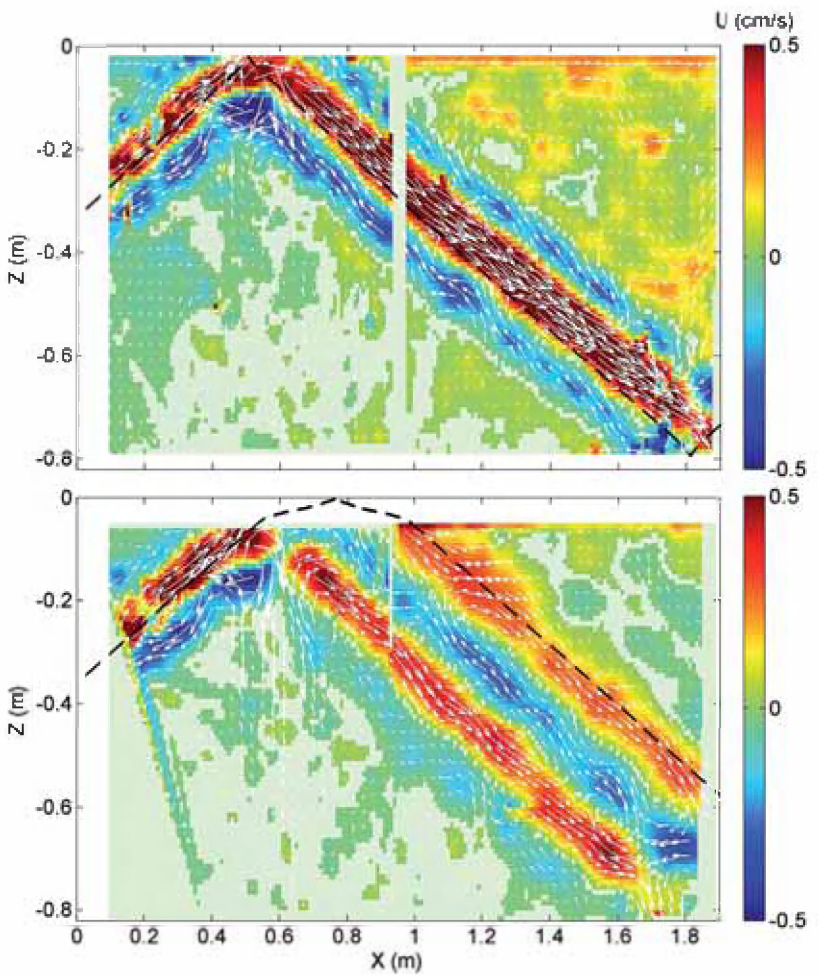

Fig. 3. Snapshots from two experiments, side-view. Horizontal velocity in colours, arrows indicate the direction of velocity. The beam is generated at the left-end, and propagates to the right, first upward, then downward. In the upper panel, no halocline is present; in the lower panel, a halocline is present close the surface.

settings bears out the correctness of the theoretical criterion, mentioned above. In addition, a number of new phenomena were discovered in the experiments, notably the presence of trapped higher harmonics (i.e. waves at a multiple of the forcing frequency) in the halocline, following the impact of the beam, and a mean flow extending in the forward direction, also located in and around the halocline. The latter awaits theoretical explanation.

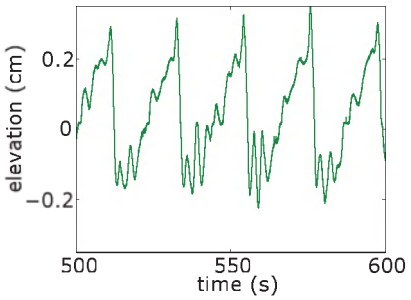

Fig. 4. Result from an acoustic probe beyond the zone of impact, showing the vertical movement of the halocline during nearly five periods.

Familiarly curved deep sea waves

Hans van Haren, Louis Gostiaux[1]*

Sometimes old concepts become newly found; this happens occasionally in the deep-sea where we probe with black-boxes in the form of self-contained instrumentation. Detailed measurements above deep-sea topography revealed curled-up waves using 100 moored high-resolution NIOZ-temperature sensors. Near the surface such waves are familiar and well-described since 150 years, but they have not been observed before in the deep-sea. The sheer beauty of the wave-train observed over Great Meteor Seamount in the NE Atlantic Ocean caught the attention of a wider public, as a cover-page of Geophysical Research Letters and a lyric descriptive in New York Times. Scientifically, we can now start estimating the effects of internal wave breaking on ocean mixing.

In search for the dominant processes of mixing in the ocean, sloping bottom boundaries are the primary areas. There, internal waves supported by the stable density stratification in the ocean interior may focus their energy, become non-linear and eventually break. Vigorous motions do occur above sloping sea floors as has been revealed via precise, fast-sampling temperature sensors a few years ago. Detailed observations from the deep ocean linking internal waves and more persistent turbulent mixing are scarce, but presented here.

Different processes drive turbulent motions each having different time scales. As has been revealed previously, *upslope* moving internal wave fronts can cause large transport of resuspended materials up a sloping bottom. These fronts have a time scale of typically 100 s and turbulent eddy diffusivity values up to 10^{-1} m^2 s^{-1}, but are generated by processes like tidal and atmospheric forcing that have time scales of typically 1-10 days. Here, we demonstrate that the *downslope* tidal phase is dominated by another, more persistent turbulence process: the density stratification supports Kelvin-Helmholtz (K-H) type overturning curled-up waves ('billows') that are created by large-scale internal wave shear (Fig. 1).

These new observations have been made between 0.5 and 50 m above the sloping side of Great Meteor Seamount, Canary Basin, using 100 moored temperature sensors, 1mK accurate, sampling at 1-Hz and designed and built at NIOZ. The K-H type overturning and associated turbulence is inferred from high-resolution temperature depth-time series, which at a first glance reveal ubiquitous 'finger-like' structures (Fig. 1a). It occurs during the 'clear-water', warming tidal phase, with low amounts of acoustic scatterers. The high-frequency finger-like motions are varying ten-times more rapidly than the smallest internal waves, but are carried by such slow waves. In more detail (Fig. 1b,c) the fingers appear as temperature variations with 5-10 m vertical amplitudes and occasionally develop as beautiful roll-up, curved overturns, or Kelvin-Helmholtz billows. The typical period of these deep-ocean billows amounts 50±10 s. They dominate the mixing across the isopycnals at some distance from the bottom with typical eddy diffusivity values of 10^{-3} m^2 s^{-1} in an environment where turbulence is about ten times smaller.

Such K-H instabilities are known for more than a century. They are well-observed in the laboratory and in the atmosphere where they are also known as 'clear-air turbulence' as they occur at altitudes with few clouds. In the ocean, near-surface observations have been made using dye, temperature sensors and acoustics. Until recently, no detailed observations of them existed from the deep-ocean, or related to sloping bottom layers. The present observations show that the ocean is in a quasi-permanent turbulent stage above sloping topography. This is important for local mixing, although at some (10-30 m) above the bottom. Sediment resuspension is little affected by these motions.

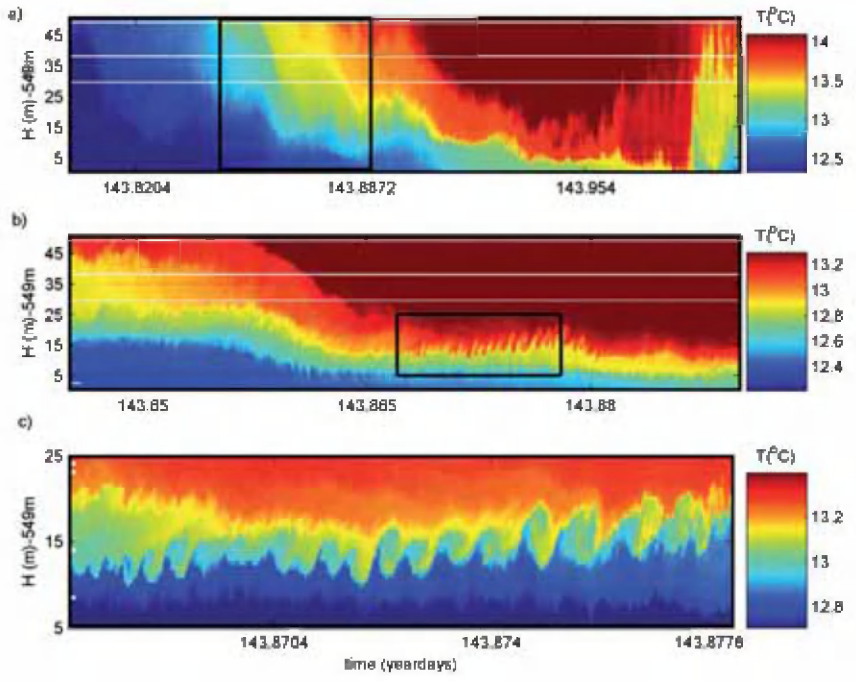

Fig. 1. High-resolution temperature variations during a downslope tidal phase above a slope of deep-sea Great Meteor Seamount (Canary Basin, North-Atlantic Ocean) using 100 NIOZ-thermistors at 0.5-m intervals. This tidal phase is 'permanently' turbulent some distance from the bottom, with finger-like motions that occasionally develop 10-m-high Kelvin-Helmholtz overturning billows. The rectangles in the top two plots a.-b. highlight the time range for the plots b.-c.; white lines indicate missing sensors.

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External Projects Physical Oceanography

- *Study of global variability of water mixing in the World Ocean and its influence on convection and internal waves in Sub-Polar zones, Dutch-Russian cooperation. (NWO).*
  L.R.M. Maas, T. Gerkema, H. van Haren.
- *Dynamics of Patterns Program: Internal Waves in 3D. (FOM/NWO).*
  L.R.M. Maas, T. Gerkema, H. van Haren, in cooperation with the centre of mathematics and informatics (CWI).
- *Transport and circulation around Madagascar (NWO-ALW).*
  H. Ridderinkhof (BDS), J. Ullgren, H.M. van Aken.
- *Indian-Atlantic exchange in present and past climate (INATEX) (NWO-ZKO).*
  H. Ridderinkhof (BDS), H.M. van Aken, J. Ullgren.
- *North Atlantic Ocean Monitoring and Modelling (BSIK – Klimaat voor Ruimte).*
  H.M. van Aken, L.R.M. Maas, H. van Haren, M.F. de Jong.
- *Variability of Atlantic Meridional Overturning Circulation (VAMOC; NWO-NERC-RCN trilateral programme , RAPID2).*
  L.P. Jonkers, G.J.A. Brummer, T.C.E. van Weering (GEO), H.M. van Aken, in cooperation with VUA, CAM (UK), NOC (UK), Bergen University (Norway).
- *Thermohaline Overturning - At Risk? (THOR) European Union (EU).*
  H.M. van Aken, M.F. de Jong.
- *Integrated Network for Production and Loss Assessment in the Coastal Environment (IN PLACE) NWO Coastal and Marine Research (ZKO).*
  M.R. Wernand, H.M. van Aken (FYS), H. Ridderinkhof (BDS).
- *Wadden Sea ecosystem data assimilation and integrated modelling NWO Coastal and Marine Research (ZKO).*
  T. Gerkema, J. Nauw.
- *Monitoring Mosselzaadinvanginstallaties (MZI) funded by IMARES.*
  L.R.M. Maas, S. Groeskamp.
- *Long-term ocean climate observations (LOCO, NWO).*
  H.M. van Aken, H. Ridderinkhof, H. van Haren, L.R.M. Maas, J.T.F. Zimmerman, T. Gerkema.
- *Astronomy with a Neutrino Telescope and Abyss environmental RESearch (ANTARES)-funded via the National Institute for Subatomic Physics (Nikhef).*
  H. van Haren, in cooperation with Nikhef and ANTARES-collaboration.
- *Cubic kilometre neutrino telescope (KM3NeT) (NWO-Esfri).*
  H. van Haren, in cooperation with NIKHEF, Amsterdam.
- *Cubic kilometre neutrino telescope design study (KM3NeT-DS) (EU).*
  H. van Haren, in cooperation with KM3NeT-collaboration.
- *Cubic kilometre neutrino telescope prepatory phase (KM3NeT-PP) (EU).*
  H. van Haren, in cooperation with KM3NeT-collaboration.
- *Budget modeling of fines in the Dutch coastal zone. (Building With Nature/Ecoshape NTW3.1).*
  C.M. van der Hout, J. Nauw, T. Gerkema, H. Ridderinkhof (BDS).
- *Development large-scale application offshore tidal energy (ERDF).*
  H.M. van Aken, J. Nauw.
- *Bornholm basin ILWAO.*
  H. van Haren, NIOZ-participant IOW-Warenmuende project.
- *Particle transport, deposition and resuspension in the Southern North Sea and biogeochemical consequences (FOKUZ).*
  M. Tiessen, J. Nauw, T. Gerkema.

Marine Geology

Research in the Marine Geology department (GEO) focuses on seabed systems where the geo-, bio- and hydrosphere interact. GEO aims at a better understanding of sediment formation through time and is actively engaged in research on:

- Processes, pathways and fluxes of ocean margin sedimentation
- Corals as archives of climate change across the tropics
- Methane fluxes from seabed seeps
- Wind-blown dust in marine systems

In 2010, the department remained strongly committed to multidisciplinary sea-going activities in research cruises world-wide, embedded in (inter)national research programmes like HERMIONE and ESONET. GEO intensified complementary science directions that came with the appointments of Jens Greinert and Jan-Berend Stuut, respectively in 2008 and 2009. Sea-going research stretched from the Arctic offshore Svalbard, the NE Atlantic around Ireland, off NW Africa, the Gulf of Mexico, across the equatorial Indian Ocean and the Pacific offshore California. Complementary fieldwork on land, linking marine sedimentary components to continental source areas, was carried out in Australia and Mauritania.

Climate change recorded by tropical giant corals in the equatorial Indian Ocean, and wind-blown dust transport off northeastern Argentina and western Australia featured prominently in a true remake of Charles Darwin's 'Voyage of the Beagle', with GEO members participating in several legs of the world cruise and associated fieldwork that resulted in well-received documentaries on international television and in newspapers. Methane release from the seabed was studied offshore California with the US Geological Survey and offshore Svalbard with the University of Tromsø. GEO became very active in PERGAMON, a COST networking action linking atmospheric, terrestrial and marine sciences to study methane release in a changing Arctic environment. Closer to home, intense sampling was carried out in the Wadden Sea to determine its carrying capacity with regard to pelagic and benthic processes as part of the multi-departmental INPLACE project.

Scientific highlights among the 35 peer-reviewed papers published in 2010 include Craig Grove's in Coral Reefs on a novel method to quantify river runoff using UV light scanning of coral cores, the special issue of Marine Geology on methane seeps off New Zealand co-edited by Jens Greinert, and Jan-Berend Stuut co-authored a paper in Nature on the relationship between colonial land use in subtropical Africa and the mobilization of desert dust. Also highly successful was the 'first international workshop on XRF core-scanning' organized by Rik Tjallingii, at the birthplace of the revolutionary technique sold world-wide by the NIOZ spin-off company Avaatech. Advancing science and technology received significant valorization funding by NWO for core scanning and the hydroacoustic detection of gas emissions.

GEO experienced significant changes with regards to staffing in 2010. Jens Greinert took over as interim head of department from Geert-Jan Brummer, who was appointed a Professor at the Vrije Universiteit Amsterdam, and Eric Epping resigned as senior scientist with important expertise in sediment-water interface biogeochemistry. The nutrient lab was relocated to MRF with important personnel changes

as Santiago Gonzales became NIOZ's radiation safety officer at BIO and Evaline van Weerlee accepted a position in MEE, while Sharyn Crayford joined the nutrient lab. At GEO, Henk de Haas was appointed as associate scientist and Piet van Gaever as experienced chemical technician. Meanwhile, Lukas Jonkers successfully defended his PhD thesis on North Atlantic sedimentation and is now with the University of Barcelona, and Furu Mienis took up a PostDoc position at MARUM, Bremen. Aneurin Henry-Edwards was appointed a joint GEO-FYS PostDoc at NIOZ and Juliane Steinhardt a PhD-researcher in the EU-funded Marie Curie project GATEWAYS.

Finally, Wim Boer and Rineke Gieles did a great job implementing the renovation of most of the GEO labs and offices.

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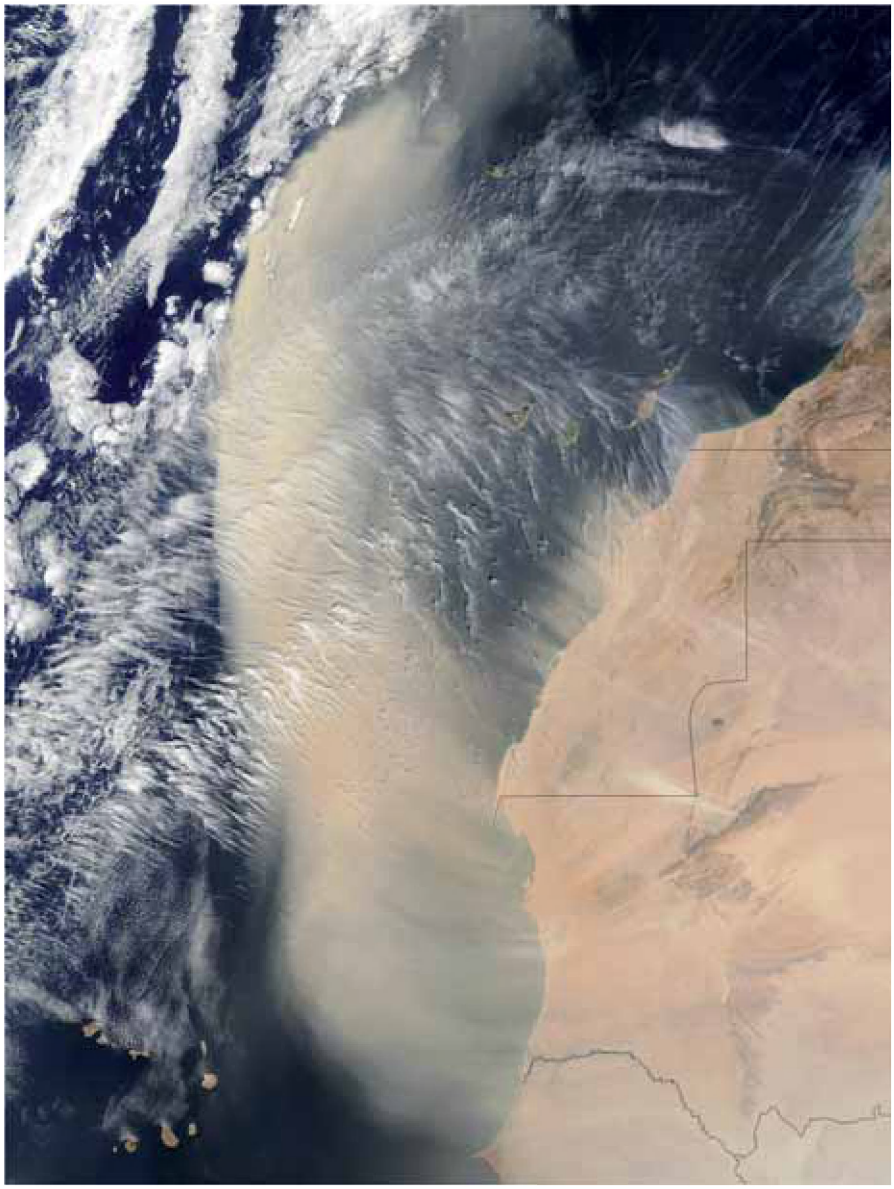

A massive plume of Sahara dust being blown over the Atlantic Ocean on 4 March 2004. The image was made by the MODIS instrument aboard NASA's Terra satellite.

Dynamic paleoceanography and paleothermometry in the Mozambique Channel, upstream of the Agulhas Current

Ulrike Fallet, Isla Castañeda, Jenny Ullgren, Chris van Assen, Sanne Vogels, Jens Zinke, Stefan Schouten, Geert-Jan Brummer, Herman Ridderinkhof*

Paleoceanography strongly relies on proxies to reconstruct past environmental conditions. In this project we developed new temperature calibrations for the so far largely unstudied Mozambique Channel in the SW Indian Ocean. We find two main drivers for temperature in the Mozambique Channel: seasonal variability and eddy migration. To characterize the effect of these drivers on fluxes and proxies, we analyzed time-series foraminiferal and organic temperature proxies. From that basis, we developed novel temperature calibrations and applied these to foraminifera and organic matter from sediment.

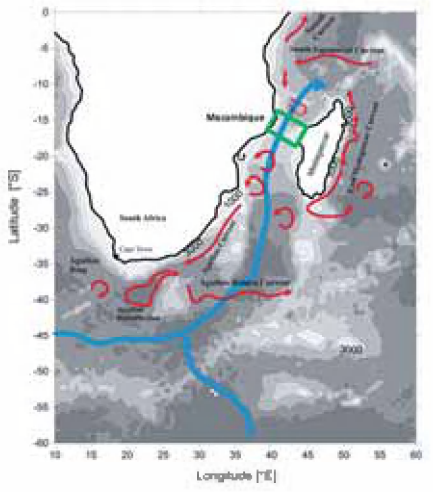

Fig. 1. The main features of circulation along the southeast African margin. Surface currents, including Mozambique Channel eddies feeding the Agulhas Current, are indicated in red. The deep counter currents from the Atlantic and Southern Ocean are indicated in blue. The green inset specifies the location of the study area with moorings and instruments (also see Fig. 2). Water depths are indicated in meters.

The world's oceans form an important component of the global climate system because they convey a substantial energy transfer between low and high latitudes. This energy transfer is driven by a delicately balanced network of surface and deep ocean currents (the 'conveyor belt'). The southern tip of Africa is a key area with regard to ocean currents because there the exchange between warm Indian Ocean surface waters (the Agulhas Current) and cold Atlantic deep waters takes place (Fig 1). Consequently, this exchange of water masses is important for the global climate system.

The Agulhas Current is fed by fast-rotating meso-scale eddies originating in the Mozambique Channel. To study the effect of eddies, we deployed an ensemble of instruments on mooring cables across the narrowest part of the Mozambique Channel that allows quantification of current transport and particle fluxes (Fig. 2).

From the particle fluxes, we analyzed a number of temperature proxies such as organic $U^{k'}_{37}$, TEX_{86} as well as $\delta^{18}O$ and Mg/Ca of foraminiferal shells (Fig. 3).

These were contrasted with satellite sea surface temperature (SST) to establish novel calibrations for an ensemble of temperature proxies for the SW Indian Ocean (Fig. 4). Additionally, we coupled these temperature proxies to *in situ* measured current velocities to establish the effect of current transport in the Mozambique Channel. The foraminiferal and organic temperature proxies were also studied in the Holocene bottom sediments to estimate how proxy signatures are transposed to the sediment.

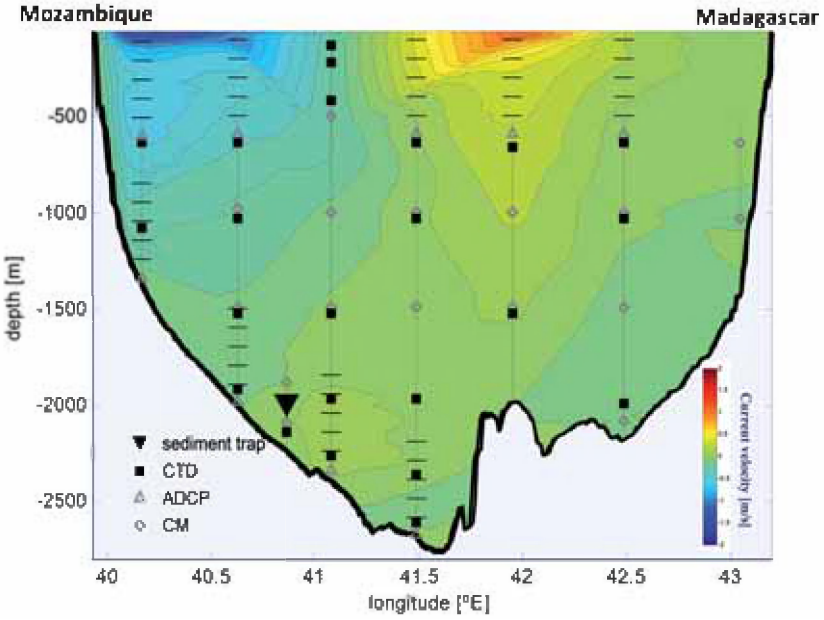

Fig. 2. Cross-section through the Mozambique Channel showing the deployed instruments on the eight mooring cables, and on the background the typical current velocity pattern of an anti-cyclonic eddy migrating through the channel. Blue indicates southwards directed transport and red northwards directed transport. Explanation of abbreviations: CTD (conductivity-temperature-depth sensor), ADCP (Acoustic Doppler Current Profiler), CM (current meter).

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We found that in the Mozambique Channel, two major, periodically recurring driving forces exert influences on the different temperature proxies: annual variation in temperature (Δ 5.2 °C) and the periodic change of water mass properties induced by the migration of meso-scale eddies through the channel (four to six per year). Despite the eddy influence, temperature proxies of surface-dwelling foraminifera (Fig. 3) closely mirror seasonal temperature changes and annual mean satellite SST of 27.6°C (Fig. 4). In contrast, organic compound concentrations and fluxes measured in this study, show no or only moderate seasonality whereas the associated proxy signatures reflect annual mean sea surface temperature. Based on these findings we developed multiple-proxy temperature calibrations for improved paleothermometry in the SW Indian Ocean. Our multiple proxy approach yields better temperature reconstructions from proxy measurements and minimizes the effect of short-term temperature variation caused by the migration of fast-rotating eddies through the Mozambique Channel.

We also measured organic ($U^{k'}_{37}$ and TEX_{86}) and inorganic ($\delta^{18}O$ and Mg/Ca)

Fig. 3. Scanning electron microscope image of surface-dwelling planktonic foraminifera *Globigerinoides ruber*. The stable isotope ($\delta^{18}O$) and trace element composition (Mg/Ca) of shells from this species were used to derive proxy-based sea surface temperature for the Mozambique Channel.

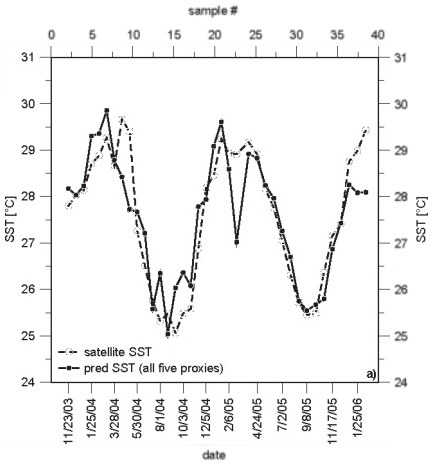

Fig. 4. Observed (dashed line) and predicted SST (solid line) obtained from satellite remote sensing and multiple linear regression, respectively.

temperature proxies in core top sediments taken across the Mozambique Channel (Fig. 5) Radionuclide analysis shows that core top sediment at this location is a mixture of reworked material (~1000 years old) and fresh sediment probably supplied by lateral and vertical sediment transport and affected by diffusive mixing into the sediment. Therefore, we caution against using core top sediments for proxy calibrations against present day SST. We observed a significant positive temperature offset of 1 – 3 °C between sediment trap and core top foraminifera which is not seen in the organic temperature proxies. We suggest that part of this temperature offset in foraminifera is due to rapid warming of the Indian Ocean over the past 100 years. That such a warming trend is not observed in the organic proxies is likely due to long-distance transport of fine grained organic particles by strong currents that might homogenize proxy signatures in core tops and settling particles.

Fig. 5. left. Ulrike Fallet with a sediment sample from the seafloor taken from the deep Mozambique Channel. right. Ulrike Fallet and the master students Chris van Assen and Sanne Vogels analyze sediment samples with microscopes for foraminiferal assemblages.

Scanning sediment cores at NIOZ

*Rik Tjallingii, Craig Grove, Roel Nagtegaal, Rineke Gieles, Wim Boer, Bob Koster, Jens Zinke, Geert-Jan Brummer**

Sediment cores provide a unique window into past and present dynamics of the seafloor. They preserve a long term record of changes in the origin and supply of sediments, their bioturbation by bottom dwellers and accumulation in a changing climate. In order to read such records, NIOZ scientists and engineers developed a digital corescanner using X-Ray Fluorescence (XRF). The highly innovative technique proved so successful that a prospering spin-off firm resulted (Avaatech) that exported no less than 22 instruments to marine research centers world-wide over the past decade. The XRF-corescanner at NIOZ is unique to the Netherlands and has become a (inter)national marine research facility, associated with Avaatech.

Since the late 1980s, the NIOZ-corescanner (Fig. 1) has emerged as the instrument of choice for rapid, non-destructive and high-resolution chemical analysis of entire cores, both freshly taken on board ships and land-based. XRF-Corescanning at NIOZ was developed to determine the chemical composition as it changes downcore in ocean sediments in order to establish long-term climate change effects such as on the transition from the last ice-age by global warming. Core-scanning data are widely employed for paleoceanographic and paleoclimate reconstructions on time scales ranging from seasons to millions of years. Consequently, non-destructive core scanning techniques with practically no limitation on sampling resolution and sample quantity have become increasingly popular over the last two decades. Results have been published in hundreds of scientific publications mainly on climate change research, including Nature and Science.

