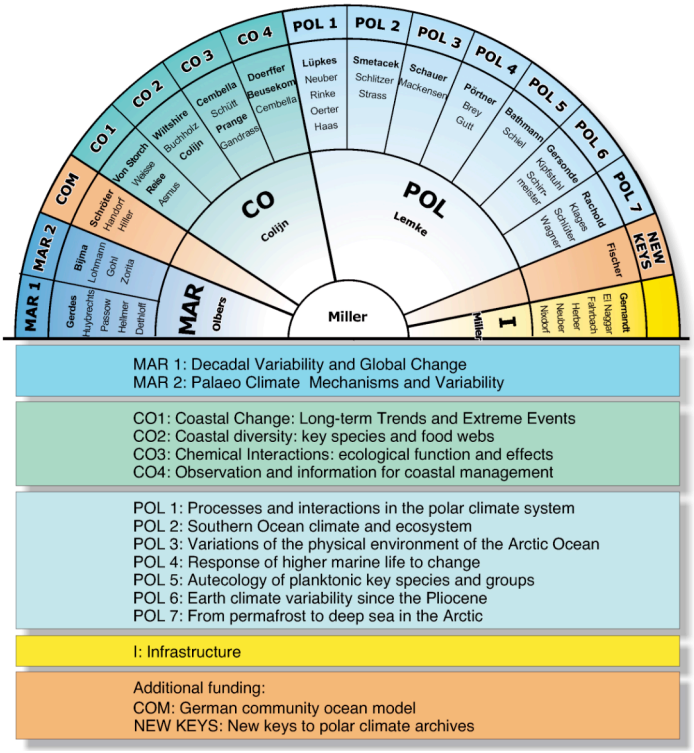
Marine, Coastal, Polar Systems & Infrastructure

MARCOPOLI



MAR 1: Decadal Variability and Global Change
MAR 2: Palaeo Climate Mechanisms and Variability

CO1: Coastal Change: Long-term Trends and Extreme Events
CO2: Coastal diversity: key species and food webs
CO3: Chemical Interactions: ecological function and effects
CO4: Observation and information for coastal management

POL 1: Processes and interactions in the polar climate system
POL 2: Southern Ocean climate and ecosystem
POL 3: Variations of the physical environment of the Arctic Ocean
POL 4: Response of higher marine life to change
POL 5: Autecology of planktonic key species and groups
POL 6: Earth climate variability since the Pliocene
POL 7: From permafrost to deep sea in the Arctic

I: Infrastructure

Additional funding:
COM: German community ocean model
NEW KEYS: New keys to polar climate archives

Midterm evaluation

22. – 23. May 2006

ALFRED – WEGENER – INSTITUTE,
HELMHOLTZ CENTRE
for
POLAR AND MARINE RESEARCH

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Introduction

This written document forms the basis for the so-called mid-term review of Alfred Wegener Institute for Polar and Marine Research by its Scientific Advisory Board. Mid-term because of the 5 year funding cycle of our present research program MARCOPOLI, which, after a strategic review in 2003 by a panel of international experts, actually started in 2004 and provides about 80 % of our basic funding.

According to Helmholtz guidelines the Scientific Advisory Board is asked to review our program activities as well as the non-program oriented research carried out, which means that all activities of the institute are in some way represented in this document.

Helmholtz Society and strategy

The 15 German national research centers have organized themselves within the Helmholtz Society. Their task is research towards solving the large and urgent problems arising in science, society and economy.

To this end Helmholtz Society focuses on 6 research areas, namely:

- Energy
- Earth and Environment
- Health
- Key technologies
- Structure of matter
- Traffic and Space

Helmholtz scientists investigate complex systems, which determine the wider environment of human life and its societal base.

Research within Helmholtz Society is directed towards securing sustainable living conditions and to broaden the technological bases for a competitive economy. Within this broad strategy research programs are defined in the 6 research areas. These research programs focus on particular topics and if applicable bundle the expertise of different Helmholtz centers thus ensuring the best possible results.

AWI's profile

The Alfred Wegener Institute for Polar and Marine Research is a multidisciplinary scientific institution. AWI is the German national polar research institution and as such promotes and carries out polar and marine science to further our understanding of the variability and functions of the global environment and of the earth system based on observations, modeling and applications. The polar and global scale research is augmented by mid-latitude marine biological research dedicated mainly towards shelf sea and coastal systems research.

AWI operates a number of large-scale infrastructure facilities, which are made available for the wider scientific community. The facilities range from ships, aircrafts, polar research stations to instrumentation pools.

AWI's research program is an integral part of the Helmholtz research area "Earth and Environment"

"Marine, Coastal, Polar Systems and Infrastructure" (MARCOPOLI) investigates the physical, biological and geo-scientific base of global marine systems including coastal regions and, with special emphasis, the polar regions. Processes and interactions, occurring in these systems, play central roles for global climate and hence for environmental change. For this reason, the actual changes in key regions and the responsible processes as well as global changes documented in specific archives are focal points of interest. As major goal it is envisaged to develop a model system with predictive capability which includes the interactions between the cryosphere, the oceans and the marine bio- and geo-chemosphere and quantifies the impact of these regimes on climate, flow of energy and matter and biodiversity on various spatial and temporal scales. Based on this understanding, the second goal is to develop scenarios for the management and sustainable utilization of the marine environment, in particular of the coastal zones.

The following objectives reflect the collaborative efforts of the contributing scientists who cover many different scientific disciplines:

To investigate the oceans' role in global climate processes and change by

- Synthesis of data and models of varying complexity
- Bridging the gaps between physical and biological sciences
- Modeling marine biogeochemistry including the functional role of organisms
- Reconstructing global climate since the Cenozoic

To evaluate natural and anthropogenic processes within coastal regions and define knowledge based management tools by

- Identifying key processes responsible for coastal changes
- Developing strategies for the sustainable use of marine living resources
- Developing an operational monitoring system for the North Sea

To assess the role of the polar regions within the earth system by

- Identifying key processes responsible for recent changes
- Quantifying lithosphere-ocean-cryosphere-atmosphere interaction
- Reconstructing global climate cycles from polar archives
- Unraveling the role of climate for evolution, biogeography, and biodiversity

We feel that the general development of our program is in line with the original projections although we also realize that there is always room for improvement. In general we can say that the program as defined has led to more interaction between the different scientific disciplines at AWI and new outlooks are starting to emerge from this increased interaction. The actual workload within the different topics is carried out within work packages and interaction between work packages is ensured by the fact that quite a number of scientists share their work and expertise between different work packages.

Through a large number of external collaborations on the national and international level MARCOPOLI contributes to national and international scientific programs and by its inherent long-term approach and predictable funding forms a reliable backbone within such programs. There is a notable impact on the national level especially through the large number of collaborating universities, where leading AWI staff hold professorships.