Initially non-destructive XRF core scanning produced semi-quantitative elemental intensities but is now heading for quantitative analysis of element composition down to trace level concentrations. Recent development of processing and calibration techniques provide promising ways for quantification of XRF-corescanner data which also raised interest for commercial applications. We published a new technique using UV-light as a source to analyse the growth banding in cores from giant corals back to the 1790s that was highly televised in the sea-going Beagle program on Dutch and Belgian TV.

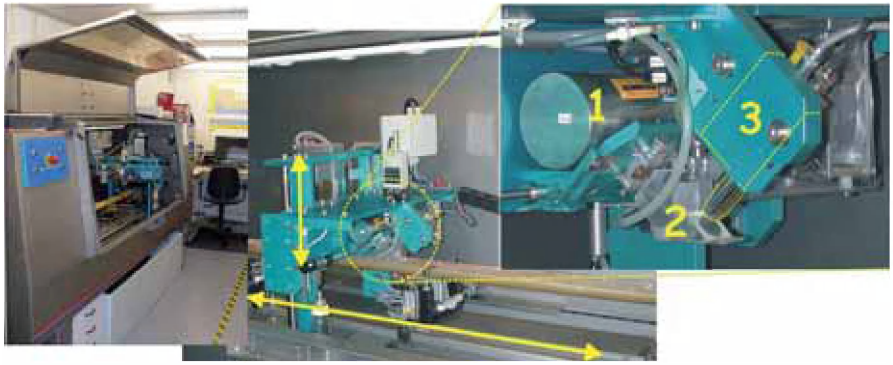

Fig. 1. Avaatech XRF core scanner at NIOZ (left) with a close-up of the XRF instrumentation (middle and right). In this configuration, the sediment surface is irradiated by an X-ray source (1) at an angle of 45°. The primary X-rays and the outgoing fluorescence radiation are transmitted through a He-flushed prism (2) to minimise diffraction and absorption. The silicon diode based detector is also mounted at an angle of 45°.

The growing number of XRF core-scanner laboratories and new developments in data-processing and calibration techniques increased the need to exchange experiences among users at various XRF core-scanner laboratories. Therefore, a three-day-workshop was organised at NIOZ from September 8-10 to discuss technical aspects and application challenges of XRF core scanning in the wider field of paleoceanography. With 80 participants from world-wide the first conference on XRF-corescanning was a great success, including the sessions organised.

Scanning climate archives.

Regional and seasonal responses become increasingly important to understand the human dimension of global climate change. High resolution climate records acquired from marine sediments, corals and cave stalagmites provide essential time-series data to establish ocean-continent-atmosphere linkages and feedbacks. Sediment records give excellent insights in the long term dynamics (10^3-10^6 years) of global climate and environmental changes, yet poorly resolve seasonal to decadal climate trends and changes. In order to retrieve time series data on ocean-climate dynamics from coral and sediment cores we need resolution in nested domains, from episodic to seasonal and multidecadal to centennia. New core scanner UV-spectral luminescence allow for climate analysis of coral cores off tropical eastern Africa to extend the observational records across the southern Indian Ocean (Fig. 2). Combined with X-ray density they allow for quantifying changes in coral calcification and growth rates at the human time scales of climate change. These may serve as regional and local benchmarks in assessments of run-off by human land-use change and climatic river run-off. Combining new properties such as UV-spectral luminescence with equally resolved chemical analysis for e.g. thermometry (Strontium/Calcium) and soil

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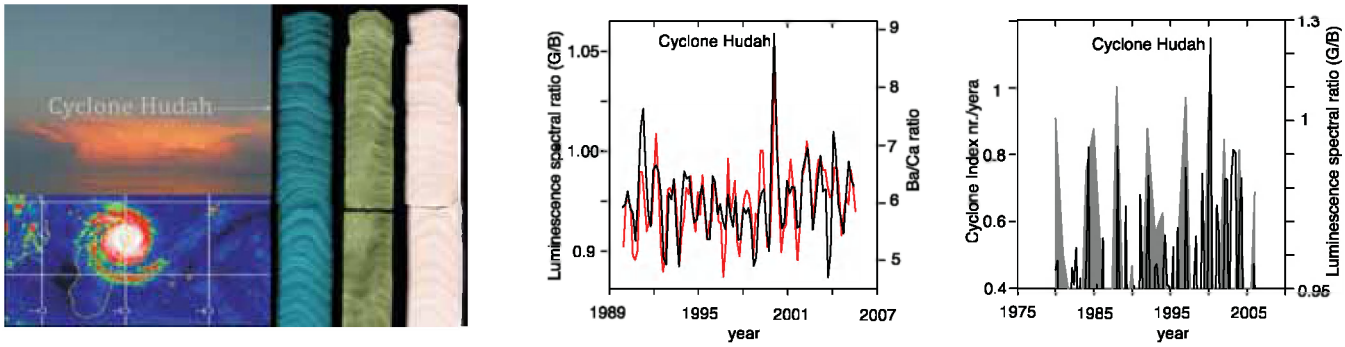

Fig. 2. Seasonality and cyclone impact revealed by growth banding of a northeast Madagascar giant coral (Grove et al., 2010). A) Coral banding visualized by UV-luminescence (blue), X-ray (grey), visual light scanning (white) can identify individual cyclone events, e.g. cyclone Hudah. B) Same coral core with monthly resolved Ba/Ca (black) and averaged spectral luminescence ratio (red) generated by novel UV core-scanning. C) Same coral core showing high luminescence ratios (black line) correspond to tropical cyclones making landfall (grey shaded) in East Madagascar since 1980. Correlation with Ba/Ca is high for the spectral G/B ratio showing seasonal runoff with a significant spike in the year 2000 corresponding to cyclone 'Hudah'.

runoff (Barium/Calcium) is greatly improving our understanding of how climate change works and the impact of anthropogenic perturbations.

Stratigraphy and sediment dynamics.

Core scanning allows constructing regional reference networks based on their XRF-chemostratigraphy and spectral reflectance in the visual light spectrum without prior knowledge of the depositional environment or sedimentation history. Chemostratigraphic records complement visual observation and assist the interpretation of regional stratigraphic frameworks in terms of past and ongoing environmental and climate change. For example, XRF-chemostratigraphy, in combination with visual and X-ray imaging, was used to determine the rate and evolution of deglacial sea-level rise and shelf flooding of the Mekong Delta, SE Vietnam, and this influenced sedimentary dynamics and transport to the deep sea (Fig. 3). Combing XRF-chemostratigraphy and X-ray imaging plays a central role in the research on cold-water coral colonies at Rockall Trough that appear only during relatively mild interglacial conditions and completely disappear during glacial conditions. Emerging and disappearing cold-water coral colonies are thought to contain valuable clues of deep water circulation in the North Atlantic.

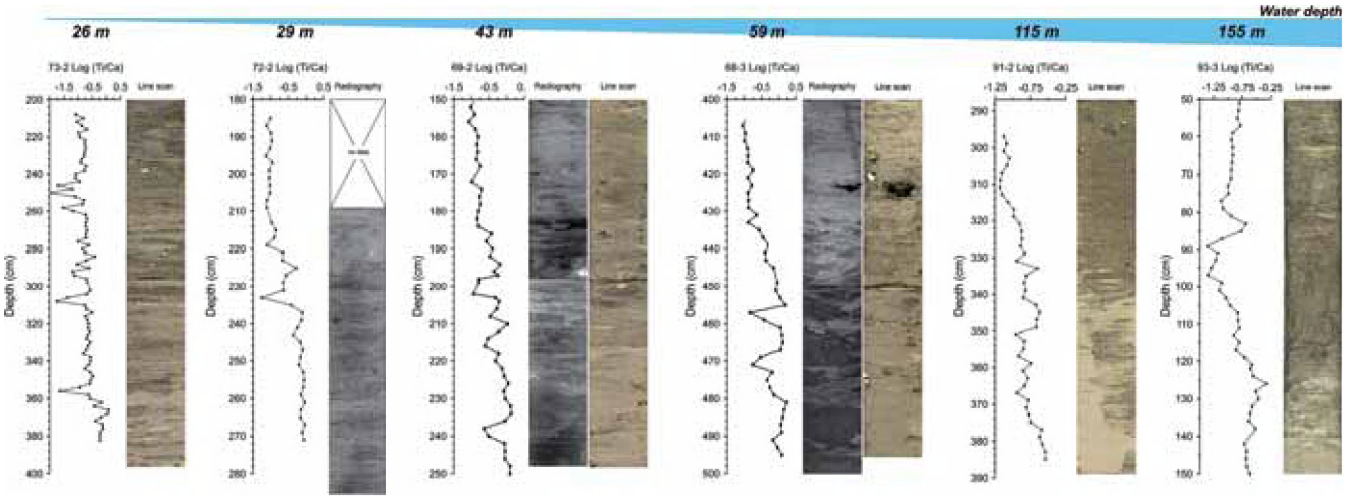

Fig. 3. Regional reference networks of XRF-chemostratigraphy (logCa/Ti), digital line-scan camera, and X-ray imaging of sediment cores off SE Vietnam (Tjallingii et al., 2010). XRF-chemostratigraphy shows the transition from a siliciclastic (Ti) to carbonate (Ca) dominated sedimentation over a depth transect between 155 and 26 m below the present-day sea level corresponding to postglacial shelf flooding. Line-scan and X-ray images show a subsequent transition from fluvial mud to marine sands and identify deep burial structures of *Glossifungites* ichnofacies that typically form under for transgressive conditions.

MODOO: testing a deep ocean observatory on the Porcupine Abyssal Plain

Jens Greinert, Henko de Stigter, Bob Koster, John Cluderay, Leon Wuis*

Sustained observation of the Earth's atmosphere, hydrosphere, biosphere and geosphere is essential for understanding the functioning and variability through time of natural systems, and for assessing the impact of human activity. Whereas instrumental data on continental climate have been collected for more than a century by meteorological stations around the world, and ocean surface variability has been continuously monitored by satellites and surface buoys for several decades, sustained observation of the ocean's interior for periods longer than a couple of years has been very rare and hampered by technical and financial difficulties. NIOZ participates in a European effort to develop a deep-sea observatory that should be remotely controlled from land via hydroacoustic and satellite communication. Expectations were high when in late May 2010 the MODOO system (MOdular Deep Ocean Observatory) was put to the test during a demonstration mission at 4850 m depth on the Porcupine Abyssal Plain west of Ireland.

Apart from severe technical difficulties associated with the operation of stand-alone observation systems in the deep sea, the length and resolution of observations by such systems are limited by battery power. Currently, continuous deployments of a maximum duration of 1-2 year can only be achieved by using energy-efficient instruments and low sampling rates. In addition, data are collected according to pre-set sampling schemes and can be accessed and evaluated only after recovery of the system, without the possibility of direct intervention during the deployment. To overcome these limitations, initiatives have been set up in the U.S., Canada, Europe and Japan to install cabled networks of deep-sea observatories at strategic locations along the ocean margins. These new observatories are supplied with electrical power and are able to exchange information via a combined electrical/optical cable connection to land. Fully functional cabled networks for deep-sea observation have so far only been achieved in the U.S. 'Mars' and the Canadian 'Neptune' projects.

In Europe, the ESONET (European Seabed Observatories NETwork) network of excellence has been active since 2007 to prepare the ground for European cabled networks whereas its successor project EMSO-PP (European Multidisciplinary Seafloor Observatory Preparatory Phase) is currently bringing together a consortium of countries to establish large cabled observatories e.g. offshore Ireland and Svalbard. However, as an alternative to such very costly cable networks, various tests have been carried out with seabed observatories communicating via hydroacoustic modem with a surface buoy moored nearby, which sends and receives information to and from land via satellite telemetry (Fig. 1). Although this does not solve the problem of electrical power limitation, it opens interesting possibilities of interactive data collection.

For the MODOO demonstration mission, a BOBO (BOttom BOundary) lander of NIOZ was prepared to be deployed in conjunction with a moored surface buoy operated by the U.K. Meteorological Office at 4850 m depth on the Porcupine Abyssal Plain (PAP), west of Ireland. This PAP site is one of the most extensively monitored open ocean sites in the North Atlantic, with observations on surface ocean hydrography, primary production, phyto- and zooplankton dynamics, export flux of particulate matter, and dynamics of deep-sea benthic fauna extending over more than two decades. The primary scientific aim of MODOO was to monitor in detail the timing of the export of particulate material from its origin in the surface ocean to its ultimate deposition on the deep sea floor at almost 5 km depth. To fulfil this aim both the BOBO lander and the moored surface buoy were equipped with instruments for recording time-series of near-bottom and near-surface particle fluxes and various hydrographic parameters. Two acoustic modems, one on the lander and one below the buoy, would establish two-way communication between the lander and the buoy, whilst the buoy would communicate to a land station via satellite telemetry.

Fig. 1. Sketch of the MODOO system, where a combination of satellite and hydroacoustic telemetry enables remote control and data exchange with an observatory located on the seabed, without intervention of a deep-sea cable. Image courtesy IFM-GEOMAR, Kiel, Germany.

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Fig. 2. Testing the BOBO lander in the NIOZ harbor.

The surface buoy is functioning well and every day transmitting meteorological and oceanographic data that is accessible via internet, but the loss of the bottom lander with all its equipment meant a serious blow to the MODOO mission. However, the test showed that two-way communication with seabed instruments via a hydroacoustic modem is feasible even at great depth. The recent experience will be put to use to implement two-way communication on the MOVE!, the MObile VEhicle for seabed research developed by NIOZ, so that in future it may be able to sample and measure remotely controlled via a surface buoy or a passing ship.

After a year of busy preparations, the lander and the buoy were eventually deployed at the PAP site on 31 May/1 June 2010 during a cruise with RRS James Clark Ross (Fig. 2 and 3). Whereas initially all seemed to run according to plan, a complete loss of communication with the BOBO lander two hours after its landing on the seabed announced major trouble. All attempts in the next hours to re-establish communication proved fruitless. An underwater camera of National Geographic Television, mounted on top of the lander to record the landing, revealed the cause of the dead silence. After detaching itself from the lander by a self-release and rising back to the sea surface, it was spotted by lucky coincidence several miles away from the deployment position. The pressure resistant glass sphere containing the camera as well as the electronic parts of the camera itself showed extensive damage (Fig. 4) suggesting it had been impacted by a violent shock wave produced by implosion of the glass buoyancy spheres of the lander. Most likely the shock killed the acoustic modem and possibly all other equipment on the lander. Since the BOBO deployment at 4850 m depth was well within the safety limit of 6500 m indicated for the spheres, the risk on such an accident had been considered minimal.

Fig. 3. The instrument cage of the surface buoy is ready for deployment.

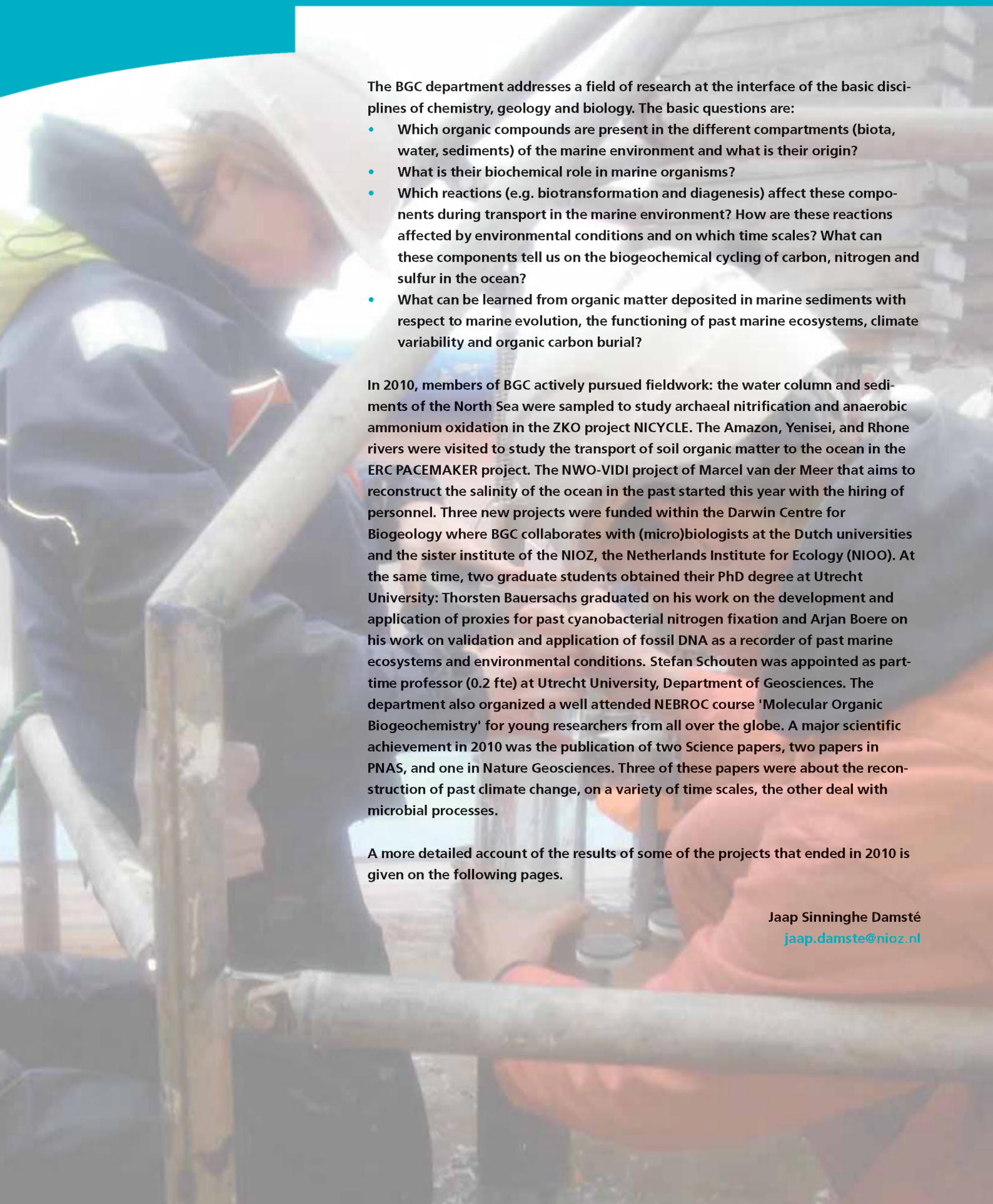
Fig. 4. Recovered National Geographic Television camera. The white material on the inside of the sphere are glass chips that broke off from the inside of the sphere.

External Projects Marine Geology

- Climatic and anthropogenic shifts in seasonal river runoff into the Indian Ocean over the past Millennium resolved by coral geochemistry and photoluminescence (CLIMATCH, NWO-ALW).
  J. Zinke, G.J.A Brummer, in cooperation with VU University Amsterdam.
- Coral Reefs and Global Change – a historical perspective spanning the western Indian Ocean. (Western Indian Ocean Marine Science Association-Marine Science for Management; WIOMSA-MASMA).
  J. Zinke, in cooperation with University of Cape Town (South Africa).
- Natural monitors benchmark environmental change: valorization of the NIOZ-Core Scanner (NWO).
  G.J.A. Brummer, R. Tjallingii, J. Zinke, B. Koster.
- Darwin revisited: Atolls and climate change in Keeling Island corals since the voyage of the Beagle (VPRO and NIOZ/NWO).
  G.J.A. Brummer, R. Nagtegaal, in cooperation with University of Wollongong (Australia) and Dutch and Belgian national television.
- Planktonic foraminiferal shell thinning due to anthropogenic CO_2 emissions? (NWO-ALW)
  G.J.A. Brummer, in cooperation with VU University Amsterdam.
- Ocean variability and impact of water column properties on proxy formation (GATEWAYS, EU-FP7 Marie Curie International Training Network).
  A. Henry-Edwards, J. Steinhardt, S. Kasper (BGC), G.J.A. Brummer, S. Schouten (BGC), H. van Aken (FYS), in cooperation with University of Barcelona (Spain) and University of Cape Town (South Africa).
- Natural, climatic and anthropogenic change of the Berau Delta/Barrier reef system: High-resolution coral proxy analysis of the modern environment and reconstruction on a seasonal to centennial timescale (WOTRO-KNAW-ICOMAR).
  R. Nagtegaal, G.J.A. Brummer, R. Bak (MEE), in cooperation with Utrecht University and KNMI.
- Temperature and salinity proxies of ocean thermohaline circulation and climate change: development and verification (NEBROC2, NWO/NIOZ).
  U. Fallet, G.J.A. Brummer, S. Schouten (BGC), in cooperation with AWI Bremerhaven and University Bremen (Germany).
- Relationships between primary productivity and the benthic environment in upwelling regions during the last deglaciation (Vetenskaps Radet Sweden).
  J.B.W. Stuut, in cooperation with Lund University (Sweden).
- Holocene desertification trends in NW Africa inferred from end-member modelling of grain-size distributions and provenance studies of terrigenous sediments (EUROPROX/DFG).
  J.B.W. Stuut, in cooperation with VU University Amsterdam and MARUM Bremen (Germany).
- A high-precision stable isotope mass spectrometer for marine tracer analysis (NWO-Middelgroot).
  S. Schouten (BGC), G.J.A. Brummer, et al. (MEE, BIO).
- Assessment of tropical environmental change and its teleconnections for the last deglaciation by means of high resolution biomarker analysis (NEBROC2, NWO/NIOZ).
  I.S. Castañeda (BGC), S. Schouten (BGC), G.J.A. Brummer, J.S. Sinninghe Damsté (BGC), in cooperation with the University Bremen (Germany).
- Mid-latitude carbonate systems - complete sequences from cold-water coral carbonate mounds in the NE Atlantic (CARBONATE, ESF/ALW).
  H. de Haas, T.C.E. van Weering.
- European Multidisciplinary Seafloor Observatory - Preparatory Phase (EMSO-PP, EU-FP6).
  J. Greinert, H.C. de Stigter, T.C.E. van Weering.
- European Seabed Observatories NETwork (ESONET, NoE EU-FP6).
  J. Greinert, T.C.E. van Weering.
- Hydroacoustic seafloor and water column mapping: New tools for multibeam backscatter analyses and 3D/4D visualization (NWO Valorization).
  J. Greinert, H. de Haas.
- Spatial methane and CO_2 flux quantification from a pockmark area in the Black Sea: SPUX. (ESF Eurofleets).
  J. Greinert, in cooperation with IFM-GEOMAR, Kiel (Germany), Ghent University, Ghent (Belgium), IOBAS, Varna (Bulgaria).
- Tropical temperature history during Paleogene global warming events (GLOW, ESF-Eurocores)
  Vrije Universiteit Amsterdam, with T.C.E. van Weering and G.J.A. Brummer as co-applicant.

- Hotspot Ecosystem Research and Man's Impact on European Seas (HERMIONE, EU- FP7).
  H.C. de Stigter, T.C.E. van Weering, M.S.S. Lavaleye (MEE), G.C.A. Duineveld (MEE).
- Tracing past to modern Indo-Atlantic exchange in sedimentary records (INATEX-B, NWO/ZKO-Oceans).
  G.J.A. Brummer, R. Tjallingii, H. Ridderinkhof (FYS), T.C.E. van Weering, in cooperation with VU University Amsterdam, Utrecht University, KNMI, University Kiel (Germany).
- MOdular Deep Ocean Observatory and its application in the Porcupine Abyssal Plain area (MODOO, EU-FP6).
  J. Greinert, H.C. de Stigter, B. Koster (MTE), J. Cluderay (MTE), L. Wuis (MTM).
- A process study on the impact of the Arabian Sea oxygen minimum zone on organic matter degradation, nutrient regeneration, trace metal cycling and foraminiferal proxies (PASOM, NWO-ALW).
  Utrecht University, J.S. Sinninghe Damsté (BGC) et al., G.J.A. Brummer (co-applicant).
- Permafrost and gas hydrate related methane release in the Arctic and impact on climate change: European cooperation for long-term monitoring (PERGAMON, ESF/COST).
  J. Greinert, A. Stadnitskaia (BGC).
- Southern Indian Ocean/Tropical Pacific teleconnections assessed by a joint coral-in situ ocean monitoring database (SINDOCOM, NWO-ALW/Climate Change).
  C. Grove, G.J.A Brummer, in cooperation with VU University Amsterdam and KNMI.
- Controls on sediment phosphorus release from temperate intertidal sediments (FCT, Portugal).
  C. Leote, H.G. Epping, in collaboration with Trinity College Dublin (Ireland).
- Consequences of phosphorus reduction for the dynamic transfer of organic matter between primary producers and primary consumers.
  L.L. Mulder, H.G. Epping, in cooperation with NIOO-CEME, IVM-VU University Amsterdam, Rijkswaterstaat, CWSS (Germany), Ecomare.
- Integrated network for production and loss assessment in the coastal environment (IN PLACE, NWO-ZKO).
  C.J.M. Philippart (MEE), H.G. Epping (co-applicant), in cooperation with NIOO-CEME, IVM-VU University Amsterdam, Rijkswaterstaat, CWSS (Germany), Ecomare.
- Construction of a remotely controlled vehicle for benthic research (MOVE!-I&II, NWO-Middelgroot/BMBF).
  H.G. Epping, J. Greinert, G.C.A. Duineveld (MEE), in cooperation with MARUM Bremen (Germany).

Marine Organic Biogeochemistry



The BGC department addresses a field of research at the interface of the basic disciplines of chemistry, geology and biology. The basic questions are:

- Which organic compounds are present in the different compartments (biota, water, sediments) of the marine environment and what is their origin?
- What is their biochemical role in marine organisms?
- Which reactions (e.g. biotransformation and diagenesis) affect these components during transport in the marine environment? How are these reactions affected by environmental conditions and on which time scales? What can these components tell us on the biogeochemical cycling of carbon, nitrogen and sulfur in the ocean?
- What can be learned from organic matter deposited in marine sediments with respect to marine evolution, the functioning of past marine ecosystems, climate variability and organic carbon burial?

In 2010, members of BGC actively pursued fieldwork: the water column and sediments of the North Sea were sampled to study archaeal nitrification and anaerobic ammonium oxidation in the ZKO project NICYCLE. The Amazon, Yenisei, and Rhone rivers were visited to study the transport of soil organic matter to the ocean in the ERC PACEMAKER project. The NWO-VIDI project of Marcel van der Meer that aims to reconstruct the salinity of the ocean in the past started this year with the hiring of personnel. Three new projects were funded within the Darwin Centre for Biogeology where BGC collaborates with (micro)biologists at the Dutch universities and the sister institute of the NIOZ, the Netherlands Institute for Ecology (NIOO). At the same time, two graduate students obtained their PhD degree at Utrecht University: Thorsten Bauersachs graduated on his work on the development and application of proxies for past cyanobacterial nitrogen fixation and Arjan Boere on his work on validation and application of fossil DNA as a recorder of past marine ecosystems and environmental conditions. Stefan Schouten was appointed as part-time professor (0.2 fte) at Utrecht University, Department of Geosciences. The department also organized a well attended NEBROC course 'Molecular Organic Biogeochemistry' for young researchers from all over the globe. A major scientific achievement in 2010 was the publication of two Science papers, two papers in PNAS, and one in Nature Geosciences. Three of these papers were about the reconstruction of past climate change, on a variety of time scales, the other deal with microbial processes.

A more detailed account of the results of some of the projects that ended in 2010 is given on the following pages.

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Structure and distribution of membrane lipids of Thaumarchaeota

Angela Pitcher, Stefan Schouten, Jaap Sinninghe Damsté*

The study of marine microorganisms mainly relies on the use of gene-based techniques but specific membrane lipids are increasingly used to complement the genetic data. In this study we developed new methods to analyse core and intact polar lipids and applied these to environmental studies and enrichment cultures of Thaumarchaeota, archaea capable of autotrophic ammonia oxidation. The enrichment cultures contained tetraether membrane lipids with crenarchaeol, a specific lipid containing a unique cyclohexane moiety, as the most abundant lipid suggesting that this is a unique tracer for Thaumarchaeota. The main head groups attached to these lipids are those with a hexose, dihexose and phosphohexose group. Crenarchaeol present as an intact polar lipid was found to be quite suitable to track living Thaumarchaeota in natural environments.

Archaea are ubiquitous, comprising a major component of the microbial assemblages in many modern-day systems. Several studies have analysed glycerol dialkyl glycerol tetraether (GDGT) membrane lipids (Fig. 1 for examples) synthesized by archaea to interpret the presence, distribution, and activity of these microbes in various modern environments. In particular, crenarchaeol, a GDGT containing a unique cyclohexane moiety, is used as a specific biomarker lipid for marine Thaumarchaeota. The use of cellular membrane lipids in molecular ecology studies provides added value to conventional (meta)genomic approaches, partly in the form of independence from biases associated with the extraction and analysis of nucleic acids. However, disentangling biomarker lipid signals derived from living and dead cells, has remained a challenge.

In this study we developed the use of intact polar lipids (IPLs) as a tool for ecological studies of ammonia-oxidizing Thaumarchaeota, important actors in the marine nitrogen cycle. Archaeal IPLs contain polar head groups bound to the core GDGT (Fig. 2 for examples) and are assumed to represent living archaeal cells as the head group is rapidly lost upon cell death. To this end, improved methods for GDGT-based IPL analyses were developed and tested on several environments: two California hot springs, the Arabian Sea oxygen minimum zone (OMZ), and the coastal North Sea. Comparisons between IPL and DNA-based molecular data reveal a more complete picture of the distribution and abundance of ammonia-oxidizing Thaumarchaeota at those sites, in addition to the general robustness of IPL analyses in modern molecular studies.