Management of the program and general AWI research is shared by work package speakers, topic speakers and heads of AWI scientific departments and sections, some of whom do this in dual capacity. This scheme allows for the necessary focus and flexibility and ensures high disciplinary standards.

Topic MAR: Ocean and Global Climate

(Spokesman: Prof. Dr. Dirk Olbers)

Report on the general development of MAR

The Programme Topic MAR – Ocean and Global Climate was initiated to acknowledge that climate dynamics and climate change in polar and coastal regions are research items which can only be dealt with on the basis of sufficient understanding of the global climate system. In MAR there is specific emphasis on the global ocean. It provides a link between polar and extra-polar parts of the climate system. On shorter time scales up to decades, ocean and atmosphere contribute to climate variability. For climate variations on time scales from multi-decades to thousands of years, the ocean is considered the key component. On even longer time scales polar ice sheets come into play. On time scales of tectonic changes, with opening or closing of water passages, the ocean circulation adjusts to the changing continental geometry. Changes in the abundance and isotopic composition of marine biomass are affected by climate conditions and document climate change in the oceanic sediment, providing an archive of climate history. All these are research issues of the Topic MAR. A major research focus of MAR is the cycle of freshwater and its impact on the climate system. The decreasing reservoir of ice in the Arctic Ocean and on Greenland is a potential driver of an increased hydrological cycle, affecting the sea-ice area, the albedo, the air temperature and the strength of the meridional overturning in the North Atlantic. Our modelling results show severe changes of sea level in the entire North Atlantic domain.

MAR thus combines our efforts for understanding global scale processes to meet the objectives of MARCOPOLI which are relevant to this topic, namely to investigate the ocean's role in global climate processes and change by

- *Synthesis of data and models of varying complexity*
- *Bridging the gaps between physical and biological sciences*
- *Models of marine biogeochemistry including the functional role of organisms*
- *Reconstruction of global climate since the Cenozoic*

As outlined in the following report the scientists of MAR have made major contributions to all these issues. MAR started with the two work packages MAR1 (Decadal Variability and Global Change) and MAR2 (Palaeo Climate – Mechanisms and Variability) and has adopted the additional funding project COM (Community Ocean Model). In the course of work various cooperations with other work packages came into being. A major step in the productivity of MAR2 was achieved with the establishment of a professorship for palaeodynamics (Prof. Lohmann) and the subsequent building of a corresponding research group.

We have acquired external funding to support MAR research. Outstanding is the EU project GLIMPSE (Global implications of Arctic climate processes and feedbacks). It aims at quantifying the performance scores of three individual Arctic regional atmospheric models.

We have organized some MAR specific science meetings. As an important example we mention the workshop on Global impacts of Arctic climate processes, organized by AWI and held in Potsdam, Germany from September 5-7, 2005, with experts from the United States, Canada, Europe and Russia, to address regional Arctic climate processes and their global feedbacks. The focus was on regional models of the Arctic, global coupled climate models and Arctic impact studies.

Workpackage MAR1: Decadal Variability and Global Change
(Spokesman: Dr. Rüdiger Gerdes)

Academic results

A) Atmospheric decadal-scale climate variability

By means of simulations with a global coupled AOGCM it is shown that changes in the polar energy sink region exert a strong influence on the mid- and high-latitude climate by modulating the strength of the mid-latitude westerlies and storm tracks. It is found that a more realistic sea-ice and snow albedo treatment changes the ice-albedo feedback and the radiative exchange between the atmosphere and the ocean sea-ice system. The planetary wave energy fluxes in the middle troposphere of mid-latitudes between 30^{o} and 50^{o} N are redistributed, which induces perturbations in the zonal and meridional planetary wave trains from the tropics over the midlatitudes into the Arctic. The improved parameterisation of Arctic sea-ice and snow albedo turned out to trigger changes in the Arctic and North Atlantic Oscillation pattern with strong implications for the European climate.

An idealised model of the northern hemisphere atmospheric winter circulation showed that the Northern Annular Mode arises from an annular pattern on a rotating aqua-planet. It is modified to a zonally asymmetric pattern by land-sea contrasts and orography connected with the localisation of transient baroclinic activity. Dynamical mechanisms of atmospheric regime behaviour are investigated in the context of a quasi-geostrophic three-level T21 model of the wintertime atmospheric circulation over the northern hemisphere. The model has realistic orography and uses a thermal forcing determined by a newly developed tuning procedure. It represents a reasonable climatology and simulates the Arctic Oscillation quite realistically. It exhibits pronounced internally generated interannual and decadal variability and, in particular, circulation regimes which agree fairly well with observed ones. Two known hypotheses about the origin of regime behaviour, as it occurs in our model, are addressed: (i) multiple equilibria and (ii) chaotic itinerancy between attractor ruins. The first hypothesis is falsified at a very high probability, while the second is likely to be true.

A new statistical approach to quantify dynamical and chemical contributions to total ozone variability has been developed. It was found that the day to day variability is dominated by a new dynamical proxy, which describes the combined effect of convergence/divergence in the flow and horizontal advection. A Lagrangian model of water vapour transport in the tropical tropopause has been developed. This new tool to study water vapour flux into the stratosphere is the first that relies on the thermodynamic equation for the formulation of the vertical transport and will result in more reliable fluxes than previously used in models.

B) Extreme anomalies and climate change

The Weddell Polynya is thought to be associated with processes that occurred in connection with the sea mount Maud Rise, centred at 65°S just east of the prime meridian. Here the static stability of the water column is particularly low through upward doming of the pycnocline, which easily leads to exchange of surface and deep water. After the mid-1970s a whole-season Weddell Polynya lasting a whole winter has not been observed anymore, but instead numerous transient polynyas have been sighted, near Maud Rise but also at other places, Moreover, the seasonal ice cover of the Weddell Sea mostly opens up first in the region near Maud Rise, instead of much further to the north near the ice edge. Within MAR1 we investigate by means of fieldwork and data analysis the mechanisms which might lead to a new large polynya.

The hydrographic data from the ISPOL expedition (Ice Station POLarstern, ANT XXII/2) into the western Weddell Sea were compared with the only other existing data from this area, obtained during the expedition Ice Station Weddell (ISW-1) in 1992. This revealed significant differences in the characteristics of winter- (WW) and bottom water (BW). The low salt WW (at the end of the Antarctic winter) during ISPOL led to a more stable pycnocline, which reduced the oceanic heat flux into the sea ice to only a few W/m^2 on an average. According to the analysis of tracer data at the IUP Bremen, the low temperatures of the BW at about 1500 m depth can be ascribed to the influence of ice shelf water. This confirmed previous speculations regarding the modification of shelf water masses under the Larsen-C ice shelf. The missing of a direct connection between shelf- and bottom water indicates a nonrecurring slide of heavy water at the continental slope. Until now, the sporadic formation of cold bottom water along the Antarctic Peninsula was only a hypothesis, based on observations in the north-western Weddell Sea. We suppose that the observed changes were caused by the variability of the Weddell eddy, a displacement of the shelf edge front and increased fresh water input into the western Weddell Sea due to a new shelf ice configuration (disaggregation of Larsen B).