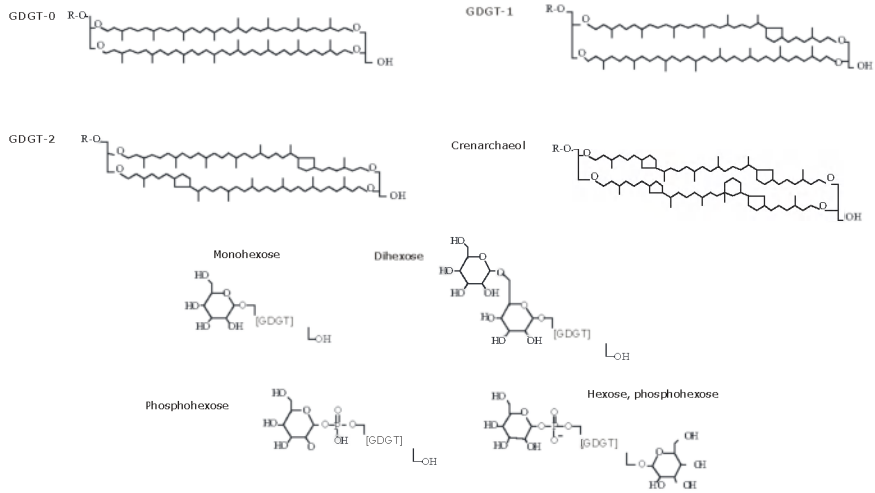

Fig. 1. Structures of tetraether lipids in Thaumarchaeota.

When IPL-GDGTs are analysed (and quantified) after removal of the polar head group by hydrolysis, the separation of core and IPL GDGTs is first necessary, in order to discern between dead and live

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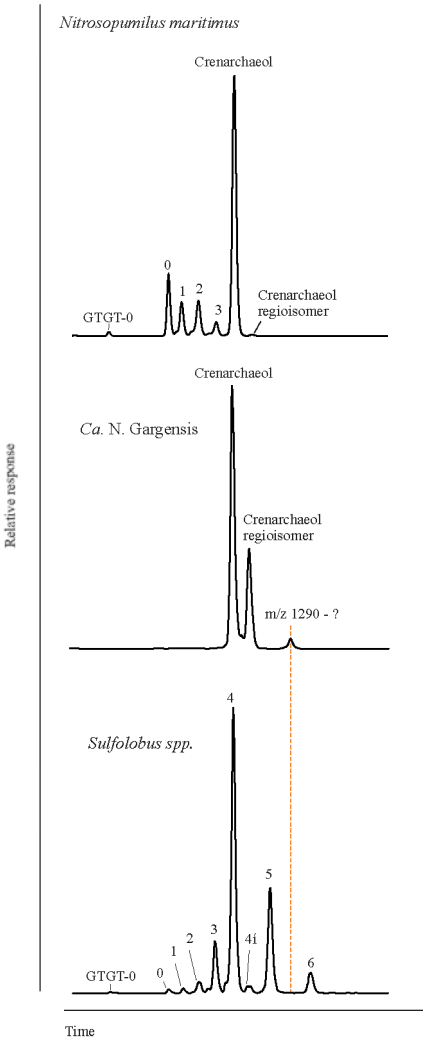

Fig. 2. High-performance liquid chromatography base peak chromatograms showing glycerol dialkyl glycerol tetraethers (GDGTs) derived from acid-hydrolyzed biomass of (a) the ammonia-oxidizing Group I.1a Thaumarchaeote *Nitrosopumilus maritiums SCM1*, (b) the ammonia-oxidizing Group I.1b Thaumarchaeote '*Ca*. Nitrososphaera gargensis', and (c) the sulfur-oxidizing hyperthermophilic Crenarchaeote *Sulfolobus solfataricarus*.

GDGT signals. Conventional separation schemes based on the separation of bacterial glyco- and phospholipids were found unsuitable for the separation of GDGT-based IPLs. A new method based on activated silica and different eluents was developed and shown to yield fractions highly enriched in core, glyco-, and phospho-GDGTs. The ability to separate core and IPL-GDGTs was used to determine of the origin of GDGTs in California hot springs, the Arabian Sea oxygen minimum zone, and the coastal North Sea. Recovery of abundant crenarchaeol in the IPL-GDGT fractions confirmed that it is synthesized *in situ*. In addition, in these environments a good correspondence between amoA gene, the functional gene encoding for the enzyme that performs the first step in ammonia-oxidation, and IPL-derived crenarchaeol abundances was found, suggesting that the IPLs recovered were recently synthesized by living ammonia-oxidizing Thaumarchaeota.

The characterization of ammonia-oxidizing Thaumarchaeota has been hampered by difficulties in their enrichment, and therefore limited data exists on the IPL-GDGTs synthesized by these microbes in culture. Analysis of the recently enriched ammonia-oxidizing Group I.1b Thaumarchaeote, '*Ca*. Nitrososphaera gargensis', revealed a GDGT distribution consisting almost exclusively of crenarchaeol and a structurally related isomer (Fig. 2). This finding extends the taxonomic distribution of crenarchaeol to a new phylogenetic cluster, group I.1b, within the Thaumarchaeota (Fig. 3). The GDGT-associated polar headgroups consisted mainly of monohexose, dihexose, phosphohexose and hexose-phosphohexose moieties. Similar IPLs were found in the Arabian Sea and the coastal North Sea where Thaumarchaeota are also abundant. Together, these data contribute substantially to the current knowledge of IPLs synthesized by these archaea and support the hypothesis that crenarchaeol is specific to ammonia-oxidizers. TEX_{86} temperatures, a geochemical proxy used to reconstruct past sea surface temperatures, calculated using the GDGT distribution of '*Ca*. Nitrososphaera gargensis' matched cultivation temperature of 46°C, however they did not change according to short term cultivation at 42°C and 50°C indicating that individual species may not adjust their membrane GDGTs dramatically according to temperature or that this physiological adaptation would take much longer.

To conclude, the present study demonstrates that intact polar GDGTs, in particular crenarchaeol, are excellent tools to study the ecology of Thaumarchaeota in modern environments. Using these tools, an improved understanding of the role of AOA in both carbon and nitrogen cycling may be obtained. Understanding better the environmental distributions of GDGTs, including crenarchaeol, will also aid in a better understanding of their use in geochemical proxies like the TEX_{86} paleothermometer.

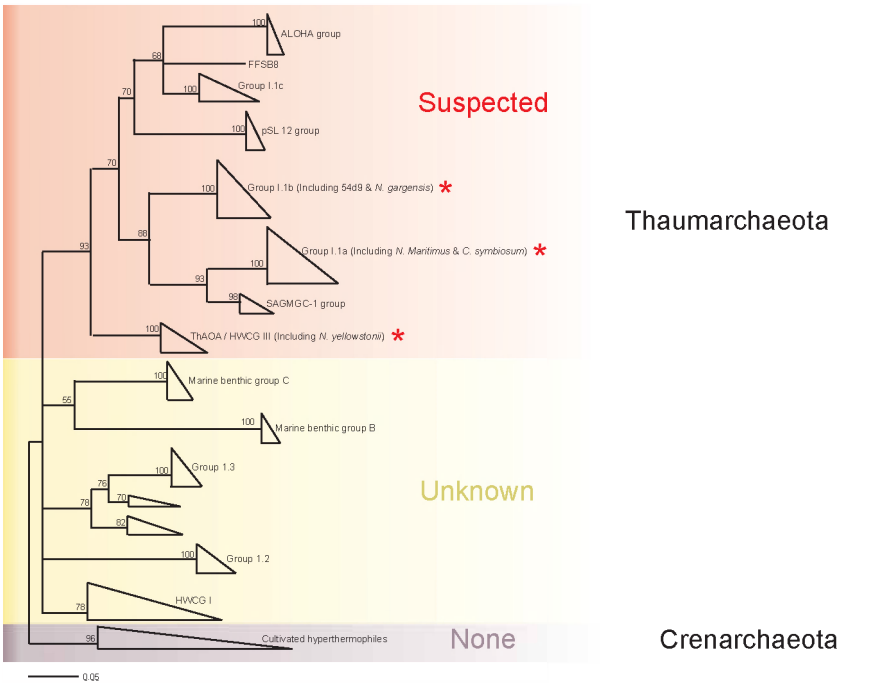

Fig. 3. 16S rRNA gene-based phylogeny of the Thaumarchaeota and Crenarchaeota highlighting confirmed (indicated with *) and suspected crenarchaeol synthesizers within the Thaumarchaeota based on the potential widespread distribution of archaeal ammonia-oxidization within this monophyletic clade and its hypothesized link to crenarchaeol synthesis.

Proboscia diatoms reveal past Antarctic oceanographic and atmospheric conditions

*Veronica Willmott, Sebastiaan Rampen, Jaap Sinninghe Damsté, Stefan Schouten**

In this study we used specific lipid biomarkers to assess the productivity of *Proboscia* diatoms in shelf waters of the western Antarctic Peninsula over the last 8500 yr. This revealed that *Proboscia* diatoms were relatively more abundant during the Late Holocene. Since the presence of *Proboscia* diatoms in coastal ecosystems has been related to upwelling conditions, it suggests that stronger upwelling of circumpolar waters occurred at that time. Since this is ultimately controlled by the interaction between El Niño Southern Oscillation (ENSO) and the Southern Annual Mode (SAM), the relative abundance of *Proboscia* diatoms could be useful to track the past effect of those climate modes on the Antarctic Peninsula.

The Western Antarctic Peninsula (WAP) has suffered the largest warming trend in the world over the last 20 years with an increase in atmospheric temperature of 1.08 °C. The WAP is therefore considered as one of the area's most sensitive to climatic change, and its marine bottom sediments are considered important archives for the investigation of past climatic variability.

Diatoms of the genus *Proboscia* are widely present in the global ocean and they are relatively abundant in Antarctic waters. The presence of *Proboscia* diatoms in other coastal ecosystems has been related to upwelling and these diatoms seem to be well adapted to the high nutrient, turbulent conditions that are typical of these coastal regions. Unfortunately, sedimentary records of *Proboscia* diatoms are constrained by the fact that they have weakly silicified frustules and that their skeletons are very prone to dissolution. An alternative approach is to use specific lipid biomarkers, so-called long chain 1,14 diols, which are synthesized by *Proboscia* diatoms and which are well preserved in sediments.

Fig. 1. Research vessel Nathanial B. Palmer with which sediment cores were taken at the coast of the Antarctic Peninsula.

In this study we investigated these *Proboscia* diols as a proxy for *Proboscia* diatom productivity during the Holocene in shelf waters of the WAP. We analysed these compounds in a sediment core, taken with the RV Nathanial B. Palmer (Fig. 1) from the Western Bransfield Basin (WBB) in the Pacific margin of the AP (Fig. 2). Its specific location together with its high sedimentation rate makes this area very suitable for obtaining Holocene paleoclimate records.

The total organic carbon (TOC) record suggests that the high productivity conditions that marked the mid Holocene period must have initiated at least at 8800 yr before present (BP) and persisted until 4600 yr BP in the northern WBB (Fig. 3). Remarkably, however, this period is also characterized by relatively low abundances of long chain 1,14-diols suggesting that *Proboscia* diatom productivity was lower than at present day. This apparent discrepancy might be explained by the fact that *Proboscia* diatom blooms

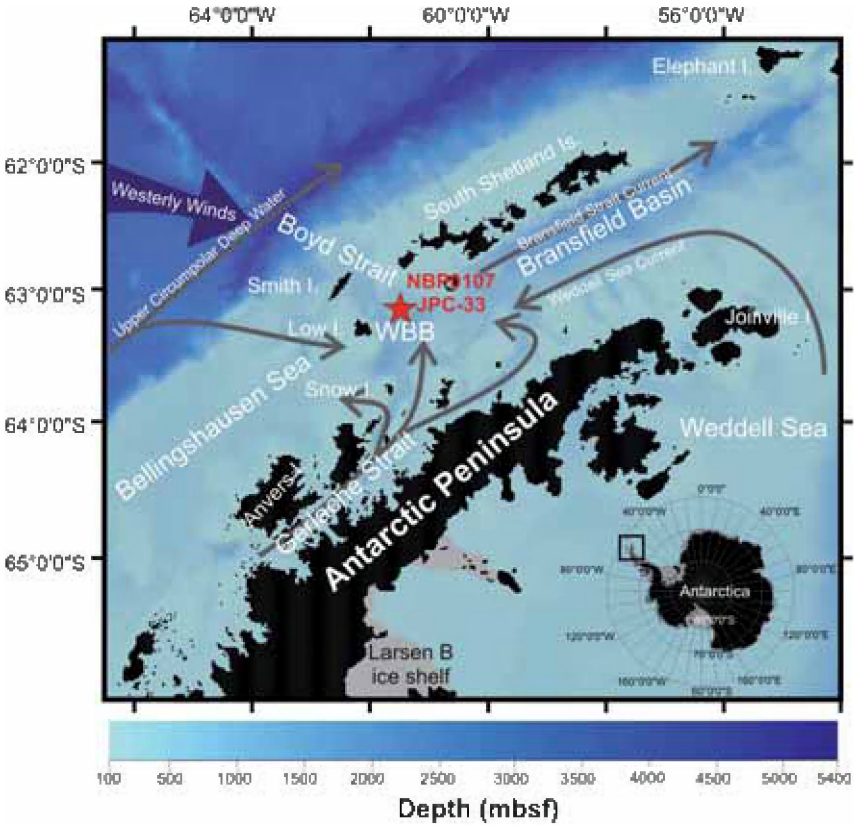

Fig. 2. Location map of jumbo piston core NBP0107 JPC-33 in the Western Bransfield Basin (WBB), northern Antarctic Peninsula. Grey arrows indicate oceanic currents.

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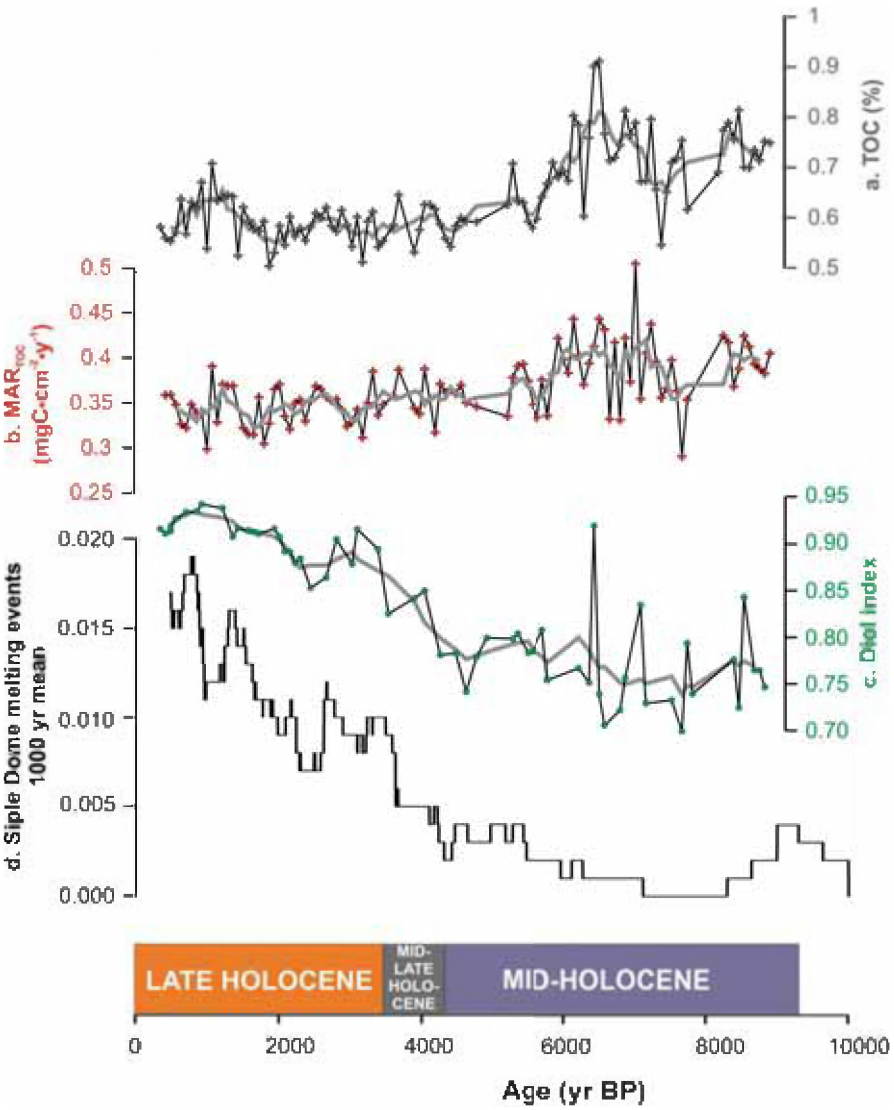

Fig. 3. Antarctic climate records of a. Total organic carbon (TOC) content of JPC-33 core, and b. Mass accumulation rates of TOC (MARTOC) reflecting general productivity. c. Relative abundance of long-chain 1,14-diols in JPC-33 core reflecting *Proboscia* diatom productivity. d. Melt frequency observed in the ice core at Siple Dome. Dark grey lines in a, b, and c represent running average with a 10% smoothing window.

seem to be enhanced by upwelling conditions, whereas general primary productivity benefits from water stratification induced by ice melting in springtime. Thus, the mid Holocene shelf waters in this area may have been dominated by strong and shallow water stratification in spring and summer and/or little Circumpolar water intrusions.

In contrast, the late Holocene period is marked by a relative rise in *Proboscia* diatom productivity which probably reflects periods of enhanced Circumpolar water intrusions in this area. On the WAP, other studies showed evidence of present and past intrusions of the Circumpolar water on the continental shelf. In addition, the periods of increased *Proboscia* diatoms productivity are coincident with increased frequency of melt layers observed in an ice core (Siple Dome) from the southern end of the WAP. This increase in melt frequency is primarily interpreted as changes in mean summer temperature linked to an increasing marine influence and atmospheric cyclonic activity on West Antarctica which would be consistent with a parallel increase in upwelling intensity along the WAP.

The circumpolar current episodic spills onto the shelf are ultimately controlled by atmospheric forcing, governed by the interaction between ENSO and SAM. Thus, the *Proboscia* diol record could be useful to track the past effect of those climate modes on the WBB, although future studies on the ecology of *Proboscia* species in this area are needed to further validate the suitability of this proxy.

Influence of sea surface temperature on vegetation in central North Africa

*Isla S. Castañeda, Jaap Sinninghe Damsté, Stefan Schouten**

Sea surface temperatures (SSTs) play an important role in influencing continental climate conditions. Precipitation in the region of North Africa is particularly sensitive to SST variability. From a site on the Guinea Plateau Margin (NW Africa), we simultaneously reconstructed SST from organic geochemical proxies and also examined continental climate conditions from organic matter produced by land plants, which is transported offshore by strong winds. Our results provide important insights into past environmental conditions in North Africa, which may have influenced migrations of our human ancestors from the African continent.

Strong off-shore winds transport large volumes of dust from the Sahara and Sahel to the Guinea Plateau Margin (Fig. 1). This dust contains plant leaf waxes, which are blown long distances across the African continent to the Atlantic Ocean, where they are ultimately deposited on the seafloor. Based on isotopic analysis of fossil plant leaf waxes (Fig. 2) we determined the relative importance of trees and grasses in the Sahara and Sahel. Trees generally require more water to survive than tropical grasses. By analyzing the carbon isotopic composition ($\delta^{13}C$) of plant leaf waxes an origin from trees or grasses can be determined, as grasses tend to be more enriched in ^{13}C compared to trees, thus allowing for past precipitation changes in tropical Africa to be examined. Throughout the majority of the record $\delta^{13}C$ values indicate that tropical grasses were even more widespread than today, suggesting severely arid conditions in central North Africa during much of the past 200,000 years (Fig. 3). However, we found that during three discrete periods, ca. 120,000-110,000 years, 50,000- 45,000 and 10,000-8,000 years ago, substantially more trees grew in Sahara and the Sahel, indicating significantly wetter conditions than at present (Fig. 3). The most recent of these wet periods, called the 'African Humid Period' is widely documented throughout North Africa and during this interval the Sahara desert contained trees, permanent lakes and was occupied by human populations. The two older wet periods coincide with times when early modern humans were migrating out of sub-Saharan Africa to Northern Africa, the Middle East, Asia and eventually Europe. At these times, wetter conditions in central North Africa likely enabled humans to cross this normally inhospitable region and migrate onto other continents.

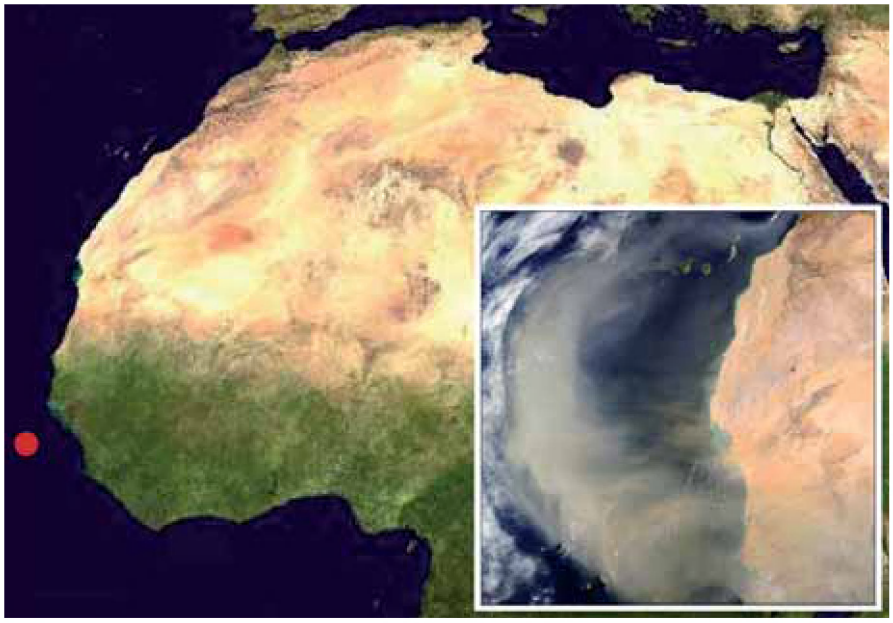

Fig. 1. Location of the studied sediment core from the Guinea Plateau Margin (NW) Africa. The insert shows a plume of Saharan dust offshore NW Africa. (Image from NASA, http://www.nasa.gov/multimedia/imagegallery/image_feature_22.html: March 2, 2003.)

Fig. 2. Compounds including the long-chain *n*-alkanes and *n*-alkanoic acids form a main component of plant leaf waxes. These compounds form a waxy protective coating that reduces moisture loss and decay.

In addition to examining the vegetation history, we also reconstructed past SST using the so-called $U^{k'}_{37}$ Index and the strength of the Atlantic Meridional Overturning Circulation (AMOC; Fig. 4) by analyzing the carbon isotopic composition ($\delta^{13}C$) of the benthic foraminifer *Cibicides wuellerstorfi*. The $U^{k'}_{37}$ Index is based on long-chain alkenones produced by haptophyte algae, which produce relatively lower amounts of the tri-unsaturated alkenone ($C_{37:3}$) at warmer temperatures. Previous research demonstrated the $\delta^{13}C$ of *C. wuellerstorfi* reproduces the $\delta^{13}C$ of dissolved carbon dioxide in the deep ocean, which is strongly dependent on ocean circulation. In the deep Atlantic, $\delta^{13}C$ variations are

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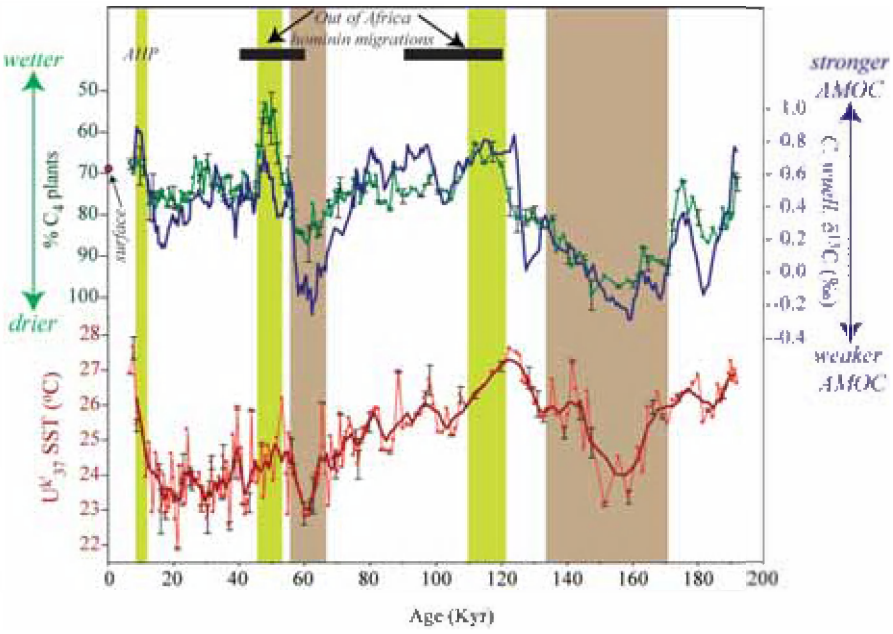

Fig. 3. Vegetation and Atlantic Meridional Overturning Circulation changes during the past 200,000 years. The $\delta^{13}C$ of *C. wuellerstorfi* (in blue) reflects variations in the strength of AMOC while the reconstructed percentage of C_4 grasses (in green) is an indicator of aridity since C_4 grasses are drought adapted and require less water than C_3 trees. The red dot labeled 'surface' represents a surface sediment sample and indicates modern conditions. Sea surface temperatures, reconstructed using the $U^{k'}_{37}$ Index, are shown in red. The 'African Humid Period' is indicated by 'AHP', and the black bars indicate the timing of the two 'Out of Africa' hominin migrations. Arid intervals, characterized by increased inputs of C_4 grasses (decreased C_3 trees), relatively cooler SSTs and stronger AMOC, are indicated by the brown shading. Wet intervals are indicated by the green shading.

largely controlled by the relative flux of North Atlantic Deep Water (high $\delta^{13}C$) and Southern Ocean Water (low $\delta^{13}C$). When higher $\delta^{13}C$ values of *C. wuellerstorfi* indicate stronger AMOC, $U^{k'}_{37}$ indicates relatively high SSTs while $\delta^{13}C$ values of leaf waxes are depleted, attesting to higher inputs from trees and wetter conditions in central North Africa. Conversely, when AMOC weakened, cooler SSTs are noted and more grasses were present in central North Africa, indicating drier conditions. Relationships between AMOC strength and vegetation in North Africa have been previously suggested by climate modelling studies and the mechanism is widely accepted: increased freshwater input to the high-latitudes leads to less saline surface waters and a decrease in the strength of North Atlantic Deep Water formation. This causes sea surface cooling throughout the North Atlantic region, which also cools the atmosphere. This leads to movement of cold air from the high-latitudes to the tropics, causing the trade winds to strengthen and the rainbelt to be displaced to the south over the African continent, thereby producing drier conditions in the Sahara and Sahel. Thus, early human migrations from the African continent were likely triggered by events originating far away in the high-latitudes of the North Atlantic. Understanding the relationships between vegetation, precipitation and AMOC are critical since some climate models predict a slowdown of AMOC with increased future atmospheric carbon dioxide concentrations.

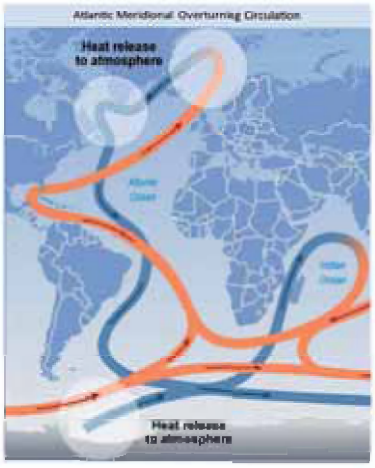

Fig. 4: Atlantic Meridional Overturning Circulation (AMOC). The atmosphere heats the oceans at the low latitudes and surface currents move these warm waters to the north. At the high latitudes, surface waters cool releasing heat to the atmosphere (white shaded areas). Eventually this water cools to the point that it becomes denser and sinks, returning as a deep southerly flowing current. AMOC is important for distributing heat around the globe and variations in the strength of this process impact global climate.