"Hind cast" simulations with two different models of the NAOSIM hierarchy imply that in the last 50 years at least two extreme events of fresh water export from the Arctic Ocean occurred. In the mid-sixties, a heavy outpouring of sea ice and fresh water from the Barents Sea into the West Spitzbergen Current caused a strong reduction of the sea surface height gradient between Greenland and Spitzbergen. This led to a drastic reduction of fresh water transports southwards and to an accumulation of low-salinity water in the Arctic Ocean. The large fresh water content decreased only slowly in the course of the following decades. We could explain a freshening of the subpolar westerly boundary currents south of Denmark Strait during the mid-1990s with an anomalously high (liquid) fresh water export through Fram Strait. This export event was preceded by a large-scale redistribution of salt in the Arctic Ocean. The ongoing measurements by moored instruments in Fram Strait have revealed an increase of the heat flux from the Norwegian Sea into the Arctic Ocean since 1997. The strongest increase was observed from 1997 to 1999, when the amount of heat transported through Fram Strait nearly doubled. After a slight decrease the next strong event started in 2004. During the first period, higher volume flux and higher temperature were equally responsible for the heat transport increase, whereas during the second event the temperature increase dominated.

C) Oceanic subpolar exchanges in both hemispheres

Exchanges between the North Atlantic and the Arctic Ocean result in the most dramatic water mass conversions in the World Ocean: warm and saline Atlantic waters, flowing through the Nordic Seas into the Arctic Ocean, are modified by cooling, freezing and melting to become shallow fresh waters, ice and saline deep waters. The outflow from the Nordic Seas to the south provides the initial driving of the global thermohaline circulation cell. Knowledge of these fluxes and understanding of the modification processes is a major prerequisite for the quantification of the rate of overturning within the large circulation cells of the Arctic and the Atlantic Oceans, and is also a basic requirement for understanding the role of these ocean areas in climate variability on interannual to decadal time scales.

The Fram Strait represents the only deep connection between the Arctic Ocean and the Nordic Seas. Just as the freshwater transport from the Arctic Ocean is of major influence on convection in the Nordic Seas and further south, the transport of warm and saline Atlantic water affects the water mass characteristics in the Arctic Ocean which has consequences for the internal circulation and possibly influences also ice and atmosphere. It is our aim to measure the oceanic fluxes through Fram Strait and to determine their variability in seasonal to decadal time scales. Since 1997, year-round velocity, temperature and salinity measurements are carried out in Fram Strait with moored instruments. Hydrographic sections exist since 1980. The results of the measurements will be used in combination with regional models, to investigate the nature and origin of the transport fluctuations on seasonal to decadal time scales.

Model simulations on the influence of the subpolar North Atlantic on the conditions in the Arctic Ocean showed that baroclinic perturbations can be traced from the eastern subpolar gyre to the Arctic Ocean. A prediction, however, is made difficult by the complexity of the initial perturbation and by the modification of water masses in the North Seas. Oceanic heat transport anomalies are consistent with deviations in the ice volume in the Arctic Ocean. As both signals occur nearly at the same time, the correlation is to be explained by heat flux from the ocean to the atmosphere and resulting anomalous atmospheric transports. In calculations with a high-resolution version of the NAOSIM hierarchy we concentrated on transports in the Fram Strait at first. The model reproduces the recirculation in this area for the first time and shows that net transports are considerably smaller than north- and southwardly transports. Model results were used to quantify the uncertainties in the measured transports.

D) Ocean, ice sheets and sea level in a changing climate

The effects of an increased fresh water input from Greenland on the sea level were examined with a global ocean-sea ice model. The direct modification of sea level through the added fresh water is relatively small. A more important alteration is caused by the modification of the large-scale circulation. The overturning in the North Atlantic weakens to about half the undisturbed value. Fresh water accumulates in the subpolar Atlantic and in the Arctic Ocean and causes the sea level to rise by up to 60cm (off Norway and along parts of the Siberian coast). The evolution of the ocean volume for the period of continuous altimeter measurements was reconstructed globally and locally by data assimilation. Thermal expansion due to surface warming was analysed and compared to measured data sets for temperature. Local ocean mass changes derived from the GRACE satellite mission were used to verify ocean model results. The agreement is limited to the largest length scales. A problematic zone for these explorations is the area of the Antarctic Circumpolar Current (ACC), for which insufficient observational data are available.

Therefore we performed several comparison experiments, during which we assimilated different constellations of additional data in the region of the Weddell and Ross seas. These data have been taken from a regional model (BRIOS). Experiments show that changes in the area of the ACC have a strong influence on the long-term trend of the ocean‘s global heat content, i.e. on the steric contribution to sea level change. As the total changes in ocean volume are given by the altimeter measurements in the experiments, this influences the fresh water budget specified by the model.

E) The impact of global change on marine organisms and consequences for marine biogeochemistry

The increase of atmospheric CO_2 concentrations and temperature leads to changes in the oceanic carbonate system and affects the calcification as well as the isotopic and elemental composition of bio-minerals. Our understanding of strontium incorporation into coccolith calcite of *Emiliania huxley* was brought forward significantly by the combination of an experimental and a modelling approach. Determination of strontium exchange coefficients for coccoliths is nontrivial, since the chemistry of seawater differs from that of the coccolith vesicle solution. Exchange coefficients of coccolith calcite found in our study and in the literature are high compared to values of inorganically precipitated calcite. Although kinetic effects can explain part of this offset, the origin of this discrepancy is yet undisclosed. We have explained the high apparent partition coefficient values measured for coccolith calcite in terms of a simple model based on the channel/carrier mediated transport of calcium and strontium ions inside the algal cell. The model is solely based on thermo-dynamical constraints and does not assume a relationship between the exchange coefficient and the crystal growth rate. Application of the model to two independent datasets shows that the discrepancy of the temperature dependence between the apparent partition coefficient observed in coccoliths and inorganically precipitated calcite can be reconciled. The hypothesis that photosynthesis is favoured by the calcification process in coccolithophorids is currently discussed. Data on the impact of varying Ca2+ concentrations and light intensity on the production of particular organic carbon (POC), inorganic carbon (PIC) and the carbon isotope fractionation, however, do not support this hypothesis. Our measurements of photosynthetic oxygen production and the absorption rates of CO2 and HCO3, taken with a membrane inlet mass spectrometer (MIMS), also do not back the hypothesis of the direct coupling of calcification and photosynthesis.

State of achievements of deliverables

1. Quantification of observed climate variations of the Arctic and Antarctic and their global consequences in terms of planetary wave dynamics

Climate simulations have been completed using an improved albedo scheme which had been implemented into the global climate models ECHO-G and ECHAM4/OPYC. This scheme takes into account melt ponds on ice and improves the simulation with the two AOGCMs in describing the observed annual cycle of northern hemisphere ice extent. It is shown that the improved parameterisation of Arctic sea ice and snow albedo can trigger a more pronounced Arctic and North Atlantic Oscillation pattern (AO/NAO).These model simulations show a tendency for an increased frequency of meridional flow pattern connected with the negative AO phase. The localized Eliassen Palm fluxes connected with these changes have been computed and compared with NCEP data. Atmospheric regimes have been analysed in the coupled AOGCMs ECHO-G and ECHAM4/OPYC, and it was shown that these are similar to the observed ones.

A quasi-geostrophic three-level model using the T21 orography of the northern hemisphere has been adapted to NCEP-NCAR reanalysis data using an automated iterative procedure, so that it possesses a realistic zonal wind structure and time-mean non-zonal extra-tropical diabatic heating identical to observations. On the basis of a 100 year perpetual winter integration the model has shown to reproduce the AO signature in the troposphere. In an idealised model of the northern wintertime atmospheric circulation, it was shown that the AO Mode arises from an annular pattern on a rotating aqua-planet and is modified to a zonally asymmetric pattern by land-sea contrasts and orography connected with the localisation of transient baroclinic activity.

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The ongoing measurements by moored instruments in Fram Strait have revealed an increase of the heat flux from the Norwegian Sea into the Arctic Ocean since 1997. The strongest increase

was observed from 1997 to 1999, when the amount of heat transported through Fram Strait nearly doubled. After a slight decrease the next strong event started in 2004. During the first period, the higher volume flux and higher temperature were equally responsible for the heat transport increase, whereas during the second event the temperature increase dominated.

2. Distinction between natural and anthropogenic contributions to the observed climate variations in both polar regions and realistic climate scenarios of the Arctic for the next decades

Long-term simulations over 500 years with coupled AOGCMs, carried out at GKSS and DMI have been used at AWI to describe decadal-scale climate variability and preferred atmospheric circulation regimes. In the coupled model ECHO-G prescribed time-evolving external functions for the solar insulation, the aerosol loading and the greenhouse gases concentration for the period 1500 to 1990 have been used. The dominant large-scale circulation patterns, i.e. the first EOFs of monthly mean data of the geopotential height at 500 hPa have been analysed. For these runs an annular structure similar to the AO and the wave train of the PNA have been detected.

Time slices of future climate simulations with the AOGCM ECHO-G using the IPCC SRES B2 forcing data carried out at GKSS, have been used for a regional downscaling of the Arctic climate for the time slices 1990-1995 and 2024-2029 and 2037-2042. The first two time slices are associated with a negative NAO index and the last time slice with a positive NAO index. It has been shown that the inclusion of soil moisture freezing and thawing processes improves the Arctic near-surface air and soil temperature simulations and exert a significant impact on projected future climate under greenhouse warming. The differences in the projected near-surface air and soil temperatures for the above mentioned time slices between two regional simulations using different land surface schemes are of the order of ±2°C.

Ocean-sea ice hindcasts and IPCC experiments for the 20th century have been used to assess long-term natural variability and trends in Arctic sea ice. With the same aim, atmospheric near-surface data have been reconstructed for the whole 20th century to force extended hindcasts.

The evaluation of the observations in the Atlantic sector of the Southern Ocean allows conclusions on the causes which lead to the formation of a large Weddell Polynya. Three components have to be considered: advective heat transport in the boundary current, vertical heat transport by mixing, horizontal transport of near surface cold water and sea ice. The advective heat transport in the boundary current is related in the short term by the east wind with stronger east winds inducing higher advective heat transport. In longer terms changes of inflow of Circumpolar Deep Water might play a role as well. The instabilities of the boundary currents are clearly related to intensity of the current. Finally the advection of cold water in the near surface layer depends on the location of the transition between west and east winds i.e. the centre of the atmospheric cyclone. Are more intense cyclone would increase the divergent ice drift over Maud Rise and the advection from the east. A slight northward shift of the centre would in addition prevent surface advection at the northern flank of Maud Rise and consequently reduce the amount of heat needed to melt ice.

A regional atmospheric model has been applied to simulate the Antarctic climate by forcing with ERA reanalysis data from 1958 until 1998 and to describe warming and cooling patterns of Antarctica in comparison with data.

3. Identification of the causes and the evolution of extreme anomalies in polar regions

The evolution of the recent warming of the Atlantic layer in the Arctic Ocean from the Nordic Seas was tracked in hindcast simulations with NAOSIM. More general work relating to the exchanges of signals between the subpolar Atlantic and the Arctic Ocean was done using numerical experiments. Furthermore, the anomalous accumulation of fresh water in the Arctic Ocean during the 1960s was found to be related to sea ice transport through the Barents Sea. The most recent fresh water export event from the Arctic was caused by increased export of liquid water and related to a redistribution of salt in the Arctic Ocean.

4. Assessment of their influences on the regional and global ocean climate

The decay of Larsen A and B ice shelves can be considered as an extreme event at the Antarctic Peninsula. The hydrographic observations during ISPOL in combination with the monitoring program in the northwestern Weddell Sea reveal significant changes in characteristics of the bottom water which contribute to the ventilation of the global abyss. Whether the changes are related to the ice shelf disappearance is subject of a recently started sensitivity study with the Finite Element Sea Ice Ocean Model (FESOM) and additional field work. The assessment of fresh water export from the Arctic Ocean on the large-scale oceanic circulation is ongoing.

5. Time series of transports at key locations in the Nordic Seas, the Arctic Ocean, and the Weddell Sea/Southern Ocean boundary

Ocean-sea ice hindcast simulations provide transport time series at key locations in the Nordic Seas and the Arctic Ocean for the last 50 years. Extensive comparison with the Fram Strait mooring array results has been done for models of different resolution.

6. Relation of these transports to forcing fields and clarification of the feedback mechanisms between poleward transports and water mass transformation processes

Analysis of large-scale model results and atmospheric reanalysis data has focused primarily on the long-term behaviour of the heat transport into the Arctic Ocean as well as occasional fresh water export events. The general relationship between transports at key locations and the forcing fields is ongoing work.