External Projects Marine Organic Biogeochemistry

- The nitrogen cycle and changes in the carrying capacity of coastal waters (NICYCLE, Part 1, ZKO).
  N. Bale, J.S. Sinninghe Damsté, in cooperation with NIOO - CEME.
- Role of cyanobacteria in present and past biogeochemical cycling (DARWIN).
  T. Bauersachs, J.S. Sinninghe Damsté, in cooperation with NIOO - CEME.
- Fossil DNA as recorder of global change and ancient biodiversity in Quaternary marine settings (NWO - ALW, SPINOZA).
  A. Boere, M. Coolen, J.S. Sinninghe Damsté.
- Passive sampler development for measuring dissolved organics.
  K. Booij, in cooperation with the US Geological Survey, the University of Queensland (Australia).
- The nitrogen cycle: foraminifera, bacteria and molecular paleontology of the marine deeper redox zone (NWO - ALW).
  J. Brandsma, J.S. Sinninghe Damsté, in cooperation with the Radboud University Nijmegen, Utrecht University.
- Application of the MBT and TEX86 temperature proxies in lakes (ERC, PACEMAKER-2).
  L. Buckles (UU), G.J. Reichart (UU), J.S. Sinninghe Damsté.
- Assessment of tropical environmental change and its teleconnections for the last deglaciation by means of high resolution biomarker analysis (NEBROC).
  I.S. Castañeda, S. Schouten, G.J. Brummer (GEO), in cooperation with the University of Bremen (Germany).
- Testing a new terrestrial palaeothermometer: Tracing the transport of terrestrial soil membrane lipids through a major river system (Yenisei, Russia) to the Arctic Ocean (NWO - ALW).
  C. de Jonge, A. Stadnitskaia, J.S. Sinninghe Damsté.
- International Census on Marine Microbes / Census of Marine Life.
  J.W. de Leeuw, S. Schouten.
- Intact polar lipids (IPLs) derived from microbial communities in extreme environments (DARWIN).
  R. Gibson, J.S. Sinninghe Damsté.
- Bacterial anaerobic methane oxidation in high temperature environments (DARWIN).
  R. Gibson, J.S. Sinninghe Damsté, in cooperation with Wageningen University.
- Development, validation and application of compound specific hydrogen isotope analysis as a tool for reconstructing Agulhas Current paleo sea surface salinity variability (EU Marie Curie Initial Training Network GATEWAYS).
  S. Kasper, M.T.J. van der Meer, S. Schouten.
- SOURCE - Tracing Amazon soil organic carbon input from land to the ocean (EU).
  J-H. Kim, J.S. Sinninghe Damsté.
- Quaternary evolution of continental climate as revealed by the MBT/CBT proxies (ERC, PACEMAKER-3).
  J-H. Kim, J. Blokker, J.S. Sinninghe Damsté.
- Impact of benthic processes on biogeochemical organic carbon cycling and organic proxy records in marine sediments (DARWIN).
  S. Lengger, S. Schouten, J.S. Sinninghe Damsté.
- Continental climate signals from marine sediments: validation of organic proxies based on membrane lipids of soil bacteria (DARWIN).
  F. Peterse, J.S. Sinninghe Damsté, in cooperation with the Wageningen University.
- Ecology and lipid chemistry of marine Crenarchaeota in present and past marine environments (DARWIN).
  A. Pitcher, J.S. Sinninghe Damsté, in cooperation with the NIOO - CEME, the Radboud University Nijmegen.
- Identification of sweet spots in gas shales.
  S. Rampen, J.S. Sinninghe Damsté, in cooperation with Shell Research.
- Ladderane and other lipids of anammox bacteria as tracers for present-day and past oceanic nitrogen cycling (DARWIN).
  D. Rush, J.S. Sinninghe Damsté, in cooperation with the Radboud University Nijmegen.
- The impact of CO2 concentrations and pH on marine microbial membrane lipids (DARWIN).
  P. Schoon, S. Schouten, J.S. Sinninghe Damsté in cooperation with NIOZ-BIO and NIOO-CEME.
- Past Continental Climate Change: Temperatures from marine and lacustrine archives (ERC, PACEMAKER).
  J.S. Sinninghe Damsté.
- From hothouse to icehouse: Evolution of Mesozoic and Cenozoic continental climate (ERC, PACEMAKER-4).
  J.S. Sinninghe Damsté.

- Lipids as indicators of N-cycling in sub-oxic zones of present and past oceans (DARWIN).
  J.S. Sinninghe Damsté, in cooperation with the Radboud University Nijmegen.
- Rapid global change during the Cenomanian/Turonian oceanic anoxic event in the tropical ocean: Examination of a natural climatic experiment in Earth history (UU).
  J.S. Sinninghe Damsté, in cooperation with the Utrecht University.
- Geobiology of deep-sea cold seep carbonates: biogeochemical interactions and feedback (NWO - Vernieuwingsimpuls, Veni grant).
  A. Stadnitskaia.
- Waddensleutels (Waddenfonds).
  J.S. Sinninghe Damsté, S. Schouten, in cooperation with MEE, Groningen University and Utrecht University.
- Developing new methods to estimate paleosalinity; understanding the past as key to future climate change (NWO Innovational Research Incentives Scheme VIDI).
  M.T.J. van der Meer.
- How salty was the sea? A crucial question to predict future climate change (NWO - ALW).
  M.T.J. van der Meer, J.S. Sinninghe Damsté (PI).
- From hothouse to icehouse: Evolution of Mesozoic and Cenozoic sea water temperatures (NWO - Vernieuwingsimpuls, Vici grant).
  V. Wilmott, R. Lopes dos Santos, J. Ossebaar, S. Schouten.
- Tracing the transport of soil organic matter to the ocean by rivers (ERC, PACEMAKER-1).
  C.I. Zell, J-H. Kim, J. Blokker, J.S. Sinninghe Damsté (PI).

Biological Oceanography

Within the department of Biological Oceanography (BIO) the main research is focussed on the study of biological and chemical processes and their interactions within the lower food-web. The department is strong in sea-going research, usually with an interdisciplinary character (including physics and geology). Although there is a focus on the pelagic food-web also complex interactions of various components of coral reefs are part of the research in the department.

As part of the GEOTRACES (NWO-ZKO, sea and coastal research) project a large cruise in the North Atlantic covered almost the entire oceanic basin. During this cruise the new CTD frame and newly designed water sampling bottles were successfully deployed and the analyses of trace metals were of a high quality. A detailed description of this highly multidisciplinary project is presented on p ..-.. in this report. It should be noted that the second large cruise in the North Atlantic Ocean as part of the STRATYPHYT (NWO-ZKO, sea and coastal research) program was cancelled because of a delay in the mid-term overhaul of the RV Pelagia. This cruise is now scheduled for spring 2011.

The EU project FORCE (7^{th} Framework Programme), Future Of Reefs in a Changing Environment, was launched with a kick-off meeting in Barbados, Caribbean. Benjamin Mueller (new appointed PhD student) started his research on the production of dissolved organic carbon (DOC) by benthic algae and corals and on the role of DOC in the growth and bioerosion by excavating sponges on tropical coral reefs. In the fieldwork period from May to August and from November onwards, ambient DOC concentrations were measured along the coast of Curaçao assessing the sources of DOC on coral reefs. A first series of incubation experiments was completed measuring DOC release from algae and corals under different ambient light levels. The most common excavating sponges in the reefs of Curaçao were identified in transects. Focussing on these species, DOC consumption will be determined in relation to growth and bioerosion during the next field trip in 2011.

In August Fleur van Duyl started the $SPOCO_2$ project on an ASSEMBLE grant of the EU 7^{th} FP. She made a fieldtrip to the Tisler coldwater coral reef in the vicinity of Tjärnö, just over the Swedish border in Norway where coldwater sponges were collected with a remotely operated vehicle at 90-100 m depth. On the collected material, experiments were conducted with labelled with ^{13}C-DIC (bicarbonate) to quantify the carbon transfer between sponge associated chemolithoautotrophic nitrifying prokaryotes (bacteria and archaea) and their host. These experiments were carried out at the Sven Lovén Centre for Marine Sciences, Tjärnö (S). Muriel de Boer started as Postdoc on multi-scale modelling of calcification in scleractinian corals in collaboration with the research group in computational biology of Amsterdam University. She will analyse transcriptome data of *Acropora millepora* samples that were collected in the Pacific Ocean off Townsville (Australia).

For the VIRANT (a NWO's Nederlands AntArctisch Programma, NAAP) project various scientists from the department of Biological Oceanography are collaborating with Dr D W Pond and Prof. A Clarke of the British Antarctic Survey (BAS). The project aims to study the impact of viruses on the microbial component of the coastal waters around the Antarctic Peninsula and its ecological implications. The study includes *in situ* and laboratory based experiments to determine the significance of viral lysis to the biological cycling of important nutrients. The NIOZ project joined in with BAS s long term monitoring program, the Rothera Oceanographic and Biological Time Series (RaTS; station is situated on Adelaide Island), which centers on making high frequency biological and chemical measurements at a small embay-

ment called Ryder Bay. Sampling commenced in November 2010 and will continue until late March 2011, thus observing the full spring through to autumn. Comprehensive sampling program of the bacterioplankton and phytoplankton is in progress to examine abundance, growth and mortality by both viral lysis and grazing. The dynamics of fatty acids and intact polar lipids will be examined in combination with data.

More close at home, in the NIOZ harbour research on the efficiency of various technologies to eliminate the organisms from ballast water using chlorine or UV-radiation as a disinfection tool continued with success. By modulating the flow rate it was possible to determine the minimal effective UV-dosage. For a second experiment an improved neutralization protocol was developed for chlorine based ballast water treatment systems involving a significant reduction of the amount of neutralization agent.

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Dissolved Aluminium and Manganese in the Polar Oceans: Small concentrations, big insights

*Rob Middag**

The concentration of dissolved trace metals in the world's oceans can tell a lot about biological and chemical cycles in the oceans. Using the new ultra clean 'TITAN' sampling system of the NIOZ the concentrations of dissolved manganese (Mn) and aluminium (Al) were studied in both polar oceans within the framework of the International Polar Year (IPY). The concentrations of Mn in the Southern Ocean were found to be so low that they could potentially limit the growth of phytoplankton, affecting the polar food web.

In the ocean, phytoplankton, unicellular organisms that convert carbon dioxide and water to sugar and oxygen using sunlight as the energy source, forms the base of the pelagic food web. Besides carbon dioxide, phytoplankton like plants on land, also need other nutrients to build their cells, mainly nitrogen and phosphorous, but also some metals. These metals are generally a part of the enzymes and required for the biochemical reactions these enzymes perform. The goal of GEOTRACES is to identify and better understand the global biogeochemical cycles of important metals (and their isotopes), also in relation to the global biological cycles and ocean currents. The Dutch branch of the IPY-GEOTRACES program was conducted with the support of NWO and the ocean expeditions were done in close collaboration with colleagues from the Alfred Wegener Institut für Polar- und Meeresforschung (AWI) in Bremerhaven with the German icebreaker Polarstern as the research vessel.

Manganese appears to have an influence on algal growth in the Southern Ocean.

Manganese (Mn) is an important part of an enzyme that is required for photosynthesis. The biological uptake of Mn had never been observed directly in the open ocean. Due to the improved precision of both the analyses of Mn as well as the analyses of phosphorous and nitrogen, NIOZ was able to report the first direct observations of Mn depletion in concert with depletions of phosphorous and nitrogen. This depletion of Mn in a constant proportion to the depletion of phosphorous and nitrogen was apparent in the Southern Ocean due to the absence of external Mn sources that could mask biological uptake. The biochemical concept of universal proportions of the elements carbon (C), nitrogen (N) and phosphorous (P) in phytoplankton of C:N:P=106:15:1 (Redfield ratio) can now be extended with a factor 0.0004 for Mn. This result could not have been accomplished in the Arctic Ocean where the Mn depletion by phytoplankton was more than compensated by external Mn supply from the big Arctic rivers.

The concentrations of Mn in the Southern Ocean were found to be so low that they could potentially limit the growth of phytoplankton. Thus far it was assumed that growth of phytoplankton in the Southern Ocean was limited by lack of iron and sunlight, but now Mn must be taken into account as well. This finding has implications for the perceived effectiveness of artificial iron fertilisation by mankind as a geo-engineering strategy, as not only iron but also Mn will have to be added to stimulate algal growth. However, shortly after iron and Mn addition in the remote Southern Ocean, most likely another metal or light will become the limiting factor, leaving the projected effectiveness of such an artificial fertilisation effort questionable.

In both Polar oceans the hydrothermal vents at the mid ocean ridges, where the earth plates move apart, where clearly distinguishable as sources of Mn to the

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deep Ocean. The elevated concentrations of Mn were observed over great distances from the source and appear to be more important than hitherto realised.

Aluminium useful for organisms after all?

Contrary to Mn, for aluminium there is no known biological function in biochemical processes in living cells. Indirect evidence was found however, that Al is incorporated in the siliceous frustules of diatoms (class of phytoplankton that build a protective siliceous shell around them) to strengthen these frustules. Linear relations between the concentrations of dissolved (unincorporated) Al and dissolved silica were observed in the Atlantic and Arctic Ocean. However, no significant relation between dissolved Al en dissolved silica could be observed in the Southern Ocean, due to the very low concentrations of dissolved Al and the very high background concentrations of dissolved silicate.
In both the Arctic and Southern Ocean elevated concentrations of Al were observed in the deep ocean basins. It is known that in these areas surface sea water, due to sea ice formation and cooling in the winter, sinks along the continental shelve to the deep ocean. This process appears to contribute to the input of dissolved Al in the deep ocean and thereby to the global cycle of Al.

Improved quantification of Southern Ocean phytoplankton as indicators for carbon fixation using remote sensing (KERGUELEN, SRON project EO-078)

Hans van der Woerd[1], *Klaas Timmermans**, *Louis Peperzak*

Remote sensing of the ocean surface by earth-orbiting satellites is widely used to quantify global ocean phytoplankton biomass. The method is based on measurements of the amount of blue light from the sun that the phytoplankton absorbs, as well as the intensity of the red light that the phytoplankton emits. Simply stated: more phytoplankton means less blue and more red light. A great advantage of satellites is that they daily cover and measure the whole surface of the world oceans. It is impossible to gather the same amount of data with ships. However, how well do these satellites measure phytoplankton biomass and how accurately can they measure primary production? Answers to these questions were found in the KERGUELEN project, based on laboratory experiments at NIOZ and field experiments near the Kerguelen, an archipelago in the Southern Ocean.

The field work.

During a large campaign in the international KEOPS project (KErguelen: compared study of Ocean and Plateau in Surface water, 2005), we measured the biochemical and fluorescent properties of the surface ocean. The data were used for interpretation of images from ocean color satellites like MODIS and MERIS. In particular it was investigated in what way the fluorescence emission of light can be used to characterize the biological state of the indigenous phytoplankton community near the Kerguelen. Distinct differences were found in photosynthetic efficiency and water-leaving fluorescence, with relatively high values for the Kerguelen Plateau and low values in the open ocean, reflecting the differences in chlorophyll-a concentrations. The co-variance of the fluorescence properties suggested that remote sensed fluorescence measurements can be used to infer differences in the physiological state of the phytoplankton, hence primary production.

The laboratory work.

For a more extensive understanding of the KEOPS field measurements, two mesocosms were constructed in the NIOZ MTEC department, in which the optical signature of single species phytoplankton growth was studied in detail and correlated with environmental growth factors. The mesocosms consisted of 130 liter cylindrical containers that received light at the surface from 'daylight' lamps. Light intensity was varied over the day to simulate the natural day-night cycle. Water and phytoplankton in the mesocosm were constantly mixed and temperature was controlled. In the bottom of the mesocosm an irradiance sensor constantly monitored light extinction in the water column. Aimed at the water surface two radiance sensors, comparable to those on board satellites, constantly monitored water-leaving radiance (Fig. 1., Peperzak et al., submitted). By dilution of a dense culture of the diatom *Chaetoceros calcitrans* that was grown in the mesocosm, algorithms were designed to calculate phytoplankton biomass from absorbed radiation, as well as phytoplankton fluorescence using the fluorescence line height method. Both algorithms were shown to be linear with chlorophyll-a concentrations of up to 80 mg m^{-3}, a value reached only occasionally in highly eutrophicated coastal waters. Therefore, the algorithm derived from the mesocosm experiment was applicable to a wide range of natural water bodies. In a next experiment, the effect of nitrogen-limited growth on the optical properties of the prymnesiophyte *Phaeocystis globosa* was tested. Depletion of nitrogen led to an increase in red fluorescence over blue absorption. Addition of nitrogen to one mesocosm reversed this effect (Fig. 2). The experiments showed that

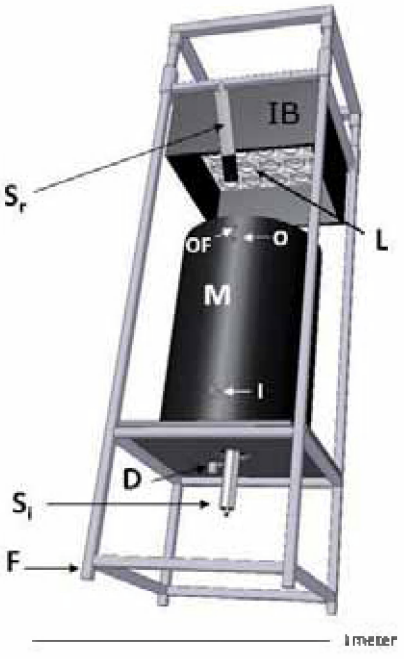

Fig. 1. Scematic representation of the mesocosm system. The mesocosm (M) is placed in a metal frame (F) , that also holds the illumination box (IB). Two spectral sensors were installed: one for bottom irradiance (Si) and one for water-leaving radiance (Sr). Water was pumped round from outlet (O) to inlet (I), while an overflow (OF) kept the waterlevel constant. The mesocosm was drained using a drain (D).

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phytoplankton biomass can accurately be measured with optical sensors using the amount of blue light that is absorbed. However, the red light intensity increased dramatically when the phytoplankton depleted nitrogen. Therefore, red light intensity is not an accurate measure of phytoplankton biomass. On the other hand, the combination of blue absorption and red emission did provide a sensitive indicator of nitrogen-stress and hence phytoplankton growth.

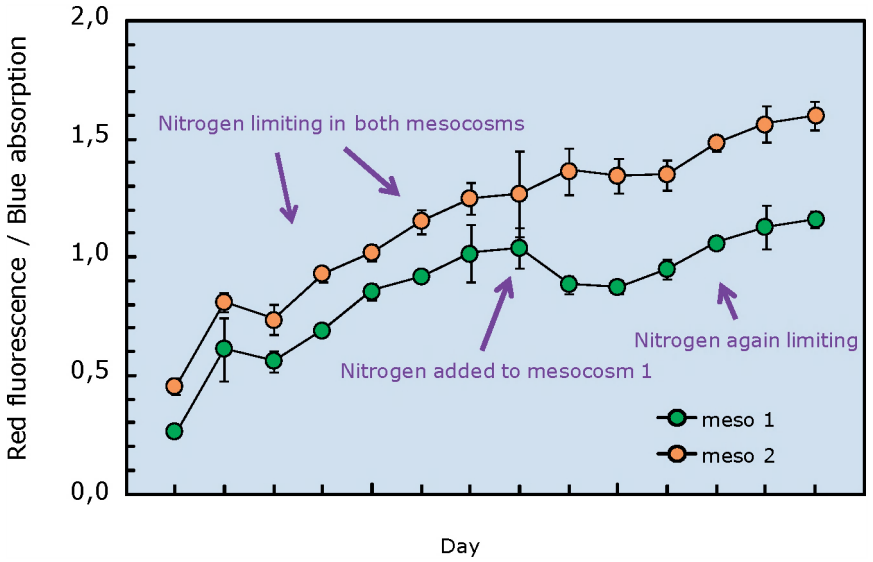
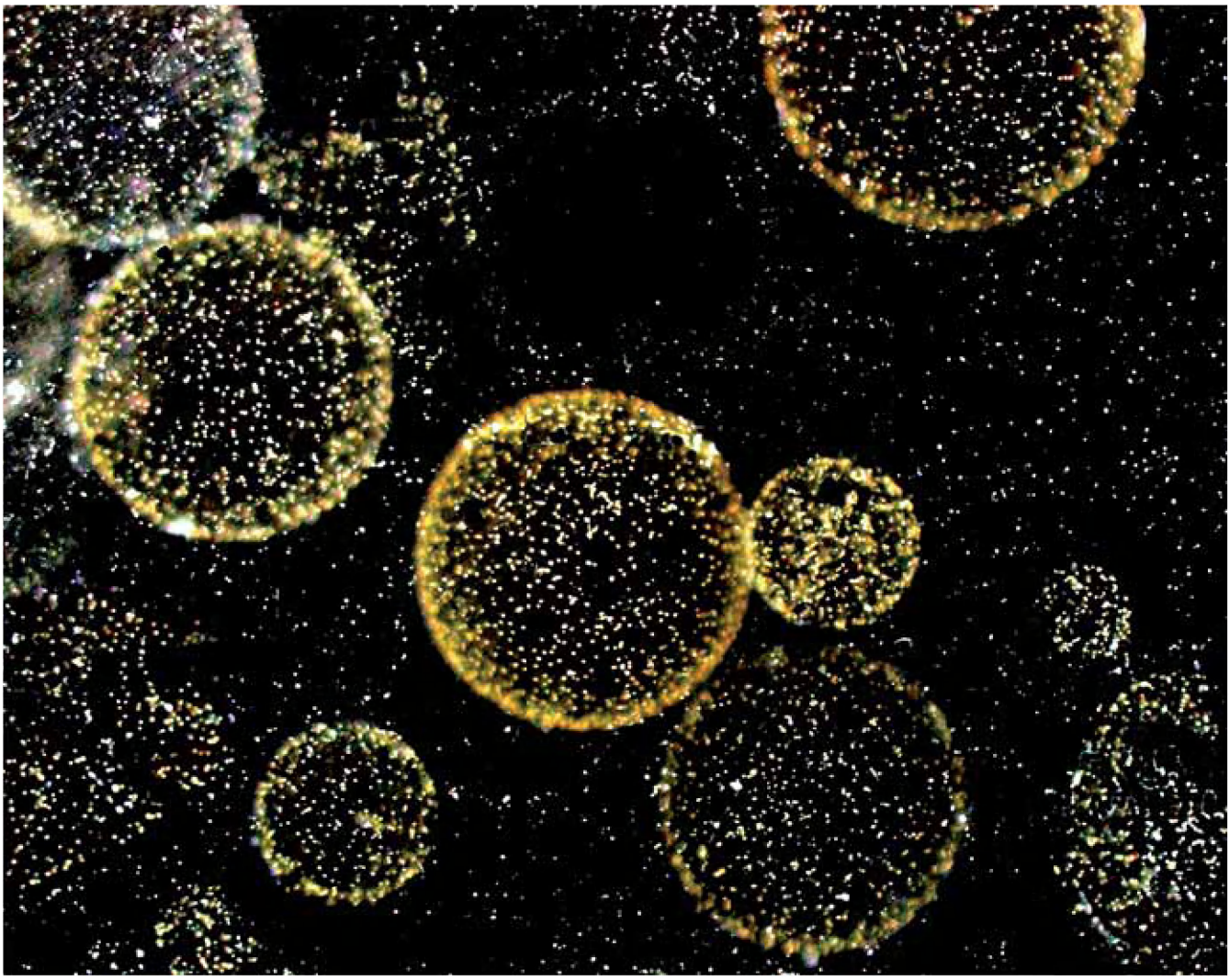


Fig. 2. Red fluorescence over blue absorption in *Phaeocystis globosa* cultures in the two mesocosms during time (days). Nitrogen depletion in the mesocosm as the phytoplankton community grows, and the resulting nitrogen stress on the phytoplankton, is reflected in an increase in red fluorescence/blue absorption ratio over time.



Colonies of *Phaeocystis globosa*.

Heterotrophic activity of archaea and bacteria in the Atlantic

Taichi Yokokawa, Gerhard J. Herndl*[1]

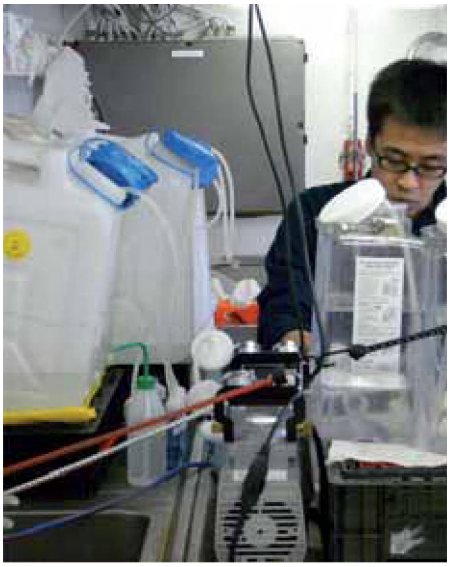
Prokaryotes (bacteria and archaea) play a major role in marine biogeochemical fluxes. The relation between microbially mediated biogeochemical transformation rates and the prokaryotic community composition is a central research topic in microbial oceanography. The objective of our study was to determine the contribution of bacteria and archaea to heterotrophic prokaryotic activity. Our results show that the contribution of bacteria to heterotrophic prokaryotic activity in the open Atlantic amounted to 72% in the surface decreasing with depth to 56% in the deep ocean. The archaeal contribution to heterotrophic prokaryotic activity was always lower and contributed about 26% to the total prokaryotic leucine incorporation throughout the water column in the Atlantic.

During the past decade, it was shown that archaea are ubiquitously present in all the major oceanic basins, contributing about one third to the total prokaryote cell numbers in the waters below the sunlit layer.

Although archaea are abundant in deep oceanic waters, little is known about their metabolic rates and consequently, their biogeochemical role in the ocean. Recent studies suggest that a substantial fraction of archaea is chemoautotrophic, incorporating dissolved inorganic carbon (DIC) and using the oxidation of ammonia as an energy source. Several studies quantifying the abundance of specific functional genes revealed, that the archaeal amoA gene coding for ammonia monooxygenase, the key enzyme in the oxidation of ammonia, is orders of magnitude more abundant than the bacterial amoA gene. This suggests that archaea might be more important for ammonia oxidation and DIC fixation than bacteria in the dark and deep ocean.

Not all archaea are chemoautotrophs however, apparently some are heterotrophs or at least mixotrophs, taking up amino acids and organic compounds. Although results of previous studies obtained on single-cell level indicate that a certain fraction of the archaea is heterotroph, the relative contribution of archaea to the total heterotroph activity of the bulk prokaryotic community was still unknown.

The aim of this study was to estimate the contribution of archaea and bacteria to the total prokaryotic leucine incorporation (as an indicator of heterotrophy)



throughout the water column of the Atlantic. To distinguish archaeal from bacterial leucine incorporation, specific inhibitors were used. Samples were collected in the context of the GEOTRACES project (NWO-ALW, 839.08.413), during the CAIBEX-2 and -3 cruises (R/V Sarmiento de Gamboa, Consejo Superior de Investigaciones Cientificas, Spain) and GEOTRACES-1 and -2 cruises (R/V Pelagia, NIOZ) by the Microbial Oceanography Group of the University of Vienna.

The abundance and leucine incorporation rate of archaea and bacteria were determined throughout the water column along a transect in the eastern Atlantic. Archaeal and bacterial abundance was determined by Catalyzed Reporter Deposition - Fluorescence In Situ Hybridization (CARD-FISH). Bacteria dominated throughout the water column, although their contribution to total prokaryotic abundance in the deep layer was lower than in the surface and intermediate layers (0 - 1000 m) (Fig. 1). Archaea contributed 20-40 % to the total prokaryotic abundance with a generally higher contribution in the deepest layer than in the surface and intermediate layers (Fig. 1).

Leucine incorporation rates were determined for the total prokaryotic community as well as for bacteria and archaea separately using selective inhibitors. To inhibit bacterial protein synthesis, erythromycin was applied and to inhibit archaeal protein synthesis, diphtheria toxin was used. Single-cell analyses were used to check the specificity of the bacterial and archaeal inhibitors. The contribution of bacteria to total leucine incorporation amounted to 72% of total prokaryotic leucine incorporation in the surface (0-1000m) decreasing with depth

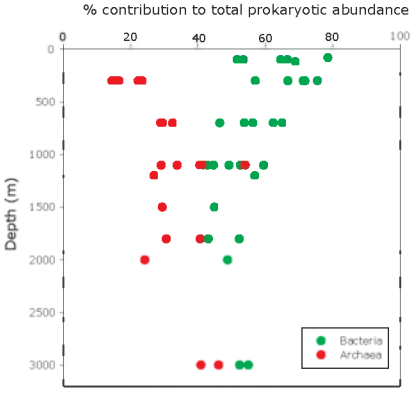


Fig. 1. Percentage contribution of bacteria and archaea to total prokaryotic abundance throughout the water column of 6 stations sampled in the eastern Atlantic (CAIBEX-2 and -3 cruises). Archaeal contributions were below detection limit (< 10%) in the surface layer (80 - 100m) at all 6 stations.

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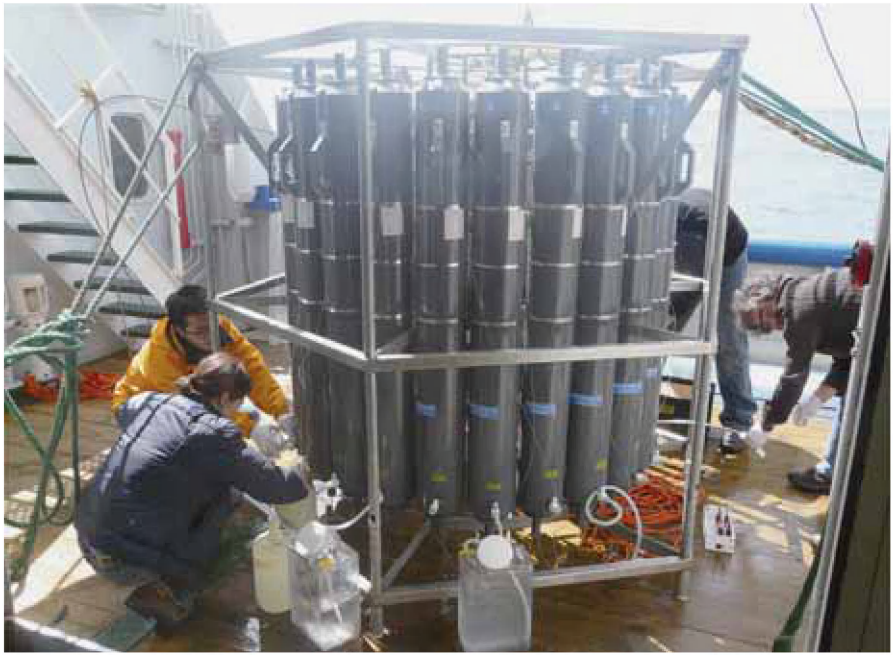
Fig. 2. Percentage of leucine incorporation rates in bacteria and archaea relative to total leucine incorporation throughout the water column.

to 56% in the deeper layers (1000-3000m), whereas the contribution of archaeal leucine incorporation contributed about 26% to the total prokaryotic leucine incorporation throughout the water column (Fig. 2). The mean cell-specific leucine incorporation rate of archaea (3.7 x 10^{-5} fmol $cell^{-1}$ d^{-1}) was 5 times lower than that of bacteria (18.3 x 10^{-5} fmol $cell^{-1}$ d^{-1}) in the surface and mesopelagic layer. In the deep layer, however, cell-specific leucine incorporation rates of archaea were similar to those of bacteria (1.8 x 10^{-5} fmol $cell^{-1}$ d^{-1} for archaea, 2.3 x 10^{-5} fmol $cell^{-1}$ d^{-1} for bacteria).