7. Reconstruction of the global and regional development of the sea level for the last 50 years with quantitative analysis of driving mechanisms: warming, evolution of ice sheets and glaciers and internal redistribution

The future fate of the large ice sheets has been investigated using IPCC scenario calculations and ice sheet models. Largest uncertainties regarding the future flux of fresh water into the oceans stem from the insufficiently known behaviour of outlet glaciers and ice shelves. Ice shelves may play an important role for the stability of grounded ice and hence sea level change. The disintegration of the Larsen B Ice Shelf was investigated by means of satellite imagery. Mechanisms leading to the disintegration of the ice shelf such as the fracturing in shear zones due to enhanced melt water production were identified. This is used in a numerical model study in order to simulate the velocity increase of the ice shelf prior to the collapse. The influence of rapid climate warming on ice shelves is further investigated by the study of gigantic tabular icebergs, which drift rapidly from cold to warmer climatic regions. Model experiments and satellite observations were used to quantify the importance of ablation and strain thinning to the iceberg decay.

8. Reanalysis of the World Climate Research Programme data for the ocean over the same period. Calculation of oceanic transports, circulation and their changes

The period of ocean state reconstruction which has been fully analysed is currently 1993-2003. For this period the evolution of global mean sea level with annual and interannual variations can be reproduced to 1.74 mm RMS difference. Its trend has been measured as 3.37 mm/year while the constrained model gives 3.45 mm/year considering only the area covered by measurements (3.53 mm/year for the total ocean). We estimate a steric rise of 2.47 mm/year in this period and a gain in the ocean mass which is equivalent to an eustatic rise of 1.07 mm/year. While the corresponding halosteric trend (0.02 mm/year) is of minor importance on global scale, it must not be ignored locally or even regionally. It shows the same order of magnitude as the thermosteric but opposite sign in many places of the ocean. Furthermore, the analysis of the model results shows that the deep ocean (below 500 m) contributes about as much to the global thermosteric sea level rise as the top layers (above 500 m).

9. Cellular model that allows for the simulation of the response of microalgae to different CO_2, nutrient and light conditions

To improve our understanding of the cellular processes regulating the inorganic carbon acquisition in marine phytoplankton the following functional modules of the cellular model have been developed.

a. Cluster-cluster aggregation kinetics described via Smoluchowski equations was applied to study polysaccharide aggregation. It was shown that abiotic processes are relevant for the formation ofparticulate organic C during a phytoplankton bloom.
b. A compartment model was used to study calcification of Emiliania Huxleyi. Sr:Ca ratios in coccolith calcite in dependence on temperature and seawater Sr:Ca ratios were explained via thermodynamics of calcite precipitation from coccolith vesicle solution.
c. The method for determination of the rate constants for the CO2 to HCO3- inter-conversion has been reassesses and optimized. The exact knowledge of these rate constants is needed in order to accurately interpret cellular flux measurements obtained with the membrane-inlet mass spectrometry (MIMS).

10. Ecosystem and biogeochemical ocean general circulation models that are able to simulate the occurrence and succession of various functional groups of phytoplankton (silicifiers, calcifiers, picoplankton) under current and future (next 100 years) climate conditions

Biogeochemical ocean general circulation models (BOGCMs) including several plankton functional types have been developed. This is an important contribution to the international cooperation `Dynamic Green Ocean Model´. First results were published by Le Quéré et al., 2005. The parameterisation of plankton processes needs further improvements (ongoing project). The role of iron in marine ecosystems has been studied by Weber et al. (2005).

Personnel

Personnel	Institutional funding	Third party funding
	Scientists / PhD / Technicians	Scientists / PhD / Technicians
AWI	13 / 2 / 4	1 / 3 / 1

Publication outcome numbers

Academic Publications Refereed only	2004-2006 publ./in press
ISI	56/11
non ISI	19/4
PhD theses	2/0
Master & Diplom Theses	0/0
Books	4/0
Book chapters	9/1

Key publications

1. Karcher, M., Gerdes, R., Kauker, F., Koeberle, C., Yashayev, I., 2005. Arctic Ocean change heralds North Atlantic freshening, Geophys. Res. Lett., 32(21), L21606. DOI: 10.1029/2005GL023861.
2. Dethloff, K., et al., 2006. A dynamical link between the Arctic and the global climate system, Geophys. Res. Lett., 33, L03703, DOI: 10.1029/2005GL025245.
3. Le Quéré, C., Harrison, S. P., Prentice, I. C., Buitenhuis, E. T., Aumont, O., Bopp, L., Claustre, H., Cotrim da Cunha, L., Geider, R., Giraud, X., Klaas, C., Kohfeld, K. E., Legendre, L., Manizza, M., Platt, T., Rivkin, R. B., Sathyendranath, S., Uitz, J., Watson, A. J., Wolf-Gladrow, D., 2005. Ecosystem dynamics based on plankton functional types for global ocean biogeochemistry models, Global Change Biology, 11, 2016-2040.
4. Alley, R., Clark, P. U., Huybrechts, P., Joughin, I., 2005. Ice sheets and sea-level changes, Science, 310(5747), 456-460.
5. Schauer, U., Fahrbach, E., Osterhus, S., Rohardt, G., 2004. Arctic warming through the Fram Strait - Oceanic heat transport from three years of measurements, J. Geophys. Res., 109(C6), C06026.

List of guest scientists

1. M. Kurgansky, University Concepción, Chile, 2004, 2005
2. G. Stenchikov, Rutgers University, 2005.
3. M. Stendel, DMI, 2005.
4. J. H. Christensen, DMI, 2005.
5. A. Ohmura, ETH, 2004.
6. R. Laprise, University Montreal, 2004.
7. H. Roscoe, BAS, 2005.
8. Philippe Tortell, University of British Columbia, March 2004
9. Thatcher Jones, Oregon State University, 10.07. – 11.09.05
10. Emma Huertas, Andalusia Institute of Marine Sciences, 20.09. -. 01.10.05
11. Elena Acera Sanchez, Andalusia Institute of Marine Sciences, 14.09.05 – 15.01.06
12. Jan Seiler, Wales, 20.06. – 23.09.05
13. Eva Ortega Retuerta, University of Granada, 20.09. – 20.12.05
14. Nina Lundholm, University of Copenhagen, 01.- 31.01.06

15. Sven Kranz, Universität Kaiserslautern, 15.08.05 – 31.03.06
16. R. Newton, LDEO, 2005
17. Karen Assmann, NERSC,Norway, 1.1.2005-31.3.2005

List of running/accepted third party funding projects

1. EU project GLIMPSE, 2002-2005, (1.200.000 €).
2. DFG project, Atmospheric water cycle of Antarctica, 2004-2006, (75.000 €).
3. SSA "SEARCH for DAMOCLES", 2006-2009, (110.000 €).
4. SCOUT-O3, 2004-2009, (404.000 €).
5. EC Integrated Project CARBO-OCEAN (300 000 €)
6. DFG Project „Can acidic polysaccharides exuded by diatoms function as iron ligands, increasing the iron availability for diatoms? (60.000 €)
7. DFG Project „Dynamik des Kohlenstoff- und Nährstofferwerbs ökologisch relevanter Phytoplankter (58.000 €)
8. DFG Project „Coccolithophore nutrient ecology“ (172.500 €)
9. DFG Project „Molecular ecology of diatom nitrate assimilation during Southern Ocean iron enrichment experiment EIFEX“ (9.500 €)
10. DAAD Programm Projektbezogener Personenaustausch Kanada (Chr. Völker)
11. Agence National de la Recherche ANR Project „Biodiversity of Open Ocean Microcalcifiers“ (33.000 €)
12. SFB 512 „Tiefdruckgebiete und Klimasystem des Nordatlantiks“, 2004-2006 (90000€)
13. EU INTAS “The Nordic Seas in the global climate system”, 2004-2006 (17000 €)
14. EU: DAMOCLES: 2005-2009 (1.1 Mio €)
15. Earth Rotation and Ocean Circulation, DFG, J. Schröter, 2006-2007 (60000€)
16. Climate Variability marine-2 (CLIVAR), BMBF, J. Schröter, 2002-2005 (237000€).

List of expeditions

1. ARK-XX/2: 16.07.2004 - 29.08.2004, Fram Strait, Yermak Plateau, Lena Trough, 2
2. ARK-XXI/1b: 13.08.2005 - 19.09.2005: Greenland Sea, Fram Strait, 2
3. ANT-XXII/3: 21.01.2005 - 06.04.2005, Atlantic sector of Southern Ocean, 4
4. ANT XXIII/1 (Bhv-Cape Town), 13.10.-17.11.2005, AWI, RV Polarstern, 1
5. ANT XXIII/2, 19.11.05 – 12.01.06, Lazarev Sea, 1
6. ANT XXIII/7, 9.11.04 – 19.01.05, Ice Station Polarstern (ISPOL), western Weddell Sea, 1
7. "North Atlantic Spring Bloom" R/V Stewart Johnson I, Harbor Branch Oceanographic Institution, USA. 15.05.2005 Fort Pierce, Florida, 07.07.2005, Reykjavik, Iceland, 1
8. P320/1 (Mauretanien upwelling), 21.3.-7.4.2005, IFM-GEOMAR, FS Poseidon, 1

List of external co-operations

1. Monash University, Melbourne, Australia (A. Lynch)
2. GFDL, Princeton, USA (S. Griffies, W. Hurlin)
3. Stanford University, USA (G.M. Berg)
4. IfM-Geomar, Kiel (K. Schulz, U. Riebesell, C. Böning et al.)
5. NOC Southampton, UK (P. Statham)
6. University of Victoria, Canada (K. Denman, K. Meissner, A. Monahan)
7. Institut Universitaire Européen de la Mer, Site du Technopole Brest-Iroise, France (B. Moriceau, O. Ragueneau, P. Van Cappellen)
8. University of Reading, UK (J. Gregory)
9. Hadley Centre for Climate Research and Predictions, Met Office, Exeter, UK (J. Ridley)
10. University of Manchester, UK (R. Braithwaite)
11. Pennsylvania State University, USA (R. Alley)
12. Univesity of East Anglia, School of Environmental Sciences, Norwich, UK (K. Heywood)
13. ACE CRC and CSIRO Matine and Atmospheric Research, Hobart, Australia (S. Rintoul)
14. Bjerknes Centre for Climate Research, Bergen, Norway (S. Østerhus)
15. University of Washington, Applied Physics Laboratory, Seattle, USA (C.M. Lee, M. Steele, J. Zhang)
16. Université Pierre et Marie Curie, Laboratoire d'Oceanographie Dynamique et de Climatologie, Paris, France (J.-C. Gascard)

17. Russian Academy of Science (V. Zalesny)
18. TU Delft (Jürgen Kusche, Ejo Schrama)
19. TU München (Reiner Rummel, Jakob Flury)
20. GFZ Potsdam (Tilo Schöne, Saskia Esselborn, Frank Flechtner)

List of co-operations in MARCOPOLI

POL1 and POL3: on the processes inside the Arctic Ocean domain as they influence the polar-subpolar exchanges. The fluxes through Fram Strait have a significant influence on the Arctic Ocean Circulation, and signals which are generated in the Arctic Ocean propagate through Fram Strait into the subpolar North Atlantic. The sub-workpackage “Extreme anomalies” collaborates with POL1 to identify the impact of the decay of the Larsen A&B ice shelf not only on deep and bottom water characteristics but on the freshwater balance in the whole Weddell Sea.
POL2: on the Maud Rise Polynya and the Weddell Sea circulation concerning extreme events and provide information on the subpolar exchanges which are essential processes in the Southern Ocean and subject to significant changes.
MAR2 and POL6: regarding the interpretation and understanding of climate proxies.
POL1: regarding the role of sea ice and icebergs in the Weddell Sea freshwater cycle.

List of memberships in national and international committees

K.Dethloff:	member of ISAC Planing Group member of ICARP Model group member of German IPY Committee chair of ARCMIP
E.Fahrbach:	member CLIVAR/CliC/SCAR Southern Ocean Implementation Panel, member ASOF ISSG, member SCAR/SCOR expert group on physical oceanography, member IPY Joint Committee member ICES Working group on oceanic hydrography
H.Hellmer:	member scientific steering committee NERC project “Autosub under ice”
P.Huybrechts:	member of the Scientific Steering Committee of WCRP COPES (World Climate Research Programme/ Coordinated Observation and Prediction of the Earth System) for 'Understanding Sea-level rise and variability' contributing Author of the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report on Climatic Change
F. Karcher:	member Scientific Steering Committee and chair Working Group 7 (Numerical Experiments) of International ASOF
F. Kauker:	member Scientific Steering Committee of DAMOCLES
U.Passow:	member Hutchinsons Award committee (ASLO)
M.Rex:	member WMO Ozone Assessment Author Panel 2006
D.Wolf-Gladrow:	member Committee `European Doctoral School/PhD programme´ member Scientific Steering Committee of CARBOOCEAN (European Integrated Programme) member SCOR/IMAGES Working Group 124 on Analyzing Links Between Present Oceanic Processes and Paleo-Records (LINKS) member Scientific Board of the Institute for Baltic Sea Research in Warnemünde member Scientific Board of NEBROC (= NEtherlands BRemen OCeanography)
J.Schröter:	member, Principle Investigator und Co-Investigator Jason-1 Science Working Team (OSTST) member, GRACE European Science Team member, IAG Special Study Group SSG2.163 "Gravity field missions: calibration and validation". co-chair, International Working Group on Ocean Modelling with Unstructured Meshes member, IAG Special ICCT group on multiresolution member, coordination of the DFG Program SP 1257: „Mass-Transports“ member of coordination group and head of modelling in the Indian Ocean Tsunami Early Warning System (GI-TEWS). editor of the journal “Ocean Science”

Workpackage MAR2: Palaeo Climate – Mechanisms and Variability
(Spokesman: Prof. Dr. Jelle Bijma)

The existing infrastructure at the AWI offers a unique research environment to study past, present and future variations of climate change where science benefits from the interactions between the groups. One focus of MAR2 is on the reconstruction and modelling of past climate change from a marine perspective. Geophysical data and proxies are used as model input and for validation, respectively.