Taken together, our results indicate that archaea and bacteria exhibit similar heterotrophic activity on a per-cell level in the deep waters of the Atlantic, while in the surface and upper mesopelagic waters, cell-specific heterotrophic archaeal activity is about one order of magnitude lower than that of bacteria.



External Projects Biological Oceanography

- European Project on OCean Acidification (EPOCA, EU-FP7).
  C.P.D. Brussaard.
- Viral impact on microbes in coastal waters of the Antarctic Peninsula and its ecological implications (VIRANT, NWO Dutch polar programme).
  C. Evans, C.P.D. Brussaard, in cooperation with the British Antarctic Survey (UK).
- Changes in vertical stratification and their impact on phytoplankton communities (STRATIPHYT, NWO Coastal and Marine Research ZKO).
  K. Mojica, C.P.D. Brussaard, in collaboration with University of Amsterdam, University of Groningen, Utrecht University-Institute for Marine and Atmosperic Research Utrecht, VU-Institute for Environmental Studies.
- Comparative genomic analysis of viruses infecting *Phaeocystis globosa* and *Micromonas pusilla,* two eukaryotic microalga of global distribution (DOE-JGI, USA).
  C.P.D. Brussaard, in cooperation with University of Delaware, Newark (USA).
- Whole genome sequencing of a *Phaeocystis globosa* virus (GENOSCOPE).
  C.P.D. Brussaard, in cooperation with IGS CNRS-UPR, Marseille, France.
- Biochemical and ecological effects of resource co-limitation on key phytoplankton species (PHYTURE).
  D. Maat, C.P.D. Brussaard.
- Consequences of Ocean Acidification for phytoplankton production and losses (Double Trouble, Darwin Center for Biogeosciences).
  K. Crawfurd, C.P.D. Brussaard, in cooperation with Utrecht University and Alfred Wegener Insitute for Polar and Marine Research, Bremenhaven, Germany.
- Virus Impact on Bacteria and Microalgae in Intertidal Sediments (Portugese funding).
  C. Carreira, C.P.D. Brussaard in cooperation with Copenhagen University.
- Influence of viruses on microbial nutrient assimilation (MPI-Bremen).
  A Sheik, C.P.D. Brussaard in cooperation with MPI-Bremen.
- 454-sequencing of aquatic polar virus communities (IcoMM and UBC).
  C.P.D. Brussaard in cooperation with British Columbia University, Canada.
- North Sea Ballast Water Opportunity project (NSWBO-Interreg IVb – ESRF).
  M. Veldhuis, E. Brutel in cooperation with 29 other partners in the North Sea region.
- Multi-scale modelling of calcification in scleractinian corals, MultiCalc, NWO,
  M.E. de Boer, J.D.L. van Bleijswijk, in cooperation with University of Amsterdam.
- Modelling the causes and consequences of environmental change.
  P. Ruardij in cooperation with CEFAS.
- Wadden Sea ecosystem data assimilation and integrated modelling (NWO-ZKO).
  J. Nauw (FYS), P. Ruardij, T. Gerkema (FYS) in cooperation with IMARES, NIOO.

Marine Ecology

The department of Marine Ecology aims for a mechanistic understanding of the structure and dynamic behaviour of marine populations and communities. Taking up one of the great challenges in modern ecology, we try to understand the properties of populations and communities on the basis of characteristics of individual organisms, whereby the focus is on the role of bottom-up (food input and competition for food and other resources) as well as on top-down (predation) processes in structuring communities.

The main research themes carried out by the Department of Marine Ecology are related to the following multi-disciplinary themes of the NIOZ Science Plan 2008-2012:

- Wadden and shelf sea systems;
- Sea floor dynamics;
- Climate variability and the sea;
- Biodiversity and ecosystem functioning.

In these various multi-disciplinary themes, the contribution of the work covers studies both at the individual and population level:

- Recruitment and dispersal in relation to the spatial and genetic structure of benthic populations;
- Competition for food, life history strategies and dynamic energy budgets;
- The structuring role of top-predators in marine ecosystems

At the level of the individual we study performance (e.g. growth, age and size at maturity, fecundity, survival, or more general energy budgets) in response to food availability and other environmental conditions, as well as the consequences of specific energetic strategies for competitive interactions and fitness.

At the population level we focus on recruitment processes around and shortly after settlement because this period is extremely important in marine benthic population regulation. Examples include adult-juvenile competition by means of settlement inhibition by adults, and competition for food affecting the age and size at metamorphosis, the structuring role of top-predators.

Long term data sets form the backbone of our studies: in the Wadden Sea on phytoplankton (from 1974 onwards), macrobenthos (Balgzand transects from 1974; grid sampling from 1996), fish fauna (fyke net series from 1966) and waders (colour ringing programme from 2001), and in other intertidal areas and in the North Sea (NIOZ benthic mapping from 1986 onwards).

In 2010 the department was again successful in the open competition both at a national and an international level. Worth mentioning are the two prestigious Wadden Sea projects funded by the Waddenfonds and coordinated by NIOZ: WaLTER (Wadden Sea Long-Term Ecosystem Research, coordinated by Katja (C) J.M. Phillippart and Metawad1 (connection of the Wadden Sea in a network of worldwide intertidal ecosystems; a flyway perspective).

Within the department, there is a continuous focus on quality improvement as reflected in 2010 in the successful reviewing certification of the benthos activities of the department in the form of ISO 9001.

This year Casper Kraan (Spatial ecology of intertidal macrobenthic fauna in a changing Wadden Sea) and Piet van den Hout (Struggle for Safety: Adaptive responses of wintering waders to their avian predators) defended their PhD thesis.

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Climate-induced changes in estuarine predator-prey systems: a bioenergetics approach

Vânia Freitas, Henk van der Veer*

It is generally believed that the globe is undergoing a period of rapid climate change that includes substantial warming. A major challenge to ecologists nowadays is to predict possible impacts of such temperature shifts. Reliable predictions can only be achieved on the basis of an understanding of the mechanisms underlying climate-driven changes at the individual, population and community levels. With a multidisciplinary approach, this study focussed on the sensitivity of some common predator-prey interactions to changes in seawater temperature. Our results show that global warming is likely to benefit crustaceans as predators with negative consequences for bivalve prey survival.

In temperate shallow-water systems, predation on newly-settled bivalves by the brown shrimp *Crangon crangon* (Fig. 1) and shore crab *Carcinus maenas*, causes substantial mortality and may ultimately affect adult bivalve stocks, which are important food sources for shorebirds. These crustaceans are also part of an intricate predator-prey system, acting simultaneously as predators and prey for other abundant epibenthic fish including flatfish, gobies and larger demersal species like cod and sea bass.

Fig. 1. Small shrimps and gobies caught with a beam trawl.

Because of the ecological significance of these interactions, the aim of this work was to develop a mechanistic framework to study the impact of temperature changes on epibenthic predation based on eco-physiological data and modelling tools. The starting hypothesis was that the temperature effect on size-dependent interactions boils down to physiological principles as both growth performance of prey and crustacean predation are temperature-related. In this respect, not only temperature but also food conditions are a key factor determining the vulnerability window of prey to predation. In cold-blooded animals, temperature influences growth rates and hence the time prey take to escape predation by reaching a safe size, and food conditions ultimately determine if prey can achieve this size refuge.

Temperature tolerance and sensitivity

Specific temperature responses (tolerance range, sensitivity) were determined based on experimental data reported in literature (Fig. 2). There were differences between species, with crustaceans presenting higher temperature sensitivity and tolerance ranges compared to their potential fish predators and bivalve prey. Based on these results it is hypothesized that crustaceans, particularly the shrimp *C. crangon*, will benefit from warming trends via a release from predation by their own predators, and by improving their growth potential. In addition, the narrow tolerance range and low upper thermal limit of the Baltic clam *Macoma balthica* indicate that global warming may be particularly harmful for this species (Fig. 2). This might be the underlying reason for the progressive decline of *M. balthica* observed in the Wadden Sea in the last decades.

Assessing food conditions for growth

To elucidate prevailing food conditions in the field, we used a Dynamic Energy Budget (DEB) model which quantitatively describes growth in relation to habitat conditions (i.e. food and temperature). With a single model for prey and predators, food level (f, ranging from 0 to 1) was determined in two ways: 1) direct reconstruction of the assimilated food

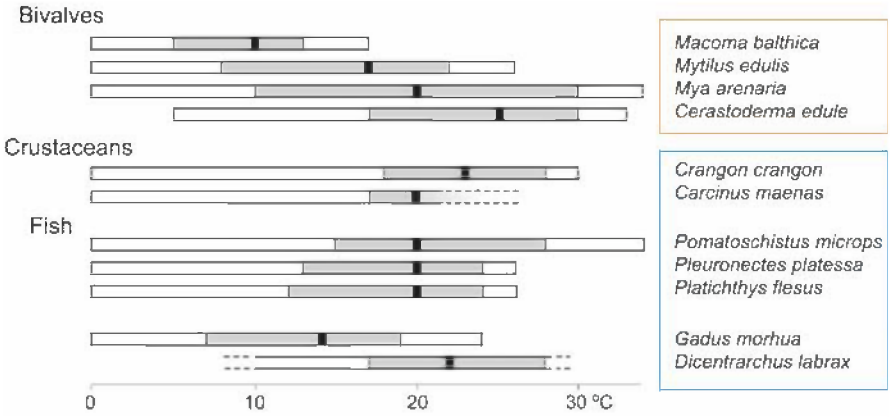

Fig. 2. Overview of optimal temperature (bold vertical bar), temperature performance breadth (grey horizontal bar) and temperature tolerance range (total horizontal bar) of the various bivalves (orange) and epibenthic predators (blue).

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(Fig. 3a); and 2) indirect assessment of food conditions by comparing observed growth in the field with DEB-predicted maximum growth assuming unlimited food (f=1) and at the actual seawater temperatures (Fig. 3b).

Growth patterns of the various species from several areas along the NE Atlantic coast were collected from the literature and by field sampling. From the Wadden Sea, the long-term monitoring program at Balgzand provided valuable data concerning the epibenthic communities. Sampling at Minho estuary (Portugal) and Valosen estuary (Bodø, Norway) provided information from a warm and a cold-water system, respectively (Fig. 4). The DEB-based approach revealed that bivalves appear to suffer from food limitation, irrespective of latitude. On the other hand, in crustaceans, feeding conditions seem to be optimal and hence, growth appears to be largely determined by the water temperature. These contrasting growth conditions of the bivalves as prey and crustaceans as predators point to a disadvantageous position of the bivalves. This is expected to intensify under a warming climate scenario since more intense predation by crustaceans will not be compensated by rapid bivalve growth which could reduce the time spent within a vulnerability window.

It is currently unclear to what extent these expected general patterns interact or may be modified by local population adaptations to temperature, or feedback interactions like cannibalism among crustaceans. Further research on these topics is strongly recommended.

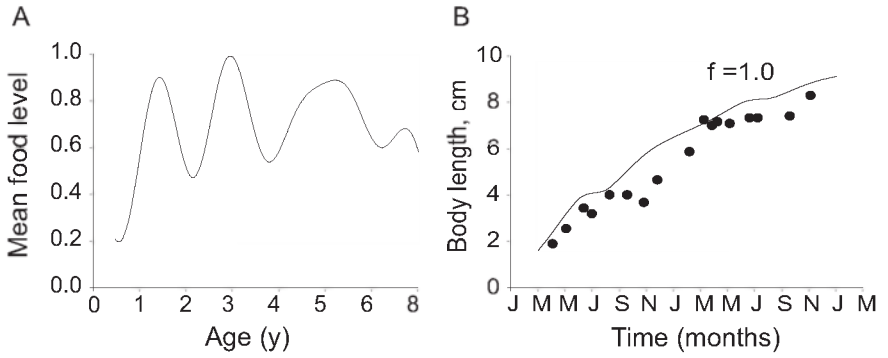

Fig. 3. Determination of food conditions in prey and predators using a DEB model. Direct food reconstruction in the cockle *Cerastoderma edule* (A) and indirect estimation of food levels in the sand goby *Pomatoschistus minutus* (B). Dots are mean length observed and line is the growth curve predicted by the model assuming food levels are maximum (f =1).

Fig. 4. Sampling in three different areas across the European Atlantic coast. a) Minho Estuary (NW Portugal), b) Balgzand (The Netherlands), and c) Valosen Estuary (NW Norway).

Wintering in benign tropical climates is not necessarily a 'summer holiday': Afro-Siberian red knots *Calidris canutus canutus* – a case study

*Jutta Leyrer, Theunis Piersma**

Breeding successfully in high arctic regions is challenging because summer is so short. Migrants that attempt to breed there have to time their migration to arrive in the breeding grounds in an optimal way. Migration itself is very energy consuming, mostly has a tight time schedule and has been commonly regarded as the 'most dangerous' period of year with the highest mortality. To our surprise, we found quite the opposite: our study population of Afro-Siberian red knots spending eight months in the benign climates of tropical Mauritania experienced a higher mortality during exactly that period rather than during migration and breeding. Possibly because upon arrival back in their wintering grounds the birds face multiple stress factors: an energetically costly moult and/or fierce competition for good foraging sites. Yet, investing in a good foraging site could give them a much better start into the subsequent migration.

This PhD project focused on aspects that influence migratory performance and survival during the annual cycle in long-distance migrating red knots. It was largely based on demographic analyses of eight years (2002 – 2009) of observations of individually colour-marked birds from a Mauritanian population.
Birds that breed in the high arctic benefit from 24-hour daylight and super abundant insect food during the summer to raise their offspring. Yet in these high latitudes, summers only last two months. Incubating eggs and raising chicks take about six weeks and, consequently, there is not much flexibility before or afterwards. Optimally, the chicks hatch when insect abundance peaks. To achieve this, adults ought to arrive early and in good condition to obtain a good territory and a good mate, but not too early, as the tundra might still be covered by ice and snow. Whether the adults manage this task depends often on what happens at their wintering grounds, sometimes ten thousands of kilometres away.

A year in the life of the Afro-Siberian red knot

About 75% of the Afro-Siberian red knot *Calidris c. canutus* population winters at the Banc d'Arguin, a Wadden Sea-like area on the coast of Mauritania, West Africa. Here they spend 8 – 9 months per year (Fig. 1). In early May, they migrate

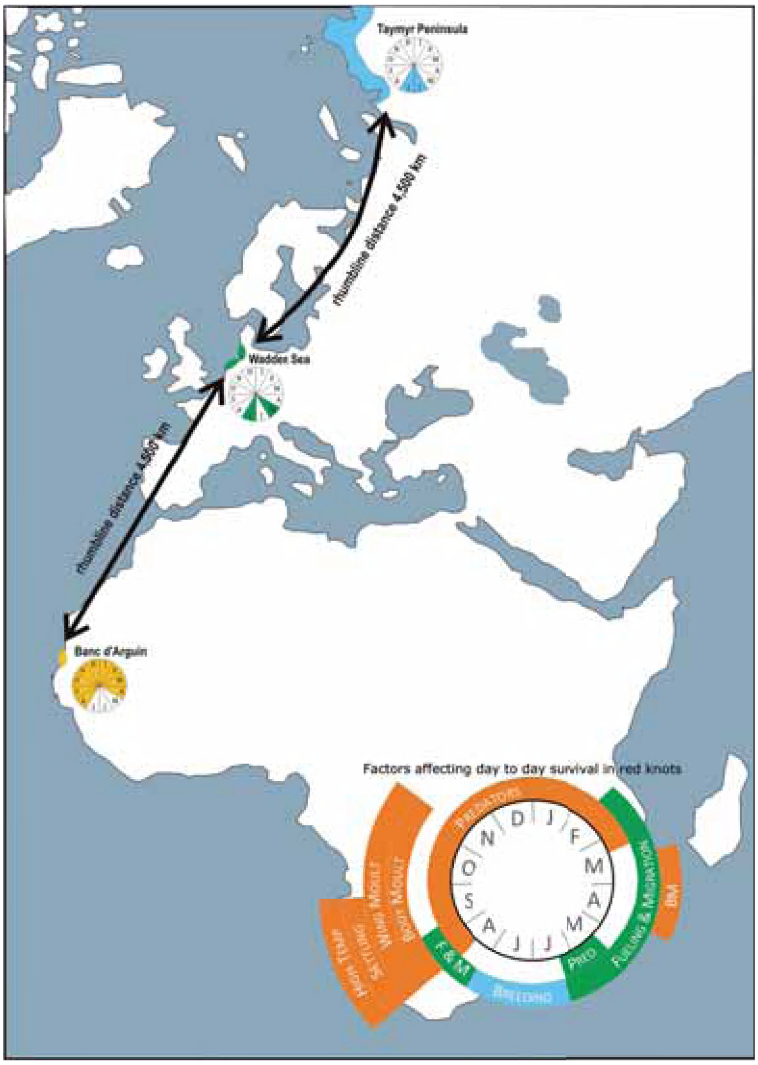

Fig. 1. Afro-Siberian red knots each year spend 8-9 months at their key non-breeding area Banc d'Arguin, Mauritania, West Africa (yellow). During May they migrate north via the key staging sites in the Schleswig-Holstein Wadden Sea (green) to the Siberian breeding grounds on Taimyr Peninsula (blue). In July/August, they migrate back via the Dutch Wadden Sea (green) and arrive back in Mauritania from mid August onwards.

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north to their breeding grounds on Taimyr Peninsula, Siberia, and stop only once in the Schleswig-Holstein, Germany, part of the Wadden Sea. There, they double their body mass within about three weeks. They need these reserves to cover the 4500 km distance, but also to have some extra fuel in case there is no food available when they arrive in their breeding areas. Immediately after the breeding season, the adult red knots migrate back south as soon as possible, leaving the offspring behind to find their own way. The first adults arrive back at Banc d'Arguin by mid August, less than four months after they have left for northward migration to the breeding grounds. This being the situation, we commonly expect that mortality is higher during a stressful migration and breeding season than during a stationary wintering period, like the eight months at a rather benign climate at Banc d'Arguin. In contrast, we observed that most individuals die during the winter months, and especially just after arriving back at Banc d'Arguin in autumn (Tab. 1). In fact, early autumn seems to be a relatively stressful period for the knots (Fig.1 inset). Possibly, knots die as a consequence of delayed effects from being exhausted after migration and the breeding season. Also, upon arrival, they immediately start moulting all their feathers. Moult oppresses the immune system and makes the birds more vulnerable to diseases. Growing feathers also means more metabolic activity because new tissue has to be created. This extra work implies that the body machinery is producing more heat which the birds need to get rid of. They do this by, e.g., raising their back feathers to expose skin to the air. But, during early autumn ambient temperatures are very high in Mauritania (day temperatures regularly exceed 40°C)

Table 1 Seasonal estimates of bi-monthly apparent survival and standard errors of *Calidris canutus canutus* red knots in their wintering area Banc d'Arguin, Mauritania, West Africa, in 2006 - 2009.

period	bi-monthly survival
May - August	1.00 ± 0.00
September - November	0.93 ± 0.02
December - April	0.96 ± 0.02

Fig. 2. Study site at Iwik Peninsula, Banc d'Arguin, Mauritania. Shown are two high tide roosts, Abelgh Eiznaya and Baie d'Aouatif, 3 km apart. Relocation probabilities (Ψ) from Baie d'Aouatif to Ablegh Eiznaya were three times higher than reverse, indicating that Abelgh Eiznaya was a better site to be than Baie d'Aouatif.

which makes it difficult to lose body heat. The potentially resulting hyperthermia (overheating) is more damaging to an organism than hypothermia (undercooling) and could thus be (also) responsible for the higher mortality during that period of time. Last not least, in our study site at Banc d'Arguin we observed that foraging habitat differs in quality and there appeared to be fierce competition for good spots. Once a knot had settled in a good site, it showed hardly any relocation to a less good site, while knots from the less good site were more likely to relocate to the good site (Fig. 2). We think that only knots that hurry back to the wintering areas and arrive there early and in good condition have the best chances to obtain a good foraging spot. We further think that although the investment in getting settled at a good foraging place has advantages in the long term (e.g., giving a head start into the subsequent spring migration), it may demand a lot of resources from the birds and thus increase risk of mortality in the short term.

Do deep-sea scavengers use plant material and algae as a food resource?

Rachel Jeffreys, Marc Lavaleye, Magda Bergman, Gerard Duineveld, Rob Witbaard*

Deep-sea fish depends directly or indirectly on food produced in the upper layer of the oceans. It is well known that food dumps can occur in the deep-sea after the spring or autumn bloom of algae, forming a green carpet on the sea floor. This food carpet attracts benthic invertebrates, especially large sea cucumbers. Our baited time-lapse cameras at the sea floor showed for the first time in a number of video clips, that deep-sea grenadiers, the most abundant demersal fish in the deep ocean, rapidly respond to and feed vigorously on large plant food falls mimicked by spinach. Similar behaviour was demonstrated in reaction to simulated dumps of plant debris (phytodetritus) at the sea-floor. This 'vegetarian behaviour' highlights the variability in the scavenging nature of deep-sea fish.

Deep-sea communities living at and near the sea floor in the deep ocean primarily rely on food sources produced at other places. This is often in the form of remains of algae and zooplankton which live in the upper 200 m of the oceans and sink to the sea floor after dying. Benthic invertebrates such as sea cucumbers are the primary consumers of this food source. Deep-sea grenadiers are the most abundant bottom-living fish in the deep ocean; they are generally considered to be the top predators/scavengers in deep-sea communities. Previous baited camera experiments with bottom landers and stable isotope analyses have demonstrated that carcasses from animals living in surface waters are also an important component in their diets. Some grenadier stomachs even contained vegetable material dumped from ships, e.g. onion peels, oranges, and algae. These latter observations led us to the question: is plant material also an attractive food source for deep-sea fish?

Fig. 1. Preparing the spinach bait at the foot of the ALBEX lander (Autonomous Lander for Benthic EXperiments). Right panel is after a 5 hours deployment.

In October 2008 we simulated a plant food fall using spinach blocks fitted at a benthic lander equipped with a baited time-lapse camera on the Atlantic Iberian margin at 3000 m depth (Figs. 1 and 2). Deep-sea grenadiers and cusk-eels were rapidly attracted by the bait and fed vigorously on it (Fig. 3). The majority of the bait was consumed within a half hour. These observations indicate that (1) plant

Fig. 2. Recovery of the ALBEX lander with the spinach experiment.

Fig. 3. Behaviour of deep-sea grenadiers and a cusk-eel at the spinach bait at 3000 m on the Atlantic Iberian margin. (A) Attraction to and investigation of spinach bait, (B) 'feeding frenzy', fishes vigorously attacking bait, (C) spinach spilling out of stocking after attack, (D) consumption of spinach by grenadier.

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material can produce an odor plume similar to that of animal carrion and attract deep-sea fish, and (2) deep-sea fish readily eat plant material. Since higher plant remains are scarce in the deep-sea, these results led us to ask if remains of marine algae material, *i.e.*, phytodetritus, might also be a food source for deep-sea fish. In October 2009 we simulated a phytodetritus dump at the seafloor in two contrasting environments: (1) the NE Atlantic where carpets of phytodetritus have been previously observed and (2) the nutrient-poor oligotrophic western Mediterranean, where the deposition of phytodetritus at the seafloor is a rare occurrence. We recorded the response of the scavenging fauna to phytodetritus released from an in situ benthic lander equipped with baited time-lapse cameras (Fig. 4). In the Atlantic Iberian margin at 3000 m, grenadiers and cusk-eels were again attracted by our vegetarian dish (Fig. 5A-C). The phytodetrital patch was significantly diminished within 2 hours. Abundance estimates calculated from first arrival times of grenadiers at the lander corresponded well with abundance estimates from video-transects, indicating that fish were indeed attracted by the scent of the algal bait. In the western Mediterranean, however, only a single grenadier was observed investigating the phytodetrital patch but the fish showed no real interest in the bait (Fig. 5D). Abundance estimates from first arrival times at the bait were lower than estimates obtained from video-transects and trawl catches. This suggests that the Mediterranean fish were not readily attracted to this food source. The phytodetrital patch was significantly diminished after 6.5 hours mainly by invertebrate activity (Fig. 5E).

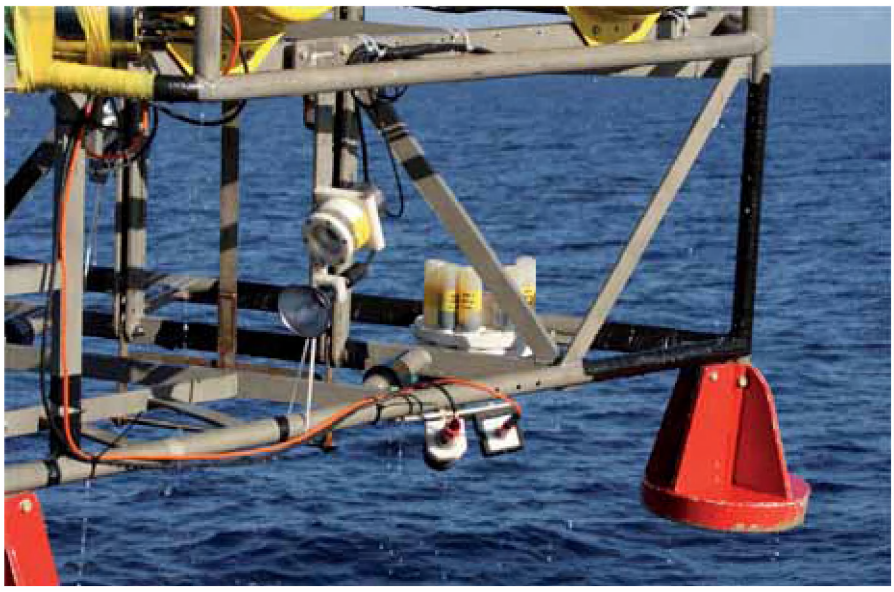

Fig. 4. Detail of the ALBEX lander with the phytodetritus experiment. The carousel with algae pots to mimic a phytodetritus dump and the video cameras with lamps are visible.

Stable isotope values of the fish at both study sites did not demonstrate a strong trophic link to phytodetritus, whereas their fatty acid profiles indicated a strong link between their lipid pool and algae, which may be attributed to trophic transfer.

This study suggests that deep-sea fish, such as grenadiers on the Atlantic Iberian margin, is attracted to phytodetritus in areas where this reaches the sea-floor regularly. The study represents to our knowledge the first *in situ* documentation of deep-sea fish ingesting plant material and phytodetritus and highlights the variability in the scavenging nature of deep-sea fish. In the future, we will try to quantify the exact contribution of this vegetarian food source to the diet of grenadiers. A BBC news video clip of our spinach experiment can be viewed via www.nioz.nl/media.

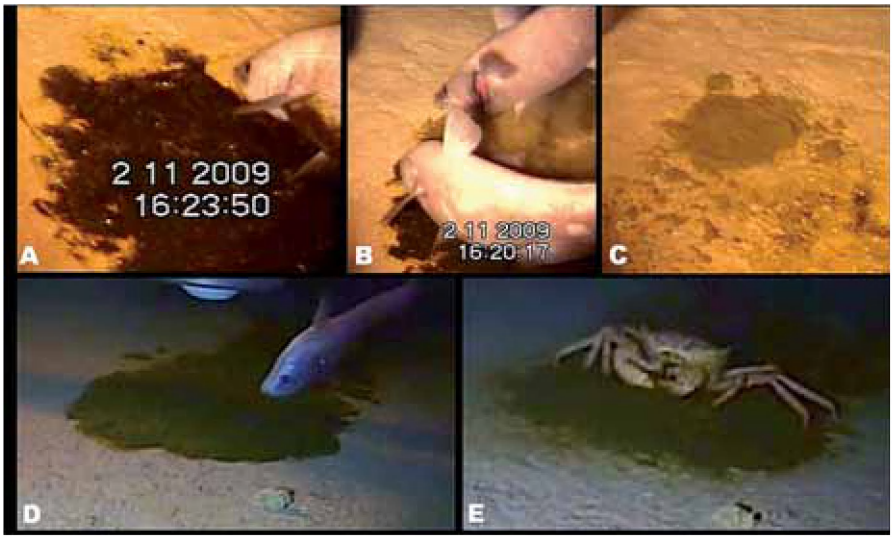

Fig. 5A-C. Behaviour of grenadier fishes at the phytodetritus patch at 3000 m on the Atlantic Iberian margin. (A) Attraction to and investigation of the phytodetritus, (B) investigation and ingestion of phytodetritus, (C) the diminished phytodetritus patch after a few hours.

Fig. 5D-E. Behaviour of a grenadier fish (D) and a *Chaceon* crab (E) at the phytodetritus patch at 3000 m in the Mediterranean.