Academic results

A) Mechanistic models of palaeoproxies

Within MAR2, the section "Marine Biogeosciences" focuses on validation and development of proxy relationships. Testing prognostic climate models for future climate change critically depends on our ability to quantitatively reconstruct past climate. This basically translates to using robust proxies for palaeo-temperature and -salinity in order to accurately reconstruct the thermohaline circulation (density fields). However, despite more than 50 years of palaeoceanographic research, palaeosalinity remains the single most important oceanographic parameter which can currently still not be quantified by a single proxy from sedimentary records. Therefore, one of the scientific highlights was a couple of successful pilot experiments towards development of such an independent salinity proxy.

Two haptophyte algae, *Emiliania huxleyi* and *Gephyrocapsa oceanica*, were cultured at different temperatures and salinities to investigate the impact of these factors on the hydrogen isotopic composition of long-chain alkenones biosynthesized by these haptophyte algae. There was no significant correlation of the fractionation factor $\alpha_{alkenones\text{-}H2O}$ with temperature but a negative linear correlation was observed between the $\alpha_{alkenones\text{-}H2O}$ and salinity with a 5.4‰ change (!) in fractionation per ‰ salinity. This demonstrates that salinity has a substantial impact on the stable hydrogen isotopic composition of long-chain alkenones in natural environments (δD) and hence, that δD has a huge potential to estimate palaeosalinity! We will continue along these lines of research and are confident that it will have a significant impact on the palaeoceanographic and palaeoclimatologic community.

B) Palaeoclimate simulations and climate reconstruction

Different records of the global sea surface temperature were analysed to identify dominant climate modes during the early-to-late Holocene (ca. the last 9.000 years). For this purpose, records of sea surface temperatures, deduced with the aid of the Alkenone method, are statistically analysed and compared with model results of simulation calculations with a coupled atmosphere-ocean model. High latitude cooling and low latitude warming is detected. The temperature trend shows furthermore a heterogenic behaviour that can be compared with a transition of the Arctic Oscillation/North Atlantic Oscillation pattern from a positive phase in the early Holocene to a negative phase during the late Holocene. Such a transition was equally confirmed by model calculations with a coupled atmosphere-ocean model.

At the GKSS, the simulations of the last millennium with the model ECHO-G have been extensively used to test climate reconstruction methods. The simulations are considered as a surrogate world, where artificially pseudo-proxies can be constructed from the grid-point simulated temperatures. The output statistical methods to reconstruct past temperatures can be directly compared with the simulated target variables, for instance the northern hemisphere mean annual temperature. The main results indicate that special care has to be taken when applying present reconstruction methods. The method for the assimilation of proxy data in climate models DATUN has slowly been further developed. The technical complications in the implementation of this method have revealed to be larger than previously assumed. There exists a risk that this method cannot be fully implemented in the present program period. Other parts of the sub-topic are not affected by this delay.

C) Ocean gateway and basin evolution – consequences for ocean circulation and ice sheet development

A compilation of aeromagnetic data and the acquisition of seismic data allowed establishing a new crustal opening model for the Fram Strait. The high resolution magnetic data set shows clear spreading anomalies, which provide better constraints on the open geometry and age. New constraints on the evolution of the southern basins are derived from deep seismic and seismic reflection data sets, showing that the break-up between East Greenland and Norway occurred

asymmetrically. The next step is to develop an animated opening model for the northern North Atlantic. New seismic data on the Yermak Plateau are also used for site survey issues for a full IODP drilling proposal in the Fram Strait submitted in 2005. Projects off southeast Africa serve an improved geodynamic reconstruction of Africa and the Antarctic as well as the development of marginal conditions for the Cenozoic ocean current history of the region around the Agulhas Plateau. The Mesozoic geodynamic model for the dispersal of Gondwana in the Atlantic sector was calculated from existing geophysical data. New magnetic data provide new constraints on the evolution of the Mozambique Ridge. The results are surprising as they indicate that this ridge is of oceanic and not continental crustal origin, resulting in a revised geodynamic model for the Southwest Indian Ocean and the Lazarev Sea. A full IODP drilling proposal was submitted in 2006, focussing on Mesozoic and Cenozoic geodynamic evolution as well as climatic, glacial and environmental conditions.

A further IODP drilling proposal for the gateway south of Africa has been submitted in 2006, aiming at the reconstruction of both the development of the Agulhas Plateau and the evolution of Atlantic palaeo-currents. A new plate-tectonic reconstruction of the South Pacific has been completed in a high temporal and spatial resolution, which now serves as the basis for a first gridded palaeo-topographic model of the region. This development includes a nearly completed modelling of crustal development and magmatic events in the New Zealand region before, during and after the break-up of the Gondwana continent. In a close collaboration with POL-6, an IODP proposal was submitted with the aim to reconstruct the paleoceanographic evolution of the Southern Pacific and its relationship to the shallow and deep water opening of the Southern Ocean gateways.

A sediment deposition model was developed for a drift at the Antarctic Peninsula, showing different periods of sediment transport as the result of an expansion of the ice sheet for the period between 15 and 9 Ma and its retreat from 9 Ma onwards. By correlating seismic data along the southwest African continental slope with climate information from palynological data, we succeeded in identifying a change from a humid to a dryer climate for the continent at 2.2 Ma.

State of achievements of deliverables

1) Mechanistic understanding of the incorporation of isotopes and cations in calcite and opal

The status of mechanistic models for the isotopic composition of foraminiferal calcite shells has been reviewed (Zeebe et al., submitted). First, as yet empirical, salinity-δD relationships have been developed in laboratory experiments (Schouten et al, 2006). Fieldwork has been carried out to develop stable silicon isotopes in diatoms (δ^{30}Si) as a proxy for relative usage of silicic acid. Samples were collected during an iron fertilization experiment (Polarstern ANT XXI/3, Wolf-Gladrow, Klaas). The samples will be measured in a new laboratory for the analysis of δ^{30}Si which is currently set up by one of the world experts in this field (Christina De La Rocha was hired in 2004).