External Projects Marine Ecology

- Grazing experiments on the effects of phytoplankton species composition on the grazing rates of zooplankton through seasonal field surveys (IN PLACE, NWO - ZKO).
  M. Loebl, H.G. Epping (GEO), C.J.M. Philippart, in cooperation with Royal Netherlands Academy of Arts and Sciences, VU University Amsterdam, Common Wadden Sea Secretariat, Ecomare.
- Consequences of phosphorus reduction for the dynamic transfer of organic matter between primary producers and primary consumers (P REDUCE, NWO - ZKO).
  L. Mulder, H.G. Epping (GEO), C.J.M. Philippart, in cooperation with Royal Netherlands Academy of Arts and Sciences
- Age determination in bivalves: validation of the seasonality of shell growth bands along the European coast.
  J.F.M.F. Cardoso, H.W. van der Veer, in cooperation with CIIMAR/CIMAR (Porto, Portugal).
- Pervasive impact of intertidal migrant top predators on species diversity and size structure of its prey may lead to spatial knock-on effects between ecosystems, NWO VIDI grant (Vernieuwingsimpuls).
  J.A. van Gils.
- The trans-Arctic biotic interchange: snapshots-through-time of adaptive differentiation in the bivalve genus *Macoma* (NWO-MEERVOUD).
  P.C. Luttikhuizen.
- Physiological performance of the Peppery furrow shell *Scrobicularia plana* (da Costa 1778) along the European coast (Portuguese Science Foundation)
  S. Santos, P.C. Luttikhuizen, H.W. van der Veer, in cooperation with CIIMAR/CIMAR.
- Climate Change Impacts on the Marine Environment: Research Results and Public Perception (CLAMER, EU 7th FP)
  C.H.R. Heip, C.J.M. Philippart, T. Watmough.
- Science-Policy Interfaces for Biodiversity: Research, Action, and Learning (SPIRAL, EU 7th FP)
  C.H.R. Heip, C.J.M. Philippart, E. van Haastrecht.
- Monitoring macrozoobenthos in intertidal and subtidal western Dutch Wadden Sea (MWTL, RWS-Waterdienst).
  R. Dekker, in cooperation with Wageningen IMARES and NIOO-CEME.
- Project Research Sustainable Shellfish culture (PRODUS, Ministry of agriculture, nature and food quality).
  R. Dekker, in cooperation with Wageningen IMARES.
- Intraspecies differences in DEB parameters: phenotypical versus genetic subpopulation variability (EU grant)
  V. Freitas, H.W. van der Veer.
- A regime shift of benthic organisms in the Wadden Sea: causes and consequences for higher trophic levels (ZKO)
  E. van der Zee, H.W. van der Veer, T. Piersma.
- Sediment samples Wadden Sea (IMARES)
  S. Miguel, H.W. van der Veer.
- Shorebird ecological demographics and conservation initiative (Global Flyway Network, BirdLife Netherlands and several other sources).
  T. Piersma.
- The Synoptic Intertidal BEnthic Surveys (SIBES, NAM, ZKO).
  T.Piersma, H.W. van der Veer, A. Dekinga, S. Holthuijsen, G. Aarts, S. Duijns.
- Ecological feedback on intertidal flats. (WaddenEngine, ZKO).
  T. Piersma, H.W. van der Veer, in cooperation with Groningen University and NIOO-CEME.
- Monitoring food chain diversity (Waddensleutels, Waddenfonds).
  T. Piersma, H.W. van der Veer, J. Sinninghe Damsté (BGC), Stefan Schouten (BGC) in cooperation with Groningen University, NIOO-CEME and Natuurmonumenten.
- Drivers of shorebird abundance on the intertidal flats of Banc d'Arguin, Mauritania (Fragile Connections, WOTRO).
  J. A. van Gils, M. van der Geest, T. Piersma, J. van der Meer.
- Monitoring Wadden Sea – West-Africa ecological linkages (Metawad, Waddenacademie -KNAW.
  T. Piersma, P. J. van den Hout.
- Bering Strait Mudflats and Shorebirds (USGS and Swedish Arctic Research Council).
  T.Piersma, A. Dekinga in cooperation with the Alaska Science Centre of the US Geological Survey.
- Vogeltrackers (Ecomare).
  B. Spaans, T. Piersma in cooperation with Ecomare.
- A tool for long-term monitoring of coastal waters (FerryBox, RWS)
  A. Waser, J. van der Meer.
- Population dynamics of mussel beds in the Wadden Sea (Mosselwad, Waddenfonds)
  J. van der Meer.

- Local eel management (LNV)
  J. van der Meer.
- Pilot project Local eel management in Friesland (LNV)
  J. van der Meer
- Modelling bivalves energetic processes from individual and population perspectives and the upscale to an ecosystem level towards the study of interactions between the bivalves and the ecosystem (MARETEC, Portugal)
- *S. Saraiva, J. van der Meer.*
- The effects of the offshore wind park Egmond aan Zee (OWEZ) on recruitment of benthos (NZW, NUON/SHELL).
  M.J.N. Bergman, G.C.A. Duineveld.
- Effects of the construction of an offshore wind park on macrobenthos (NZW, NUON/shell).
  R. Daan, M. Mulder, M.J.N. Bergman.
- Pilot study of the applicability of the 'NIOZ Mussel monitor for valve activity' on *Ensis directus* during a long period under controlled conditions (RWS-havenproef).
  R.Witbaard.
- Relation between valve activity of *Ensis directus* and environmental factors in the Dutch coastal zone in the spring (RWS – Ensis field experiment, in cooperation with BWN-NTW3.1 and Deltares).
  R.Witbaard .
- Relation between valve activity of *Ensis directus* and environmental factors in the Dutch coastal zone in the autumn (RWS – Ensis field experiment, in cooperation with BWN-NTW3.1 and Deltares).
  R.Witbaard.
- Climate-related shifts in the NCP ecosystem, and consequences for future spatial planning (BSIK, Klimaat voor Ruimte).
  G.C.A. Duineveld, R. Witbaard, J. van der Meer, S. Saraiva, J. Drent, P. Honkoop.
- GIS-charts of bottom fauna for an offshore wind farm (BSIK, We@Sea).
  M.S.S. Lavaleye.
- Hotspot ecosystem research on the margins of European seas, workpackage 2: Deep water coral reefs (HERMES, EU).
  M.S.S. Lavaleye, G.C.A. Duineveld.
- BIOdiversity and ecosystem FUNctioning in contrasting southern European deep-sea environments (BIOFUN, ESF).
  R. Jeffreys, G.C.A. Duineveld, M.S.S. Lavaleye.
- Biodiversiteit van de volle zee. (IMARES, LNV).
  M.S.S. Lavaleye.
- Hotspots of Biodiversity in the North Sea (IMARES & Directie Kennis en Innovatie of Ministry of Economy, Agriculture and Innovation).
  M.S.S. Lavaleye, M.J.N. Bergman.
- Assessment of the interaction between corals, fish and fisheries, in order to develop monitoring and predictive modelling tools for ecosystem based management in the deep waters of Europe and beyond (CoralFISH, EU).
  G.C.A. Duineveld, M.S.S. Lavaleye.
- Hotspot Ecosystem Research and Man's Impact On European Seas (HERMIONE, EU).
  M.S.S. Lavaleye, G.C.A. Duineveld.
- Predator avoidance strategies in bivalves and possible shifts in competitive power (NEBROC).
  H. Andresen, J. van der Meer.
- Integrated Network for Production and Loss Assessment in the Coastal Environment (IN PLACE; NWO-ZKO).
  C.J.M. Philippart, H.G. Epping (GEO), in cooperation with NIOO-CEME, IVM-VU, RWS and Ecomare.
- Causes and consequences of selective feeding by juvenile bivalves, subproject of part of consequences of phosphorus reduction for the dynamic transfer of organic matter (P-REDUCE; NWO-ZKO).
  V. Lehmpfuhl, C.J.M. Philippart, in cooperation with NIOO-CEME.
- The Wadden Sea as a Long-term Ecological Research site (WaLTER; Waddenacademie)
  C.J.M. Philippart, in cooperation with IMARES and SOVON.
- Beached bird survey monitoring programme, 2009/2010 (Rijkswaterstaat Noordzee, Rijswijk)
  C.J. Camphuysen.
- Beached bird survey monitoring programme, 2010/2011 (Rijkswaterstaat Noordzee, Rijswijk)
  C.J. Camphuysen.
- Porpoise Conservation Plan (Ministry of LNV → EL&I, The Hague)
  C.J. Camphuysen.

- GPS Logger project Lesser Black-backed Gull (in collaboration with IMARES & Waardenburg Culemborg)
  C.J. Camphuysen.
- The implementation of policies and activities that promote professional preparedness to marine wildlife emergency responses in the European coastal countries (EMPOWER)
  C.J. Camphuysen.
- Philopatry in Lesser Black-backed Gulls (Ministry LNV; Rijkswaterstaat Noordzee)
  C.J. Camphuysen.
- Linking long term developments of the macrozoobenthos with the eutrophication status in the international Wadden Sea. Common Wadden Sea Secretariat, Wilhelmshaven.
  J. Drent.
- Budget modelling of fines in the Dutch coastal zone (Building with Nature, in cooperation with FYS).
  R.Witbaard.

Retrofit RV Pelagia, spring 2010

*Rint de Vries[1], Theo Buisman, Erica Koning**

NIOZ's flagship, the ocean-going vessel RV Pelagia needed a compulsory 20 year special survey for the classifying society Bureau Veritas in 2010. After a European tender, the work was carried out at the Astander Shipyard in Santander, Spain from January to April. Besides the improvements essential for the special survey such as new nautical equipment and technical installations, a ballast water treatment unit and a HiPAP or USBL underwater positioning instrument were installed. The total refit cost NIOZ 4.5M and we hope that this will enable RV Pelagia to sail prosperously for at least another 15 years.

The ever-expanding area of operation of RV Pelagia: from the North Sea (1991) via the Mediterranean (1998) to the Indian Ocean and the tropical Atlantic Ocean (2000 -2010)

RV PELAGIA is NIOZ's largest sea-going research vessel. The ship was built in 1990 at Verolme Shipyard in Heusden, The Netherlands and was originally intended to work in the North Sea and adjacent areas. The director at the time, Prof. Dr. Jenne Zijlstra, wanted a ship for North Sea research and as a result decided that the ship would only need limited cable length on the CTD winch and accommodation for up to12 scientists. The ocean-going scientists at NIOZ, however, together with the ship's building committee, made sure that 6000m of cable was installed on the ship, thereby extending the ship's possible working range to the ocean proper.
Since 1990, PELAGIA's working range has indeed extended steadily and the ship has since sailed from far up in the North Atlantic to Brazil and has by now sailed around the African continent twice, via the Mediterranean, the Suez Canal, the Red Sea and the Indian Ocean

PELAGIA has now been in service for over 19 years. During the last five years the cruising schedule has been overfull with a peak of 359 operational days in 2009. Thus, the need for an overhaul and/or refit of main the components on board became evident. Such an extensive refit would best be carried out together with the ship's compulsory '20 year Special Survey' for Bureau Veritas (BV), the classifying society, in 2010/2011.

RV Pelagia entering Durban Harbour (21- 03-2009) in her original colours.

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To prepare for the 20 year Special Survey, as early as 2007 the NIOZ directors contracted the 'Bureau voor Scheepsbouw' (BvS, naval architects and marine engineers) to carry out an independent survey of RV PELAGIA, to report on the actual condition of the vessel and to give advice on what needed to be done to maintain the vessel in a condition that meets the requirements of the Dutch Flag Authorities and Bureau Veritas (BV) for the next 10 to 15 years. The first inspection on board was carried out in November 2007 on Madeira; a second inspection took place in Las Palmas and a final inspection, together with invited subcontractors, in Barcelona. BvS reported in February 2008 and as a result it was decided that the ship would undergo a refit and major overhaul at the end of 2009 and in early 2010. In the mean time, a major investment proposal was submitted to the Netherlands Organisation for Scientific Research NWO, asking for funding for additional scientific equipment such as a Remotely Operated Vehicle (ROV), Ultra Short Base Line (USBL), Dynamic Positioning (which would have meant installing a retractable thruster) and a deep-sea echo sounder. Despite excellent reviews the proposal was finally rejected, thereby limiting the refit work mainly to the essentials needed for the compulsory special survey and improvements on nautical and technical installations, including a ballast water treatment unit because in the near future it will become compulsory for ships to treat their ballast water before it is released back into the sea. BvS then compiled the technical specifications for the work to be carried out and prepared a European tender. Nine shipyards applied for the refit, 3 of which were asked to send in an offer. Eventually, the Astander Shipyard in Santander, Spain was awarded the contract. It was then decided that Theo Buisman (NIOZ) and Rint de Vries (for BvS) would accompany the ship to Santander to supervise the refit process.

For the first half of January 2010, while waiting for the contract to be signed, the ship was moored in her homeport of Texel. The time on Texel was put to good use by starting with parts of the maintenance and refit work. New main circuit breakers were installed in the main switch boards, a new fire detection system replaced the old one, the emergency diesel generator was overhauled completely and the starboard (SB) aft knuckle boom crane was removed from its pedestal to be replaced by a new crane at the yard. On Monday January 25th PELAGIA finally arrived in Santander. Almost immediately the work on the vessel began by removing the main mast, A-frames and winches. Because the dry dock was not available yet it was decided to remove the diesel generator sets through the container hold instead of through the SB hull. This meant that a pass way had to be made through the forward engine room bulkhead and through the 3 double bottom ballast tanks in the container hold, to allow for the removal of the whole generator sets in one piece. The sets were hoisted out via the container hatch and transported to the workshop for dismantling.
On its way to the workshop a flatbed car tipped over and the SB generator set fell from the car, resulting in serious damage to the diesel engine and generators. The 380 Volt generator was beyond repair, but fortunately this generator had been built by the Spanish company Indar that was able to make a whole new generator in a limited time frame, so eventually minimal time was lost and the re-instalment of the sets could be completed before the engine room bulkhead and tanks in the container hold were closed. New, more fuel efficient and environmentally cleaner Caterpillar diesel engines had been ordered in the USA more than a year in advance to make sure they would be in The Netherlands on time. The engines arrived in Papendrecht at the Pon/Cat workshop in November 2009, where they were further prepared for fitting on board and later on transported to Santander by truck.

An empty engine room after removal of the generator sets.

PS diesel engines brought into the engine room, due to the limited space it was a tight fit.

Pelagia in drydock gridblasting the hull.

In the mean time the ship had been dry-docked and the work on the hull, propellers, rudder and other parts started in earnest. The hull and all ballast- and freshwater tanks were grid-blasted. The initial idea to locally grid blast some of the ballast tanks was abandoned after a test had revealed that the original coating had hardened in such a way that all paint came off. It was then decided to grid blast all water tanks completely,

Removal of the grid after gridblasting of the bulwark.

which meant a lot more work for the paint contractor and a lot of additional holes in the ship's hull to give access to the tanks. A total of 26 access holes, two for each tank and holes for removing the bow thruster and drive motor, were made in the hull, and of course these all had to be closed afterwards. The workers of Indasa, the contractors responsible for blasting and painting the tanks, did an excellent job. Due to the limited space most tanks were difficult to work in but the job was done thoroughly with excellent result.

On the main deck the wooden deck covering was removed, the deck and bulwork were grid blasted after which additional container locks, to position containers, and lashing bars were welded in. The steel deck underneath the wood turned out to be heavily pit corroded and for a couple of days welders did their best to fill in the deepest holes, a very time-consuming job, after which the deck was painted and new wood covering could be applied.
On the bridge almost all nautical and communication instruments were removed, the consoles and chart table were modified and new instruments were installed. The navigation and communication instruments had been ordered well in advance to make sure that they would be available in time for the refit. All removal and installation work was carried out by the Kelvin Hughes Company in Rotterdam who also delivered most of the new equipment for the bridge.
In the accommodation, work started by removing all the old furniture from the mess room and the bar. In almost the entire accommodation the floor covering

New lay out of bridge consoles with new instruments.

Acces holes for removal and reinstalment of the bow thruster closed.

was removed and replaced by new carpet in the cabins, and 'imitation oak ship deck' design vinyl in mess room, corridors and other multifunctional areas.
The mess room was redesigned and refurnished completely. The initial proposal drawn up by ship's crew members with input from NIOZ personnel was further worked out by Ronno Honigh, interior architect on Texel, and later finalised by Oliver Design, a Spanish company specializing in the architectural design of Yachts, Ferries and Cruise Ships. Oliver Design was responsible for all the work carried out in the accommodation and for the redecoration work. This also involved installation of Pullman beds in 9 cabins to replace the existing built-in double berths. All mattrasses, bedding, curtains etc. were renewed. In total 18 bathroom doors in the cabins had to be renewed because of severe corrosion damage to the existing doors. New thermostatic controlled taps were fitted in the shower cabins. One of the major jobs

The mess room cleared from furniture and floor covering.

on hand was the renewal of all vacuum (sewage) piping and hot and cold fresh-water pipes on all three decks in the accommodation; this meant that 75% of all ceilings had to be removed to give access for this job.

Because of the contamination in fresh water pipes they had to be renewed.

While the ceilings were open, additional cabling for a new LAN system and for the new information screens in accommodation, labs and CTD-room could be pulled. Furthermore, cables were pulled from the bridge to the engine control room for the new Alarm and Monitoring System (AMS).

Apart from installing new electronically managed diesel engines and overhaul of the generators and main electric propulsion motor, the installation of a new AMS system was the biggest job that had to be carried out in the engine room. A complete new installation was installed, replacing the old Rietschoten en Houwens system, with several substations placed in the accommodation and one substation on the bridge. The job also involved changing the hardwired bridge controls of the diesel engines and ballast system into remote control via the AMS system, to free space on the bridge consoles to suit the newly purchased nautical instrument such as two new Ecdis (electronic card) screens, a deep sea echo sounder screen, and HiPAP control units.

Sorting out the wires for the new Alarm and Monitoring System.

Engineers Jaap and Marcel at work in the Engine Control Room after the refit.

The HiPAP or USBL (underwater position locating instrument) is the only major piece of scientific instrumentation that was installed as part of the refit. Although the major investment proposal was turned down and funding therefore limited, the USBL was considered to be such a valuable addition for deep-sea research that NIOZ decided to purchase it anyway. The USBL is discussed in more detail in the annual report of the Marine Technology Department. To install the HiPAP, a recess had to be made in two double bottom fuel tanks to be able to fit the outboard valve and HiPAP cylinder. Positioning the equipment in the ship was critical because the available space was extremely limited, therefore Theo and Rint had a hard time but in the end they managed to get the position exactly right. A second difficult point to tackle was the installation of the new deep-sea echo sounder system. The Spanish BV surveyor did not like our solution at all and it took a lot of convincing, even from BV's Rotterdam office, to get it installed so that it would work.

Placing the Hipap cylinder, to get it in was quite an achievement.

In order to be able to maintain a pleasant working temperature in the container hold when sailing in tropical waters, two large air-conditioning units with ducting were installed, but this made it necessary to increase the capacity of the sea water coolers in the engine

Water Ballast Treatment Unit just fits in a recess SB- Aft in the engine room.

Testing the new SB-aft crane

room.
The engine room had its own challenges to tackle: the first one was how to move the new diesel engines inside because these were slightly higher than the old ones. A second challenge was to find a place for the new Ballast Water Treatment Unit which removes living micro-organisms from the ballast water upon intake and upon discharge. This unit now snugly fits in a small recess on the SB side on the engine room floor and does not take up too much space in an engine room that is already filled to capacity. Finally a new bilge water separator and a new Reverse Osmoses water generator were installed.

Workers from Bakker Sliedrecht cleaned and overhauled both Synthy drives (RPM regulators of the main propulsion and bow thruster), which took three persons three weeks to accomplish. Propulsion motor, bow thruster motor and two generators were sent to Bakker Repair in Holland for overhaul. Piet Grisnigt, driving the NIOZ truck, made several trips to transport machines, parts and stores to and from Santander.

In the workshop, all winches were dismantled completely and overhauled. Hydraulic pumps, cylinders and winch motors were sent all over Spain for overhaul. Two pumps were beyond repair and had to be renewed. Fortunately Theo Buisman managed to get two renovated pumps from Hydrauvision in the Netherlands so that the system could be completed.

A new knuckle boom crane, with more lifting capacity and longer reach than the old one was installed SB-aft. This new crane has its own independent hydraulic power pack.
The top of the main navigation mast had to be renewed because it was heavily corroded. The complete mast was grid blasted, modified to fit the new radar scanners, V-sat and other new instruments and was newly coated before being put back on the ship.
Lots of minor and major jobs came up during the refit. Every day new additional work orders (a total of 223!) were received from the yard and this was quite frustrating at times. It was always difficult to negotiate with the yard, as both parties stood their ground but because work had to continue, deals had to be made and in the end the parties always came to an agreement.

Early April the ship was ready for sea trials and these went well. Some jobs were not fully finished yet but because the ship had to be on Texel in time to be commissioned for the first scientific voyage, PELAGIA left Santander on the 10th of April. Back on Texel the ship was fitted out for the upcoming research cruise and several outstanding jobs could be finished then. On April 23rd the ship was ready to sail for her first cruise after the Refit.


Leaving Astander Shipyard for the home voyage to Texel


Leaving Texel after the refit

Open ship party.

Evaluation.
In September the ship returned to Texel for a short stay between cruises. This time was used to correct some shortcomings that had arisen during the previous trips. One of the more difficult matters was to solve the apparent pollution of the fresh water in the tanks. The tanks were cleaned and inspected but no apparent cause could be found. Water analyses showed a high iron content in the water, explaining the brownish colour, but no other particulars were found.

On September 9th a very successful 'open ship celebration' took place for NIOZ personnel and relations to show the final result of the retrofit. Recently, in December 2010 and January 2011 the finalist outstanding jobs were finished and already some new improvements were carried out. Besides these outstanding jobs, normal maintenance jobs were carried out to prepare the ship for the 2011 cruise program.

The retrofit has improved the capabilities of the ship and should lead to less maintenance and lower fuel consumption and cleaner exhaust gasses in the future. The standard of living on board has improved as well. We hope that PELAGIA will sail prosperously for at least another 15 years.

An additional comment from Rint: 'During PELAGIA's stay in dry dock we were lodged in Hotel Las Anclas at walking distance from the yard. Every day we passed an old brick wall separating the yard from the street. During the months we passed this wall to go to the yard, the wall was being renewed and Theo felt that the wall was made up from the money the yard made out of the additional work orders. Before leaving the yard he expressed his feelings and presented the director of the Yard with a copper plate engraved with the words 'Pelagia Wall' which they promised to mount on the wall. Recently we received proof that they actually had!

Looking back on our time in Spain, it was an interesting time, long working days for every one but a nice experience nevertheless. Special thanks to all the NIOZ people involved, who had to work in sometimes harsh conditions and had to work long days. The yard succeeded in delivering the vessel on time, quite an achievement when taking into account all the extra work that had to be done.'

The Pelagia Wall

Coffee break in the superintendents office.

Scientific Support Services

MARINE RESEARCH VESSELS AND FACILITIES

*Erica Koning**

The NIOZ research vessel Pelagia sailed 226 operational days for 10 cruises. Of these 10 cruises, 4 were performed within the National Programme for Sea Research (ZKO: Zee- en Kustonderzoek), 4 were EU/ESF or NIOZ programmes and 2 were charter cruises. Our active participation in the Ocean Facilities Exchange Group (OFEG) continued.

Marine Research Facilities

The Marine Research Facilities (MRF) is a national structure integrated within NIOZ. MRF advises the Earth and Life Sciences branch (ALW) of the Netherlands Organisation for Scientific Research (NWO) on the technical, logistic and financial aspects of the National Programme for sea research, maintains the national equipment pool and runs facilities, including several marine research vessels. NIOZ-MRF supplies suitable ship capacity, dedicated technicians and sea-going equipment to teams of scientists from Dutch research institutes and universities and assists the chief scientists in planning, preparation and execution of the cruises. NIOZ participates with RV Pelagia and its equipment pool in the Ocean Facilities Exchange Group (OFEG), wherein ship time is exchanged between 6 European partners on a bartering basis.

Research vessels

Research vessel Navicula is a 25 m ship specially designed for working in the shallow Wadden Sea. RV Navicula was built in 1980 and elongated in 1999, with another major upgrade in 2004. This year, a new kitchen was installed. In 2010 RV Navicula sailed for 197 days and worked mainly in the Dutch Wadden Sea with a few excursions to the German and Danish parts of the Wadden Sea and the coastal North Sea. 116 days of Navicula ship time were funded by NWO within the National Programme for Sea and Coastal Research (ZKO) and by third parties. With the start of the 'IN PLACE' (ZKO), 'GETIJ' and 'Building with Nature' programmes Navicula now accommodates a wide variety of scientific disciplines.

RV Pelagia is our largest sea-going facility, a 66 m research vessel developed for oceanographic research in coastal seas, on continental shelves and on the open ocean. RV Pelagia was built in 1991 (ISM Certified) and was designed as a multipurpose research vessel. Onboard scientific activities include seismic surveys, the operation of a variety of CTD and water sampling systems, diverse biological sampling instruments and coring devices

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as well as the deployment and recovery of deep-sea moorings and bottom landers, including a deep-sea crawler (MOVE!). In the first 4 months of 2010 a major midlife refit was carried out, during which all the ship's facilities were updated and Pelagia was outfitted with a USBL-system (Ultra Short Base Line) enabling state-of-the-art communication with underwater instrumentation.
A more extensive report on the refit can be found elsewhere in this annual report.

RV Pelagia cruise programme

Because of the midlife refit RV PELAGIA sailed a relatively short program of 226 operational days divided over 8 cruises. The cruise programme included two charter cruises. The first charter cruise of 31 days sailed in August from Hamburg for the German Federal Maritime Hydrographic Agency BSH in Hamburg. A second charter cruise of 30 days was carried out in the subtropical North Atlantic in October for a science team from the University of Vienna, Austria led by former NIOZ scientist prof. dr. Gerhard Herndl.

The Netherlands Organisation for Scientific Research NWO funds seagoing science projects within the National Programme for Sea and Coastal Research (ZKO). In 2010, 97 days of ship time were funded by NWO for the 2009-2011 ZKO programmes GEOTRACES and INATEX. Furthermore, NIOZ funded 54 days, 23 of which were for matching of EU/ESF projects, charterers funded 66 days and 13 days were funded by NIOZ for a technical training cruise within the OFEG framework. To allow additional ship time for programmes that ran in previous years but needed follow-up ship time, NIOZ and NWO pooled resources and set up the VTLP programme (VaarTijd Lopende Projecten), where NIOZ funded 70 days of ship time and NWO provided additional funding to cover project costs. The NiCYCLE programme that sailed in November was funded within this VTLP programme. An overview of the Pelagia cruises in 2010 (including charters) is presented below; this overview also comprises the cruises by other research vessels with Dutch participation. Details

Overview of cruises in 2010

Pelagia cruises	Departure	arrival	area	Project	Chief scientist
PE 318	Texel	Scrabster (UK)	North Atlantic	UCC test	L. Gerringa (BIO)
PE 319	Scrabster (UK)	Bermuda (UK)	North Atlantic	GEOTRACES-1	L. Gerringa (BIO)
PE 320	Bermuda (UK)	Bermuda (UK)	Carolina Margin	TRACOS	F. Mienis (GEO)
PE 321	Bermuda (UK)	Fortaleza (BRA)	North Atlantic	GEOTRACES-2	M. Rijkenberg (BIO)
PE 323	Texel	Texel	North Sea	BSH	H. Klein (BSH)
PE 324	Texel	Galway (IRL)	Irminger Sea	CAMP/THOR	H. van Aken (FYS)
PE 313	Texel	Vigo (ES)	Porcupine	CoralFish/Hermione	M. Lavaleye (MEE)
PE 314	Las Palmas (ES)	Las Palmas (ES)	(sub) tropical Atlantic	MOCA	G. Herndl (U Vienna)
PE 315	Las Palmas (ES)	Texel	North Atlantic	PC test OFEG	H. de Haas (GEO)
PE 316	Texel	Texel	North Sea	NiCYCLE/FOKUZ	L. Stal (NIOO-CEME)

Other cruises	Departure	Arrival	Area	Project	NIOZ scientist
R/V KNORR	Bridgetown (Barbados)	Fortaleza (BRA)	Amazon offshore	Amazon paleoclimate	C. Zell (BCG)
F.S. ALKOR	Warnemunde (DE)	Warnemunde (DE)	Baltic Sea	ILWAO	H. van Haren (FYS)
R/V G.O. Sars	Bergen (NO)	Bergen (NO)	North Atlantic	CoralFISH	G. Duineveld /M. Lavaleye (MEE)
RV POURQUOIS PAS?	Brest (F)	Brest (F)	Atlantic	PC test cruise	J. Schilling / Y. Witte (MTM)
FS METEOR	Reykjavik (IS)	St. Johns (CND)	Irminger Sea	THOR	F. de Jong (FYS)
FS ALGOA	Port Elizabeth (SA)	Toamasina (MOZ)	SE Madagascar	INATEX	J. Ullgren (FYS)
FS POLARSTERN	Cape Town (SA)	Punta Arenas (Chili)	South Atlantic	CASO/CCAMLR	E. Jones (BIO) / K.Bakker (AA)

of the cruises within the National Programme are given in the next subchapter.
To accommodate the cruises by RV Pelagia, diplomatic clearance has been granted by Denmark, France, Germany, Greece, Iceland, Ireland, Norway, Portugal, Spain, and UK. Besides calling at homeport Texel, port calls for changes of crew and scientific party as well as for (un)loading of scientific equipment took place in Scrabster (UK), Bermuda (UK), Fortaleza (Brazil), Hamburg (Germany), Bergen (Norway), Vigo (Spain) and Las Palmas (Spain).

National Programme for Sea Research

In 2010 the National Programme, facilitated by NWO/ALW grants, consisted of 3 cruises. Two cruises sailed on RV Pelagia and for logistic reasons the South African research vessel FRS ALGOA was chartered for the INATEX cruise on the Mozambique margin. In chronological order the following programmes, some of which are highlighted below, were carried out in 2010:

1. GEOTRACES leg 1
2. TRACOS
3. GEOTRACES leg 2
4. INATEX-PHYS
5. CoralFish/Hermione
6. Piston Core training
7. NiCYCLE

1: GEOTRACES (Global Change and Microbial Oceanography in the West Atlantic Ocean; Chief scientist Loes Gerringa (leg 1) and Micha Rijkenberg (leg 2).

GEOTRACES is an international program (www.geotraces.org) that aims to improve the understanding of biogeochemical cycles and large-scale distribution of trace elements and their isotopes in the marine environment. An overview of the first results is given elsewhere in this annual report. In 2010, the first two transects of this programme sailed with RV Pelagia, leg 1 from Reykjavik to Bermuda and leg 2 from Bermuda to Fortaleza (Brazil). Due to logistic problems caused by the eruption of Eyjafjallajökull on Iceland leg 1 sailed from Scrabster (UK) instead. **The final leg currently sailed in March 2011 aboard RRS James Cook (U.K.; arranged within the barter agreement).**

2: TRACOS (TRans Atlantic COral Studies); Chief scientist Furu Mienis.

The TRACOS project forms a contribution to WP4 of the EU-HERMIONE project and aims to study the ecology and geological history of the cold-water coral (CWC) communities that live on mounds in the Cape Lookout CWC area (N. Carolina Margin, USA). TRACOS was initiated in 2008 as a cooperation between the NIOZ departments of Marine Geology and Marine Ecology and partners at the Herriot-Watt University (Edinburgh, UK), School of Ocean Sciences (Bangor, UK), and at the University of North Carolina at Wilmington (USA) to study cold-water coral habitats on both sides of the Atlantic ocean sharing skills, technology and other resources. Landers and mooring equipped with instruments recorded the particle flux to the CWC communities in conjunction with hydrographic variables (turbidity, temperature, current speed)in an attempt to identify forcing factors of the particle and food supply to the local CWC communities and triggers for coral growth and mound formation

3. INATEX (INdo ATlantic EXchange); Chief scientist: Jenny Ullgren.

Deployment of current meter moorings in the East Madagascar Current
The East Madagascar Current forms an important part of the southwest Indian Ocean circulation and is one of the links between the South Equatorial Current and the Agulhas Current, but neither mean flow nor variability of this current are well documented. Together with our ongoing measurements in the Mozambique Channel a new array of 5 current meter moorings measuring the flow of the EMC will help to complete our understanding of the current system of the Indian Ocean. In September-October 2010 NIOZ employees Jenny Ullgren, Sander Asjes, Jack Schilling, and Yvo Witte joined the South African research vessel FRS Algoa on a research cruise from Port Elizabeth (SA) to Toamasina (Madagascar). After exploring a transect across the continental slope at the proposed location of the mooring array, recording water depth - quite different from the historical charts - and measuring water properties all five moorings were successfully deployed.

4: Coral Fish / Hermione; Chief scientist: Marc Lavaleye.

The purpose of the CORALFISH/ HERMIONE cruise was to collect observational data and seabed samples for two EU-programmes: HERMIONE and CoralFISH. HERMIONE studies various

hotspot ecosystems such as canyons and cold water coral mounds (Whittard canyon and Belgica Mounds, Irish Margin). Relations between seafloor morphology, particle transport and benthic fauna in Whittard Canyon were studied by means of multibeam, video surveys, video-guided boxcore sampling, benthic lander deployments and water pump samples (SAPS). CoralFISH intends to make estimates of fish abundance on and off coral mounds (Belgica Mounds) by means of video surveys across mounds and a novel baited video lander. A video clip of a vegetatian rattail fish can be seen at www.nioz.nl/media.

NIOZ scientists on foreign ships

In addition to the National Programme, NIOZ scientists participated in a number of cruise programmes on OFEG and non-OFEG ships. In March, Gerard Duineveld and Marc Lavaleye participated in a CoralFISH cruise off Northern Norway on the Norwegian research vessel G.O. Sars.

In May, NIOZ technicians Jack Schilling and Yvo Witte were invited to an OFEG training cruise on the French research vessel POURQUOIS PAS? where technicians from IFREMER, NERC and NIOZ joined forces to compare and optimize piston core systems. In November, this initiative was repeated on RV PELAGIA on the return trip from Las Palmas. When leaving Las Palmas, Pelagia passed FS Polarstern on her way down to the Southern Ocean with a NIOZ-MRF auto analyzer container on board.

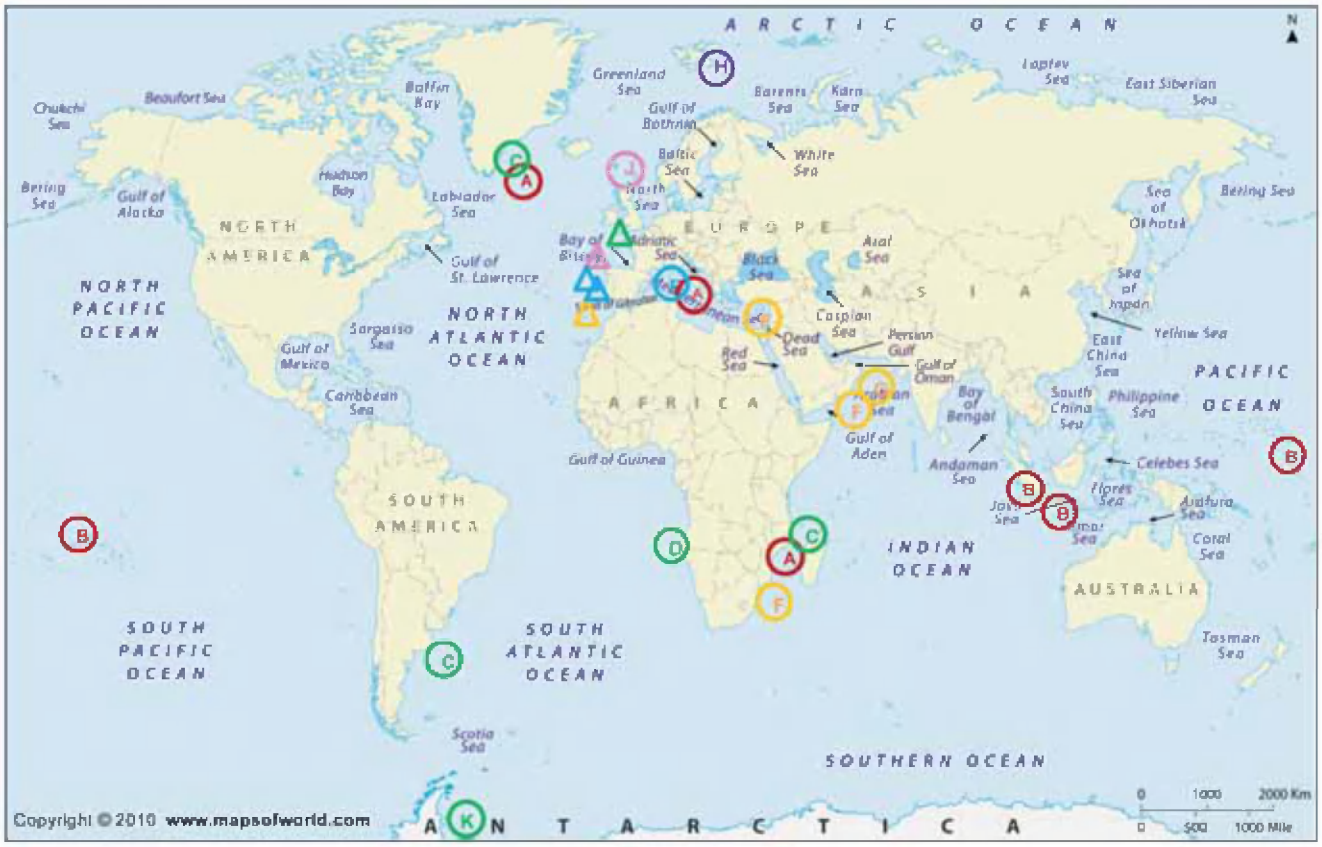
Ocean Facilities Exchange Group (OFEG)

OFEG's main purpose is to use resources from its 6 European member states efficiently by bartering (exchanging) ship time and large equipment without the need to exchange money. This arrangement has significant advantages because it allows scientists access to areas of the ocean that would otherwise be out of reach. Furthermore, OFEG invests in the interoperability and exchange of marine technicians for training and support on board. Within this framework, several training cruises were organized in 2010, dedicated to piston coring and seismic cooperation.

In 2010 NIOZ had its first barter exchange with our Spanish counterpart CSIC when RV Sarmiento de Gamboa was used for the recovery of MOVE! after the first 9 months deployment East of Mallorca.

OFEG meetings and other international activities

This year OFEG met twice for regular meetings, in April at the Institute of Marine Research (IMR) in Bergen, Norway and in December at IFM-Geomar in Kiel, Germany. Alongside with OFEG, the OFEG-TECH group met in December in Kiel as well.
Erica Koning participated in the European Research Vessel Operators (ERVO) meeting that convened in Southampton, UK in April. Furthermore she participated in the International research Ships Operators Meeting (IRSO) that convened in Kiel, Germany in May.



OFEG ship exchange activities since 2008; red circles: German ships with A: Dutch scientists and B: UK scientists; Green circles: UK ships with C: Dutch scientists, D: German scientists and K: Norwegian scientists; Yellow circles: RV Pelagia with F: German scientists and G: UK scientists. Blue, pink and purple circles are Spanish, French and Norwegian ships respectively. Triangles show OFEG training cruises.

MARINE TECHNOLOGY

Marck Smit, Hein de Baar, Marcel Bakker, Jan Blom, Lorendz Boom, John Cluderay, Piet Grisnich, Henk de Haas, Johan van Heerwaarden, Edwin Keijzer, Bob Koster, Martin Laan, Sven Ober, Harry de Porto, Jack Schilling, Yvo Witte.*

The first four months of the year were quite calm for our seagoing scientific cruise support team, because of the midlife overhaul of RV Pelagia in Spain (see elsewhere in this annual report). However, at the end of the year, the total amount of work still proved to be about 3% higher than in 2009. In the second half of 2010, we had a very busy scientific cruise program. In total we have been working on 299 projects throughout the year 2010 of which the major ones that were finished this year are highlighted.

Novel Ultraclean PRISTINE® water sampler for the GEOTRACES[1] Program

After 3 decades of working with Go Flo PVC samplers, our scientists needed a cleaner and better water sampler for the correct analysis of the ultra-low levels of trace metals occurring in the open ocean. Since these were not available on the market, we decided to design them ourselves in cooperation with a commercial partner in Austria (www.georg.fisher.at). This has resulted in an entirely new sampler made of ultra clean PVDF plastic with metal parts of titanium. Entirely new butterfly valves were designed for closure of the sampling cylinder on both sides. This new type of water sampler was baptized as the PRISTINE® water sampler.

The valves are in a closed postion when the samplers are passing through the sea surface layer and they open a few meters below the surface. The openings weredesigned as large as possible to ensure excellent flow-through conditions during downcast and upcast movements. Teflon valves for sub sampling are placed at lowest position to ensure drainage of the complete sampler, including settling particles. The top valve can be connected to gas pressure for filtration at the bottom sub sampling valve.

24 PRISTINE® samplers of 27 litres each are mounted on an all-titanium frame which is deployed with a new Kevlar hydrowire cable with internal signal cables to allow on-line communication of the temperature, salinity, depth and fluorescence values between the Rosette sampler at depth and the CTD-operator on board. This allows for the rapid ultraclean sampling of the deep oceans for minute levels of trace metals.

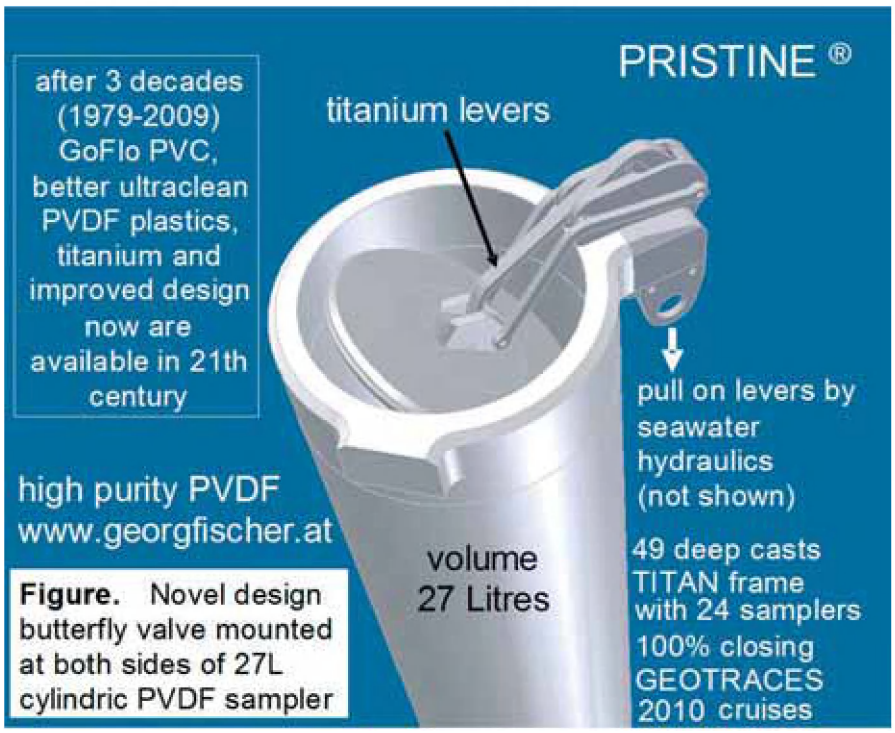


Figure. Novel design butterfly valve mounted at both sides of 27L cylindric PVDF sampler

[1] An international study of marine biogeochemical cycles of trace elements and their isotopes (www.geotraces.org)

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A-frame for the GEOTRACES cruise

The Southern Atlantic trajectory of the GEOTRACES cruise will be carried out — on board of the British RV James Cook by OFEG ship barter arrangements. For this cruise it is essential to have the NIOZ Kevlar Cabled Clean winch on board. After extensive operational considerations, a special A-frame was designed and constructed.

Deep Sea Kevlar Cable Winch: extensive overhaul and installation of new Hi Tech Kevlar cable

The mid life overhaul of the RV Pelagia created the possibility for us to realize a vast number of repairs and modifications.

During the overhaul, the winch was equipped with a new, Hi Tech Kevlar cable, which is unique in the world. The new features of this cable are 4 single mode optic fibers, 25% stronger and a 78% higher conductor surface.

Because of the change in cable diameter, modifications had to be made on 19 sheaves, the grooved Lebus sleeves and the cable drum. The 20' container for the hydraulic power-pack was also renewed.

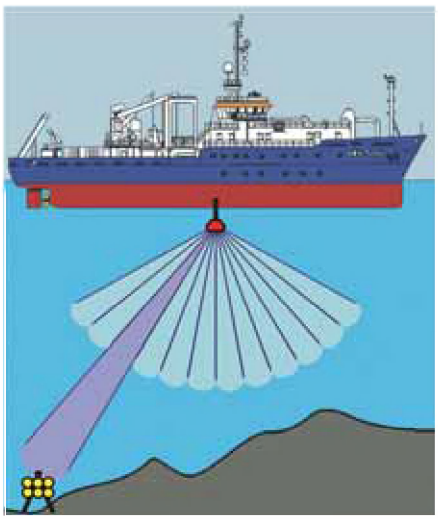
The Deep Sea Kevlar Cable winch was almost completely dissembled.....

...and after the overhaul is was again as good as new.

USBL subsea navigation system for RV Pelagia

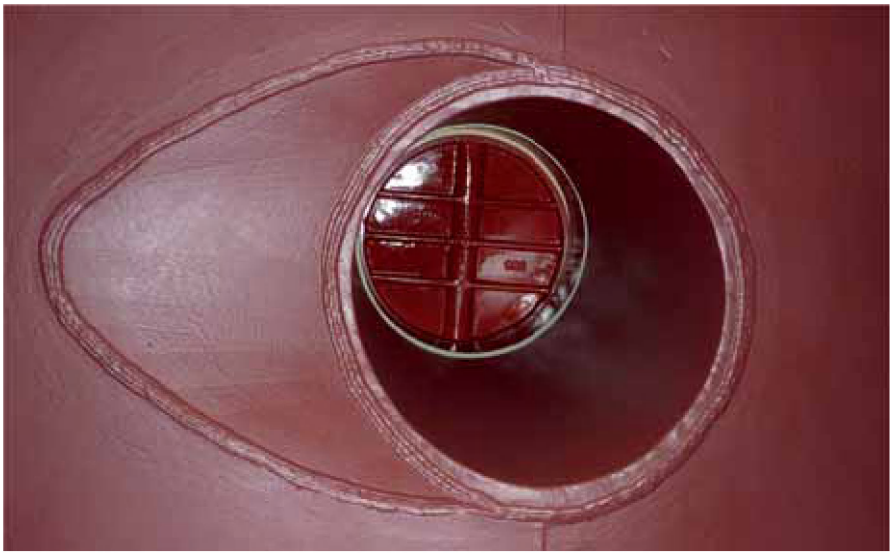
Determining the exact location of an instrument on land or at the surface of the ocean is done by means of satellite based GPS navigation, using radio wave transmission. Since radio waves do not penetrate into sea water, sound waves are used as an alternative to determine the position of scientific instruments under water. During the mid life refit of de RV Pelagia, a Kongsberg HiPAP100 USBL (Ultra Short base Line) navigation system was installed for this purpose. This system consists of a hull unit that communicates with transponders mounted on the instruments of which the location has to be determined under water. From the combination of sound travel time in water, the time needed to transmit information between hull unit and transponder, and the direction of the incoming sound wave transmitted by the transponder, the position of the instrumentation relative to the ship (and thus the geographic coordinates) can be calculated.

The maximum range of the system is 10 km, with a positioning accuracy of 0.2% of the range. This system is expected to become operational in the first half of 2011.



During operation the USBL deployment pole pierces 1.5 m below the ship's bottom

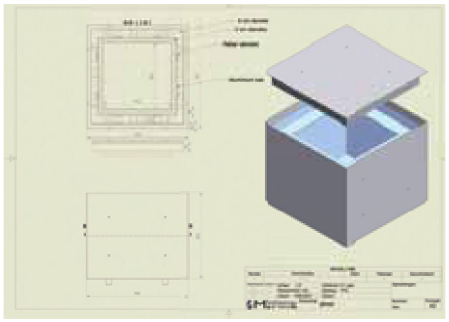
The USBL sonar head in its docking station above the gate valve



Bottom up view from under the vessel looking in the USBL opening.

High accuracy calibration tank

In the physical oceanography department, the generation and behavior of internal waves are studied, because they play a main role in the vertical mixing of the ocean. Since internal waves are registered by means of temperature differences, the sea water temperatures should be measured over a considerable area. For this purpose, very accurate thermistor strings have been developed. Calibrating these thermistors down to 1 mK (0.001 °C) was usually done at sea, in temperature stable water layers in the deep ocean. In practice this often resulted in a limited calibration range of 5 - 7 °C. In the newly designed and constructed 80 liter calibration tank, the calibration range of temperatures has been extended to -2 °C - 30 °C , with an accuracy of 1 mK.



Inauguration of the Lander test basin

The construction the bottom lander test basin was finalized with the installation of a water treatment installation. Now it is ready to use for testing bottom landers and other seagoing instruments and equipment.

Eighteen lab containers on the road

The end of the year was marked by intensive logistic activities for preparing three scientific cruises: two cruises on the German RV Meteor and one cruise on the British RV James Cook. A lot of work had to be done to prepare the transports of 18 laboratory and equipment containers. Under wintry conditions, these containers were delivered in the ports of Rotterdam and Antwerp for further transport.

Happy clients express their compliments

The ultra clean trace-metal group of the Biological Oceanography department was really excited with the field results of the new PRISTINE sampler, as described in the first paragraph.
For this reason, they declared the Marine Technology department to be 'the heart of NIOZ' at a a festive meeting and argued that leading marine technology is a prerequisite for performing state-of-the-art marine science.

New double capstan winch for mooring operations

During mooring cruises on British vessel, the effectiveness of a dedicated double capstan winch was experienced by our scientists and technicians on board. Therefore we have purchased a copy of this Lebus winch to improve our mooring operations.

Data Management Group

Taco de Bruin, Ronald de Koster, Jan Nieuwenhuis, Rob Louws, Ira van den Broek*

2010 was a year with several major new initiatives for the Data Management Group (DMG) as well as consolidation of many other activities. The DMG developed the PEPSy systeem, to keep track of all scientific project-related information. A one week data processing actvity for polar data was organized at the University of Groningen. The DMG took the lead in developing an international polar metadata profile. A new system to log onboard measurements was introduced and scientists and crew were instructed how to work with the new system. In December, the DMG was successful in winning a grant for the NIOZ-led WaLTER project, as leader of the data workpackage.

The DMG is a separate group within the department of Physical Oceanography, funded by NWO-ALW and NIOZ, with a NIOZ-wide and national responsibility for oceanographic data management. The DMG represents NIOZ and the Dutch academic oceanographic community within the National Oceanographic Data Committee (NODC). It also serves as the National Polar Data Centre (NPDC). The main tasks of the DMG are to assist scientists during all phases of a project with data management and, secondly, to archive and keep accessible all relevant data of NWO- and NIOZ-sponsored cruises.

Much attention was given to supporting the Dutch polar researchers, the Dutch IPY projects and the National Arctic and Antarctic Programme (NAAP). Ira van den Broek as the Dutch National IPY Data Coordinator, organized a week dedicated to processing data from the LASHIPA project. A system for management of the data collected on the field station in Sweden by the Vrije Universiteit Amsterdam was developed and scientists were assisted with various data management tasks. All these activities form building blocks of a national polar data management infrastructure. On the international level, the dormant website of the SCAR Standing Committee on Antarctic Data Management (SCADM) was revitalized and rebuilt almost from scratch. At the IPY conference in Oslo, the Polar Information Commons initiative (PIC, www.polarcommons.org) was launched with major input from DMG. The DMG also took the lead in the development of an international, ISO19115 compliant polar metadata profile.

Rob Louws, the national data manager for the ZKO Wadden Sea projects, engaged in developing a data and information system for all scientific projects. This Projects, Expertise and Personnel System (PEPSy) is the central part of a hybrid system of databases through which both metadata and data of scientific projects carried out by NIOZ scientist and others, will be archived and made available. The PEPSy system will be rolled out in 2011. Coupled with PEPSy, data systems for the ZKO Wadden Sea projects have been developed.

Jan Nieuwenhuis is in charge of long term archiving of all raw and final data collected during cruises onboard RV Pelagia and other research vessels. As a member of the committee which started to modernise the NIOZ website, he contributed his experience as web-developer for the DMG to make several project websites as well as maintaining the cruise diaries on the NIOZ website.

Ronald de Koster, senior systems analyst and data base administrator, is responsible for all data and information systems. During the mid-life overhaul of RV Pelagia, a new French system for logging all measurement activities, was installed. The DMG adapted the system to NIOZ-needs and instructed crew and scientists. The regular activities, such as safeguarding the (raw and final) data in a secure archiving system, entering data into the data sharing systems the DMG manages and contributing to the national and European data infrastructures, were continued. The NIOZ data systems are being used very frequently. The CODIS data and information system with hydrographic data had an average of 504 hits per day, while the Corebase system with sediment core metadata even toppled that number with an average of 721 hits per day. In 2010 more than 6000 datasets were downloaded from the NIOZ data bases. Especially important for NIOZ as a whole is expanding the scope of the NIOZ data systems by linking these to larger national and international systems, such as the data infrastructures of the National Oceanographic Data Committee (NL-NODC) and the European SeaDataNet and EMODNet systems. These in turn, are the European contribution to global systems such as GMES and GEOSS.

In December, the management of data from the Wadden Sea got a big boost when the WaLTER project was granted. WaLTER stands for Wadden Sea Long Term Ecosystems Research and aims to harmonize the existing and future monitoring activities in the Wadden Sea on a national and interdisciplinary scale. Taco de Bruin is the workpackage leader for the development of a data access portal for all data related to the Wadden Sea. This Wadden Sea data portal will make use of and be linked to the technical infrastructure developed within the NL-NODC.

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http://www.nioz.nl/dmg

The DMG staff participated in a series of national and international meetings related to oceanographic and polar data management. At these meetings, DMG staff members gave 13 oral presentations and presented 7 posters on various aspects of scientific data management. Taco de Bruin is the NIOZ representative in the National Oceanographic Data Committee (NODC) and chairs the NODC. As participant in the NODC, NIOZ actively participates in international organizations as the IOC Committee on International Oceanographic Data and Information Exchange (IODE) and the ICES-Working Group on Data and Information Management.Taco de Bruin also co-chaired the IPY Subcommittee on Data Policy and Management (until June 2010) and co-chairs the new CODATA Task Group on Governance of Polar Data.

Publications

Dissertations

1. Bauersachs, T. Development and application of proxies for past cyanobacterial nitrogen fixation. Utrecht University, 168 pp.
2. Boere, A.C. Validation and application of fossil DNA as a recorder of past marine ecosystems and environmental conditions. Utrecht University, 176 pp.
3. de Jong, M.F. Hydrographic variability in the Irminger Sea. Utrecht University, 208 pp.
4. Hazewinkel, J. Attractors in stratified fluids. Utrecht University, 107 pp.
5. Jonkers, L.P. Rapid oceanographic changes associated with last glacial ice-rafting events: Observations from the past and present northern North Atlantic. Vrije Universiteit Amsterdam, 142 pp.
6. Kraan, C. Spatial ecology of intertidal macrobenthic fauna in a changing Wadden Sea. Groningen University, 200 pp.
7. Middag, R. Dissolved Aluminium and manganese in the Polar oceans, 237 pp.
8. van den Hout, P.J. Struggle for Safety: Adaptive responses of wintering waders to their avian predators. Groningen University, 200 pp.

Refereed papers in scientific journals

1. Aguilar, J.A. et al. (ANTARES-collaboration incl. H. van Haren). Measurement of the atmospheric muon flux with a 4 GeV threshold in the ANTARES neutrino telescope. Astroparticle Physics 33, 86-90.
2. Aguilar, J.A. et al. (ANTARES-collaboration incl. H. van Haren). Zenith distribution and flux of atmospheric muons measured with the 5-line ANTARES detector. Astroparticle Physics 34, 179-184.
3. Aguilar, J.A. et al. (ANTARES-collaboration incl. H. van Haren). Performance of the front-end electronics of the ANTARES neutrino telescope. Nuclear Instruments and Methods Physics Research A 622, 59-73.
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9. Bahr, A., Pape, T., Abegg, F., Bohrmann, G., van Weering, T., Ivanov, M.K. Authigenic carbonates from the eastern Black Sea as an archive for shallow gas hydrate dynamics - Results from the combination of CT imaging with mineralogical and stable isotope analyses. Marine and Petroleum Geology 27, 1819-1829.
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Symposia, Courses & Public Outreach

Symposia

at NIOZ

Netherlands Marine Geosciences Symposium, 2 September.

The first symposium of the newly started Netherlands Marine Geosciences platform brought together a group of about 45 people (from graduate students to senior scientists) from various universities and research institutes in the Netherlands including NIOZ, Utrecht University, VU Amsterdam, KNMI, and NITG-TNO. The symposium was entitled 'The (paleo-) Atlantic Ocean and global climate' and focused on the role of the Atlantic Meridional Overturning Circulation in global climate. The programme consisted of three oral presentations by Frank Peeters (VU Amsterdam), Lucas Jonkers (UAB, Spain and ex-NIOZ PhD) and Jan-Berend Stuut (NIOZ).

XRF Core Scanning Workshop, 8-10 September

With a growing number of XRF core scanning labs and users, the interest of the community in sharing and exchanging knowledge and experience also increases. The aim of this at NIOZ workshop was to discuss and share experience on application and calibration of XRF data in geosciences, technical aspects and processing of data, and future developments of XRF core scanning. The workshop was visited by more than 60 participants from Europe, USA and China. All major objectives discussed and conclusions are summarized as a workshop report in the Pages Newsletter of May 2011. This workshop was organised by Rik Tjallingii; more details on http://www.nioz.nl/xrfworkshop.

North Sea Days 7 & 8 October

The North Sea Days are meant to bring scientists, policy makers and professional users of the Dutch part of the North Sea together. The main topics of this year were the design of a new monitoring network and developments to increase the sustainability of the maritime and fishing industry. A great success in the program was the presence of fishermen in the audience and the presence of the large North Sea trawler TX 36 'Jan van Toon' equipped with an experimental 'Sumpuls' net, a combination of a sumwing beam of 12m and an electronic pulse net and the small shrimp trawler TX 42 also equipped with a sumwing beam. 175 people attended the North Sea days; a great success.
The North Sea Days are organised by a national committee, chaired by the organizing institute in a particular year. For NIOZ Jan Boon (chair), Herman Ridderinkhof and Carmen Blaauboer formed the local organizing committee.

Symposia

elsewhere, organised by NIOZ scientists

Southern Connections Workshop, Bariloche, Argentina, 15-19 February

The workshop 'Controversies in the Late Quaternary climate of the southern hemisphere' was organised during the four-yearly meeting Southern Connections in Bariloche. This meeting brings together paleo- botanists, ecologists, and climatologists working on environmental change on the southern hemisphere. The workshop attracted 19 abstracts and consisted of 8 oral presentations and 11 posters. It demonstrated once more the importance of the three continents on the southern hemisphere in both regional and global climate development throughout the Quaternary. The workshop's contributions will be published in a special volume of the Elsevier journal 'Quaternary International', which is due in summer 2011 and which is guest-edited by the workshop organisers Kershaw and Stuut (NIOZ).

1st Working Group meeting of the COST Action PERGAMON, Brussels, Belgium, 20-21 April.

This meeting attracted 25 participants and was chaired by Jens Greinert. Strategies were discussed on how to establish links between the different marine, terrestrial and atmospheric scientific groups were discussed as well as the outline for an ESF Theme call that was submitted later in the year. More information on www.cost-pergamon.eu .

Session 'Aeolian dust' at the Annual Symposium of the European Geosciences Union (EGU), Vienna, Austria, 2-7 May.

The session 'Aeolian dust: initiator, player, and recorder of environmental change' was organised by Jan-Berend Stuut during the annual assembly of the EGU in Vienna. The session attracted 45 abstracts from a wide variety of disciplines within the aerosol community. It contained 12 oral presentations (three of them solicited by experts in the field of meteorology, remote sensing, and paleoclimatology) and 33 posters and outlined the state-of-the-art of results and remaining open questions. It was concluded that since the IPCC 2007 report we do have a better understanding of the role of aerosols in the climate system, but that the effects still lack quantification. Both the radiative properties of aerosols as well as their effects on the ocean's carbon pump are still poorly understood.

ISME-13 Symposium 'Microbes, stewards of a changing planet', Seattle, USA, 22-27 August.

Corina Brussaard organized the session 'Biogeochemistry: microbially driven, globally significant'.

17th International Conference on Aquatic Invasive Species, San Diego (USA), August 29 August–12 September.

NIOZ had 5 speakers in the session 'Ballast Water Treatment systems; current status and future perspective' and Marcel Veldhuis as keynote speaker.

2nd Working Group meeting of the COST Action PERGAMON, Brussels, Belgium, 18-20 October.

A series of oral presentations were given on terrestrial, marine and atmospheric topics related to methane release in the Arctic. The Working Groups defined their specific questions related to future impacts of the Arctic region on global climate development. New contacts between members were established by listing ship cruises and field campaigns on the PERGAMON website. 45 participants joined this meeting, which was again chaired by Jens Greinert.

International Conference & Exhibition 'Ballast Water Management', Singapore, 1–4 November.

Will there be instruments in the near future to rapidly sample and check the IMO D2 Standards without causing delay to ships? This commercial and logistic key question was discussed during the session 'Ballast water Treatment systems; current status and future developments' with 3 speakers from NIOZ and Marcel Veldhuis as key-note speaker and session convenor.

Courses at NIOZ

Combined Courses 'Marine Biology and Marine Ecosystems' 29 March–16 April.
This course is organized jointly by NIOZ and the University of Groningen (RUG). This year, it was organized by Margot Bik, Marcel Veldhuis and Hein de Baar* with the commitment of several NIOZ colleagues. The two annual practical courses for marine biology bachelor students of the University of Groningen were given as one package. A group of 26 students was divided into six teams; every team worked on two different research topics of seven working days each. The topics covered a wide range including trace metals, invasive species in ballast water, organic contaminants, optics and remote sensing, plankton communities in the Marsdiep, time series of chemistry and plankton biology at the NIOZ jetty, the energetics of blue mussels, viral impact on phytoplankton blooms, DNA characterization of cryptic species of polychaete worms, and tidal migration of fish larvae and gelatinous zooplankton. On the final day of the course, the student teams presented their results.
In their evaluation, the students offered high marks to the course and, moreover, contacts were made for follow-up research projects at NIOZ for their MSc degree programme.
*Contact person: hein.de.baar@nioz.nl

FOKUZ Marine Master Course 'How does the sea work?', 4 – 16 July.
This course was organized by Martien Baars and Herman Ridderinkhof*. It is an activity of FOKUZ ('Fundamenteel Onderzoek KUst en Zee'), a co-operation in marine research and education by NIOZ and the Centre of Estuarine and Marine Ecology (NIOO-CEME, Yerseke). In the framework of the Netherlands Marine Master's Program – an agreement between FOKUZ and four Dutch universities - the course aims to make students in their master study period familiar with a variety of field work in the major disciplines in oceanography: physical oceanography, marine chemistry, marine biology and marine geology. In total, 21

Sampling at the tidal flat 'Balgzand'

Musselwatch experiments

Accurate measurements of the body size of crabs

After the end of the FOKUZ course, Martien Baars went into retirement; seems he is going to miss it....

students participated, with 6 master students from physical oceanography (Utrecht University), 1 from a biogeological study (also Utrecht University), 13 from marine ecology studies (3 from the University of Amsterdam, 7 Vrije Universiteit Amsterdam and 3 Groningen University) and 1 PhD student from NIOZ itself.
The lectures during the course were given by 15 NIOZ and 3 CEME scientists. Field work consisted of a section in the western Wadden Sea, surveyed by RV Navicula, time-series monitoring at a tidal station in the Marsdiep-inlet, and sampling at the intertidal flats 'Balgzand' and 'Vlakte van Kerken'. The topics included hydrography, a multibeam survey, core stratigraphy, microplankton foodweb, benthic communities, mussel bed dynamics and the distribution of crabs. Subgroups of 3 students processed and presented their findings at the end of the course.
*Contact person:: herman.ridderinkhof@nioz.nl

NEBROC and Ecolmas PhD course, 'Molecular Organic Biogeochemistry'. 27 September –1 October

The course was organised by Stefan Schouten* and Ellen Hopmans in collaboration with several other members of the BGC department in the framework of the Netherlands Bremen Oceanography Collaboration NEBROC (and also partially funded through this network). The course consisted of lectures by Stefan Schouten, Jaap Sinninghe Damsté, Jan de Leeuw, Ellen Hopmans, Marcel van der Meer (all NIOZ), Julius Lipp (Bremen University) and Gesine Mollenhauer (AWI-Bremerhaven). The topics included the use of instrumental techniques, biomarker lipids, organic proxies, kerogen formation, stable isotopes and radiocarbon isotopes and intact polar lipids in biocgeochemical research and microbial ecology.
In addition to the lectures, demonstrations of analytical equipment were given at the BGC lab and working group sessions on the interpretation of analytical data. The day ended by student presentations in which PhD students briefly presented their (future) research project.
The course was attended by 8 NIOZ students and 26 external students, of which 15 from Germany and the remainder from Scandinavia, UK, France, USA, China and Japan. Since this course was oversubscribed (>50 students expressed an interest to attend), it will be held again from 7-11 February 2011.
*Contact person: stefan.schouten@nioz.nl

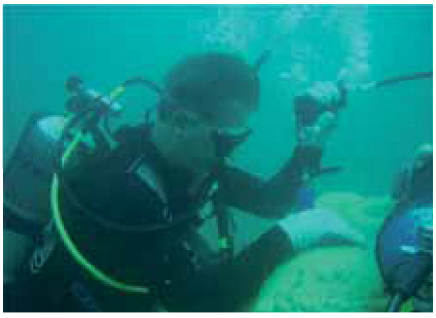
Public Outreach

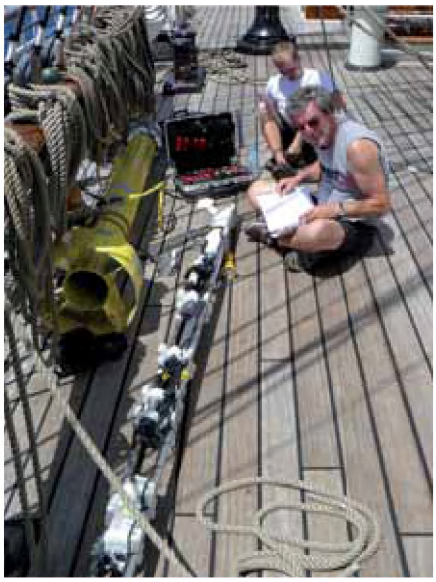
*Jan Boon**

Two main events took place in October: the North Sea Days and the Open day. The Beagle Voyage of the clipper 'Stad Amsterdam was broadcasted on the national VPRO TV until May, as the final part of the Darwin Year.
In 2010, NIOZ scientists contributed to 38 articles in national newspapers (e.g. NRC, Volkskrant, Trouw, Reformatorisch Dagblad, AD, de Telegraaf), 75 articles in regional newspapers (e.g. Texelse Courant, Noord-Hollands Dagblad, Friesch Dagblad) and 25 articles in either Technical (e.g. Bionieuws, Visserij Nieuws, Technisch Magazine) or popular Scientific (e.g. Quest, NWO hypothese, EOS) magazines. Together, this represented an advertisement value of €653,746. Our value for 2010 was also above that of 2009 (€500,126). A list of all public outreach items is available in the electronic supplement to this annual report.**

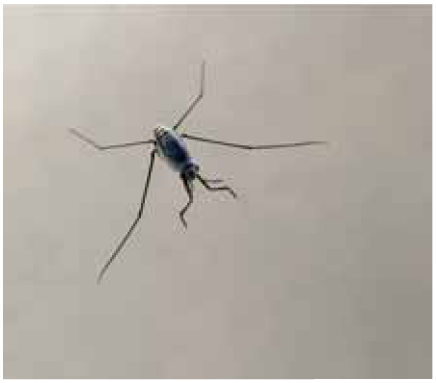
Beagle Voyage 2009-2010.

The Beagle voyage by the clipper 'Stad Amsterdam' was broadcasted by the Dutch company VPRO with weekly episodes on Dutch and Belgian television till the end of May. This project was in honour of the 200th anniversary of Sir Charles Darwin and the 150th anniversary of his famous book 'On the origin of Species'. As in 2009, a number of NIOZ scientists joined legs of the sailing trip. Martien Baars collected sea skaters *Halobates* during the Tahiti – Sydney leg, Jan-Berend Stuut was involved in an episode on the feasibility to fertilize our oceans with iron from dessert dust along the Australian coast and Herman Ridderinkhof explained the influence of the global ocean current system on our planet's climate during a leg in the Indian Ocean from Mauritius to Cape Town. Scientifically very rewarding was a separate expedition by Geert-Jan Brummer and Roel Nagtegaal to the Cocos Keeling Islands. Purpose was to drill a core of a very large coral colony to reconstruct climate changes in this tropical area since Darwin tested his hypothesis on the formation of coral islands in 1836. The sampling was very successful as the core they obtained showed annual growth rings back to 1795! The TV episode on climate change with Geert-Jan and Roel was one of the highlights of the Beagle series.





Beagle items were also broadcasted on radio and were presented on a large multi-media internet site (www.beagle.vpro.nl). NIOZ participants contributed to 33 weblogs to this site during 2010. In addition, there was a Beagle Day in the Academy Building of Utrecht University on 7 March where NIOZ displayed her research to the large audience of Beagle-fans of The Netherlands.



*: corresponding author jan.boon@nioz.nl

**: source 'de Knipselkrant' .

Open day on 9 October

Highlight of the outreach to the general public was the Open day of NIOZ, IMARES and SOVON (all inhabitants of our building) on Saturday 9 October. We can look back to a very successful day on which 1315 people were actually counted to have visited the institute; mainly from Texel and the province of North Holland.

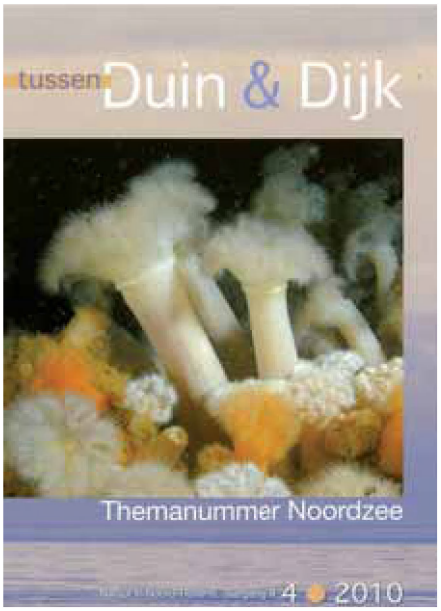
Silent water and internal waves in a stratified water column

Take your own sample from the sea floor.

Influence of pressure on the shape of equipment....

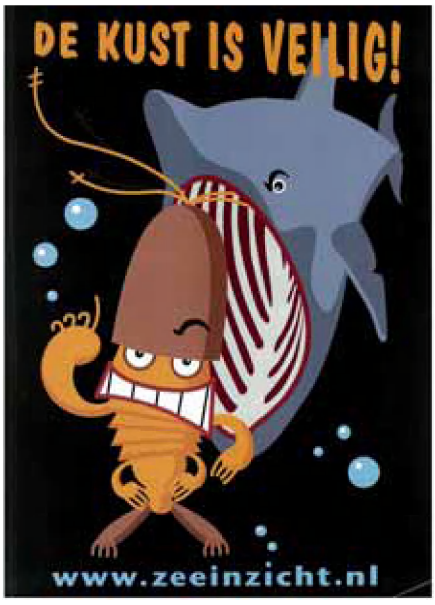
Special issue 'Tussen Duin en Dijk on the North Sea

Another highlight was the special marine issue of the magazine 'Tussen Duin en Dijk' entirely on the North Sea with 7 contributions from NIOZ scientists: plankton- Katja Philippart, seabirds and marine mammals – Kees Camphuysen, the Frisian front system - Martien Baars, marine pollution – NIOZ associate Cato ten Hallers. Our retired but still very active NIOZ scientist Gerhard Cadee was the guest editor of this issue.



Zee in Zicht/ Sea on Screen

The website 'Zee in Zicht' on the Dutch regional seas was further restyled to become more attractive for a teenage audience and a new poster/postcard was designed by illustrator Valentine Edelmann. The character 'Robbie Roeipootkreeft' ('Copepod Robby') will act as a host on parts of the website, but only on the Dutch version since the English version Sea on Screen targets a slightly older audience' ; www.zeein-zicht.nl or www.seaonscreen.org



NIOZ news in the media

The media star organism of 2010 was the knot. This wading bird was good for a number of media moments, although not at all happy: In 'De Groene Amsterdammer', Theunis Piersma explained that our Wadden Sea lacks biodiversity compared to the Banc d'Arguin in Mauritania, the wintering area of these birds. Sea grass-fields represent the richest habitat there, whereas they have almost completely disappeared from 'our' Wadden Sea. But even the Banque 'd Arguin is not an ideal place, since the wintering knots face the danger of being caught by birds of prey. Young birds are more at risk than older ones, which apparently learn to avoid danger. All this was shown by PhD student Piet van den Hout, who graduated in December. Few people get the honour to have a species named after them. It has happened to Theunis Piersma, and of course it is a knot: *Calidris canutus piersmai*, which lives in Asia and Australia. This was featured in the Dutch version of the National Geographic Magazine in September.

Immediately adjacent to the rich Banque d'Arguin is the Sahara and its dust formed another highlight. Dessert dust research in an Oceanographic Institute? Yes, because off-shore winds transport this dust towards the Atlantic Ocean where it finally settles on the sea floor. NIOZ tenure track geologist Jan-Berend Stuut and his co-workers found that for many ages in the past there is a clear inverse correlation between the amounts of dust blown into the sea and humidity on land. This suddenly stopped in the mid 19th century, when the amounts of dust increased even in relatively wet years. This coincided with the introduction of colonial peanut crop, which rapidly exhausted the soil, leaving unfertile sand that was blown to the ocean easily. Jan-Berend featured in an article in the popular science magazine 'Hypothese' of our umbrella organization NWO and he also appeared several times on TV and on the radio.

Together with their colleagues from Utrecht University and the University of Southampton - our biogeochemists Jaap Sinninghe Damsté and Stefan Schouten published a paper in Science which showed a clear relation between the high carbon dioxide levels and temperature during the Eocene; the peak in the CO_2 levels was about 3000 ppm, compared to 'only' 390 ppm in today's world. Clear indications were obtained that the temperature rise followed the rise in CO_2 levels.

Al lot of media attention was also given to an article on the increase of biodiversity in the western Wadden Sea. Towards the end of the year, our biologists Jan Beukema and Rob Dekker published a paper which showed to the surprise of many that the biodiversity of the benthic invertebrate macro fauna of the intertidal flat 'Balgzand' has increased over the last 40 years. Among the organisms that increased were invading species from other continents, organisms that immigrated from the areas south of the North Sea, and organisms that moved to the higher parts of the flat from the gullies. However, typical cold water species decreased.

Comments of NIOZ scientists on external events

NIOZ scientists are increasingly sought to give their opinion on events in seas and oceans. By far the largest event in 2010 was of course the explosion on the oil-rig 'Deep Water Horizon' and the large blow-out in the Gulf of Mexico in which close to 800 million litres of oil were finally spilt. NIOZ biologist Kees Camphuysen explained already shortly after the explosion in the 'Volkskrant', that the consequences of such disasters often bear no (linear) relation to the amounts of oil being spilt, but that the nature of the ecosystem also plays a main role. He was heavily criticized for this statement in the beginning, but towards the end of the year he proved to be largely right, at least where seabirds and marine mammals are concerned. The role of bacteria that can degrade oil in the presence of oxygen was highlighted by Corina Brussaard in the prime-time TV news program 'Pauw & Witteman'.

In March, a totally exhausted female juvenile Orca named Morgan was caught by people of the 'Dolfinarium Harderwijk' with the initial idea to cure her and release her to the open sea at a later stage. Kees Camphuysen was one of the seven international experts who pointed out the enormous risks when the origin of the animal in question is unknown to the responsible Ministry of Economic Affairs, Agriculture & Innovation. Orca's live in family groups and a few examples have shown that the release from capture of an animal can only be successful when the family groups location is known and the animal can be reconnected with its family. This led to a strong controversy with action groups pleading for the release of Morgan into the wild.

NIOZ also took immediate action when a number of very sticky dead birds washed ashore in North Holland. Kees Camphuysen organized their collection and some of the glue-like material which had totally deteriorated the plumage of the dead birds was analysed by the BGC laboratory; it proved to be poly-isobutylene, very probably from a tank-wash by a bulk carrier. This compound is indeed regarded as quite harmless in the standard toxicology sheet and regulated under the MARPOL treaty the International Maritime Organisation (Annex-II), but clearly the possible consequences for seabirds are heavily underestimated. Kees Camphuysen explained in the media and during the North Sea days that the occurrences of spills of other compounds than mineral oil by shipping appear to increase and that we still know very little about their identity.

In May and June, high-numbers of jellyfish occurred along the Dutch coast and swimmers were repeatedly stung by the compass jelly fish . Hans Witte and PhD student Lodewijk van Walraven commented on this by stating that, indeed, numbers of jellyfish in the NIOZ fike appear to increase. The reason for this is at present still unknown; possible candidates are heavy fishing, climate-change and, in case of the comb-jelly *Mnemiopsis leidyi*, import with ballast water.

Compass jelly fish; a plague for swimmers? Photo: Astra Ooms

Organization

BOARD AND SCIENCE COMMITTEE

Board

As per 31 December 2010, the Board consisted of the following members:

prof.dr.ir. P. Vellinga (chairman)	Wageningen University and Research Centre
prof.dr. E.A. Koster	Utrecht University , Faculty of Geosciences
prof.dr. J.T.M. Elzenga	CEES, Groningen University
G.F.C. van der Kamp	Naarden
ir. A. Lubbes	Fugro, Leidschendam
prof.dr. W.P.M. de Ruijter	IMAU, Utrecht University

In the report year 2010, Board and directors gathered five times, on 21 January, 18 March, 20 May, 24 September and 25 November.

On behalf of the general director of NWO, the meetings were attended by mrs. P. Vogel (NWO-CPI).
The minutes were made by mrs. C.S. Blaauboer-de Jong.

Science Committee

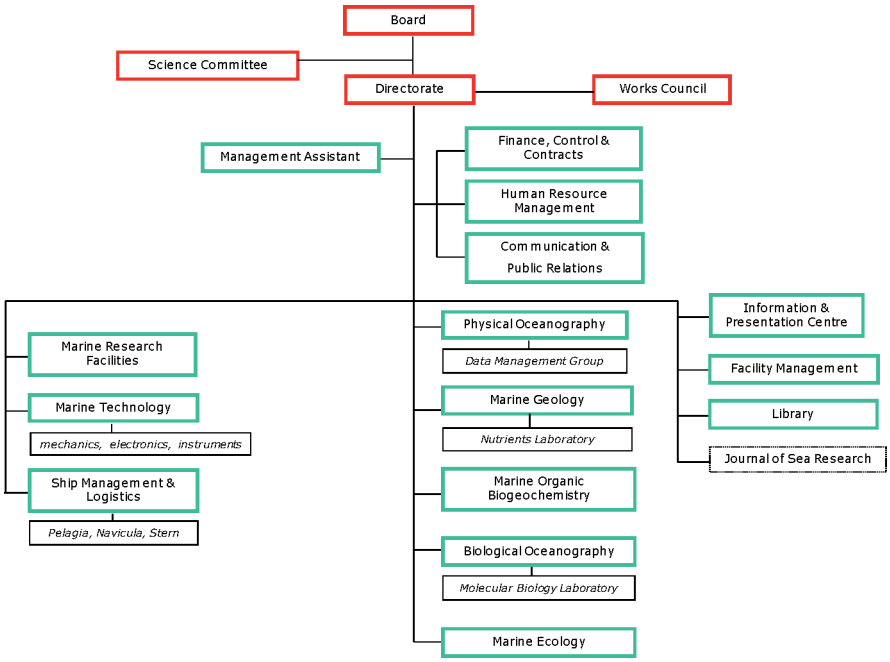
The Science Committee advises the Board and the directors with regard to the general scientific policy of the Foundation and the Institute, she evaluates periodically the scientific programme of the institute.

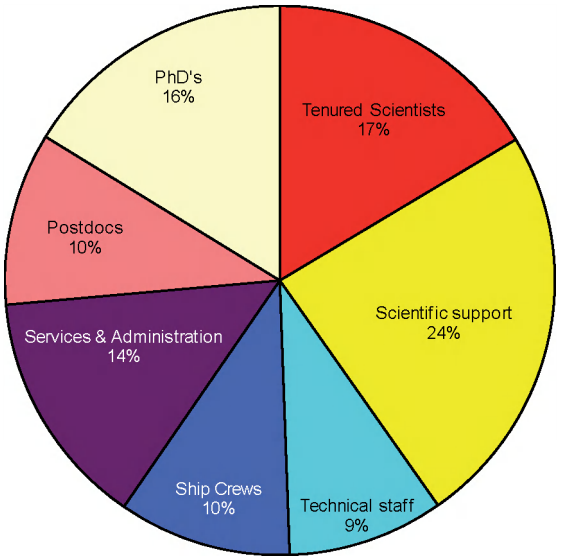
As per 31 December 2010, the Science Committee consisted of the following members:

prof.dr. W.P.M. de Ruijter (chairman)	IMAU, Utrecht University, The Netherlands
prof.dr. A. Boetius	MPI for Marine Microbiology, Bremen, Germany
prof.dr. P. Burkill	Sir Alistair Hardy Foundation for Ocean Sciences (SAHFOS), Plymouth, United Kingdom
prof.dr. J.J. Middelburg	NIOO-KNAW CEME, Yerseke and Utrecht University, The Netherlands
prof.dr. P. Weaver	NERC, Southampton, United Kingdom

In 2010, the Science Committee gathered on Texel on 20 and 21 May.

Organogram





NIOZ formation as percentage of total FTE's (225,49) at 31 December 2010. Total of employees was 251 (undergraduate students not included)

Staff list

Directors and Staff
Heip C.H.R. prof. dr.
Ridderinkhof H. prof. dr.
Koning F.A. dr.
Kralingen P. van
Blaauboer-de Jong C.S.
Raad I. de

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Vos T. MSc
Arkel M.A. van MSc
Gootjes J.P.
Groot S.P.
Honkoop P.J.C. dr.
Keijser A.
Kooijman-Biermans M.H.M.
Poleacov-Maraiala C.
Rotee Q.D.
Tuinen H.A. van
Wernand-Godee I.

Human Resource Management
Vooijs P.C.
Evers J.M.E.
Dapper R.
Kuip T.
Mulder-Starreveld J.P.

Communication & Public Relations
Boon J.P. dr.
Baars M.A. dr.

Physical Oceanography
Aken H.M. van dr.
Maas L.R.M. prof. dr.
Broek I.R.P. van den
Bruin T.F. de MSc
Eijgenraam F.
Gerkema T. dr.
Groeskamp S.
Haren J.J.M. van dr.
Hazewinkel J. MSc
Hiehle M.A.
Hillebrand M.T.J.
Hout C.M. van der MSc
Jong M.F. de dr.
Koster R.X. de
Louws R.J.
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Tiessen M.C.H. dr.
Ullgren J.E. dr.
Wagemaakers F.F.M.
Wernand M.R.
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Marine Geology
Greinert J. prof. dr.
Brummer G.-J.A. prof. dr.
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Epping H.G. dr.
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Gonzalez S.R.
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Henry-Edwards A.G. dr.
Kasper S. MSc
Löbl L. dr.
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Mulder L.L. MSc
Nagtegaal R. MSc
Ooijen J.C. van
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Tjallingii R.H. dr.
Weerlee E.M. van
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Zinke J. dr.

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Bale N.J. dr.
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Booij K. dr.
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Lopes dos Santos R.A.F. MSc
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Pitcher A.M. MSc
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Mulder M.
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Oudman T. MSc
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Segers J.L
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Weerlee E.M. van
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Witte J.IJ.
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Boks-Visser H.
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Heerschap J.H.
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Heerwaarden J. van
Keijzer E.J.H.
Marine Technology Electronics
Groenewegen R.L.
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Cluderay J.M.N.
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Boom L.
Gieles S.J.M.
Grisnich P.W.
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Adriaans E.J.
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Vis P.C.A. van der
Vorsselen W.S.F. van
Vries H. de
Vries M.J. de

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Bak R.P.M. prof.dr.
Beukema J.J. dr.
Cadée G.C. dr.
Leeuw J.W. de prof. dr.
Wolf P. de dr.

Guest scientists
Bik M.H. MSc
Cardoso J. dr.
Corte D. De Msc
Fuhr F. MSc
Goeij P.J. de dr.
Hallers-Tjabbes C.C. ten dr.
Jager C. de prof. dr.
Leote C. MSc
Lok T. MSc
Santos S. MSc
Saraiva S.A. MSc
Vooys C.G.N. de dr.

Financial report

Financial Report

*Tjerk Vos**

All amounts should be multiplied by € 1000 and are rounded to the next € 1000.
Negative amounts are given in brackets.

Balance sheet

all amounts x € 1.000

ASSETS	31-12-2010	31-12-2009	LIABILITIES	31-12-2010	31-12-2009
Fixed assets			**Capital and reserves**		
Intangible fixed assets	0	1	Foundation capital	0	0
Tangible fixed assets	37,267	32,646	Free reserve	(4,681)	(5,168)
			Designated reserve	6,847	6,076
			Special reserve fund	32,542	28,959
	37,267	32,646		34,708	29,867
Current assets					
Stocks	39	82	**Provisions**	1,266	2,036
Receivables	9,689	5,509	**Long term debts**	1,846	1,996
Cash and cash equivalents	1,245	4,602	**Short term debts**	10,421	8,941
	10,974	10,193		13,533	12,973
Total assets	**48,241**	**42,839**	**Total liabilities**	**48,241**	**42,839**

*Corresponding author: tjerk.vos@nioz.nl

Profit and Loss account

all amounts x € 1.000

	2010 actual	2010 budget	2009 actual
Profit			
Grants			
NWO basic funding	11,426	11,666	11,626
NWO investment funding	6,175	2,134	1,855
NWO additional funding	1,630	1,430	1,370
Project-based external funding	10,860	9,010	8,681
Total grants	30,091	24,240	23,531
Other operating income	589	350	442
Available provisions	408	92	-
Interests received	15	75	65
Total other income	1,012	517	508
Total profit	**31,103**	**24,757**	**24,039**
Costs			
Personnel costs	13,717	15,924	13,031
Other operating costs	6,692	5,725	6,189
Depreciation	4,260	4,284	3,799
Allocation provisions	105	60	876
Interest paid	66	71	67
Total costs	24,840	26,064	23,962
Financial costs			
Change project liabilities	1,422	(770)	(1,500)
Subtotal	1,422	(770)	(1,500)
Total costs	**26,262**	**25,294**	**22,461**
Operating result	**4,841**	**(537)**	**1,578**
Profit appropriation	(4,354)	1,279	(361)
Result after profit appropriation	**487**	**742**	**1,217**

Cashflow statement

all amounts x € 1.000

	2010		2009	
Operating cashflow				
Balance income and expenses	4,841		1,578	
Adjustments				
Depreciation	4,260		3,799	
Movement provision	(770)		533	
	3,490		4,332	
Moving working capital				
Receivables	(4,180)		(1,661)	
Stocks	43		(3)	
Short term liabilities	1,480		170	
	(2,658)		(1,494)	
	5,673		4,416	
Moving working capital		5,673		4,416
Receivables				
Stocks				
Short term liabilities				
Investments intangible fixed assets	0		0	
Investments tangible fixed assets	(9,070)		(5,434)	
Drop in investments	190		2	
Investment cashflow		(8,880)		(5,432)
Financing cashflow				
Redemption mortgage	(149)		(145)	
Finance cashflow		(149)		(145)
Total cashflow		(3,357)		(1,162)
Cash balance as at January 1		4,602		5,764
Total cashflow		(3,357)		(1,162)
Cash balance as at December 31		**1,245**		**4,602**