2) A reconstruction of the marine carbonate chemistry and nutrient utilization in the glacial ocean based on refined proxy interpretations and global carbon cycle models

The EU project “6C” that deals with this deliverable has had some drawbacks and received a no-cost extension until October 2006. By that time we expect to be able to report on the close interaction of the global carbon cycle and climate change.

3) A three-dimensional, low resolution (4°x4°) climate reconstruction of the Earth’s climate in the last 10k years, physically coherent and consistent with the available information from proxy data

See report of subpackage B). Projects involved are DEKLIM Klimaübergänge, DEKLIM MidHol, EU project SO&P.

4) Dynamical systems analysis of conceptual and simplified models unravelling the dominant modes of variability during the last glacial maximum

Within the review period, we analysed the stability of the oceanic circulation during past and recent climate changes using numerical models of different complexity. The model simulations concentrate on the last glacial maximum and present in detail the interaction of the atmospheric circulation, the transport of water vapour and the cryosphere with the oceanic circulation. It is shown that for the development and termination of ice ages, the palaeoclimatic records from ice cores and marine sediments can be explained, when an interactive oceanic circulation is included.

These circulation changes cause interhemispheric temperature gradients and shifts of the intertropical convergence zone. Conceptual models are developed to understand related feedbacks.

5) Identification of the response of diatom assemblages on Eocene-Miocene changes in ocean circulation and latitudinal thermal differentiations

Quantitative analysis of diatom assemblages from an ODP core transect (Atlantic sector) documents the middle-late Miocene thermal evolution of Southern Ocean surface waters. The data indicate gradual cooling starting around 14 Ma, which culminates around 10.8 Ma when diatoms in the Antarctic cold water sphere extended as far north as the Agulhas Ridge. This is interpreted to be related with the establishment of the West Antarctic Ice Sheet (WAIS), which represents a source of cold surface and bottom water. Around 8.5 Ma we observe the first diatoms giving hints on the presence of sea ice in the realm of the Weddell Sea. Such sea-ice distribution is only conceivable in the presence of a WAIS and related ice shelf areas.

6) Derivation of bounds for changing ice sheet extent in Bellingshausen and Weddell Sea regions

The sediment deposition model developed for Drift 7 at the Antarctic Peninsula is now being tested via a numerical simulation of sedimentation transport based on ROMS in order to derive detailed information on sediment transport mechanisms, i.e. ice-sheet development and evolution of oceanic currents. This work has just started and the model for the present situation has been realised. The next steps will comprise the use of palaeo-bathymetries derived from seismic horizons and the variation of sediment sources and current speed. In the Weddell Sea, all existing seismic data sets were compiled and analysed.

7) Scenarios for past ocean circulation changes in the Southern Ocean and assimilation into global palaeocean models

New seismic data enable an improved geodynamic model for the Cenozoic opening of the Fram Strait. Current activities concentrate on deriving a sediment-corrected palaeo-bathymetry of the Fram Strait which will be fed into a global palaeocean model. New plate-kinematic/tectonic reconstructions of the South Pacific, Scotia Sea and Southern Atlantic/Southern Indian Ocean regions in high spatial and temporal resolution form the basis for enhanced palaeo-bathymetric grids which can be used for palaeo-ocean circulation models. The models will be further improved with respect to sediment thickness and deposition rates. Gridded maps of the total and quaternary sediment thickness for the Amundsen and Bellingshausen Sea region have been generated recently and will be incorporated in a detailed palaeo-bathymetric reconstruction. In order to understand the Cenozoic climate evolution, we started to analyse the influence of the ocean passages onto the climate and associated changes in the marine and terrestrial carbon cycle using numerical models.

Personnel

Personnel	Institutional funding	Third party funding
	Scientists / PhD / Technicians	Scientists / PhD / Technicians
AWI	9 / 2 / 2	7 / 5 / 1

Publication outcome numbers

Academic Publications Refereed only	2004-2006 publ./in press
ISI	48/4
non ISI	13/3
PhD theses	2/0
Master & Diplom Theses	1/0
Books	0/0
Book chapters	0/1

Key publications

1. Eagles, G., Gohl, K., Larter, R.B., 2004. High-resolution animated tectonic reconstruction of the South Pacific and West Antarctic margin. Geochemistry, Geophysics, Geosystems (G^3), Volume 5, Number 7, doi:10.1029/2003GC000657.
2. Jokat, W., Boebel, T., Koenig, M., Meyer, U., 2003. Timing and geometry of early Gondwana breakup. Journal of Geophysical Research, 108 (B9), 24-28.
3. Storch, H. von, Zorita, E., Jones, J.M., Dmitriev, Y., Gonzalez, F., Tett, S.F.B., 2004. Reconstructing past climate from noisy data. Science, 306, 679-682.
4. Lorenz, S., Lohmann, G., 2004. Acceleration technique for Milankovitch type forcing in a coupled atmosphere-ocean circulation model: method and application for the Holocene. Climate Dynamics, Volume 23, Numbers 7-8, pp. 727-743. doi:10.1007/s00382-004-0469-y.
5. Schouten, S., Ossebaar, J., Schreiber, K. Kienhuis, M.V.M., Langer, G., Benthien, A., Bijma, J., 2006. The effect of temperature, salinity and growth rate on the stable hydrogen isotopic composition of long chain alkenones produced by Emiliania huxleyi and Gephyrocapsa oceanica. Biogeosciences, 3, 113-119.

List of guest scientists

1. Christoph Meile, University of Georgia, 01.06. – 15.07.05 (Bijma)
2. Andrew Moy, University of Tasmania, 01.09. – 04.12.05 (Bijma)
3. Duane Thresher, NASA GISS, New York, 1.6.-31.8.05 (Lohmann)

List of running/accepted third party funding projects

1. Plattendynamik des Südost-Pazifiks (PLASOPAZ). DFG, Gohl & Miller, 2001-2004, 160.000 Euro
2. Struktur und Dynamik eines submarinen Kontinents: tektonisch-magmatische Entwicklung des Campbell Plateaus – CAMP. BMBF, Gohl & Miller, 2003-2005, 65.000 Euro
3. Cenozoic development of the depositional environment in the northern Cape Basin in relation to the Initiation of Northern Hemisphere Glaciation. BMBF, Uenzelmann-Neben, 2004-2007, 62.864 Euro
4. Crustal architecture and evolution of the conjugate volcanic margins off mid-Norway and East Greenland in a total rift context. ESF, Jokat, 2004-2007, 228.924 Euro
5. Processing and interpretation of multichannel seismic and deep seismic sounding data off East Greenland. Statoil, Jokat, 2005-2008, 180.000 Euro
6. Südöstlicher Atlantik und südwestlicher Indik: Rekonstruktion der sedimentären und tektonischen Entwicklung seit der Kreide – AISTEK-I: Agulhas Transect. BMBF, Uenzelmann-Neben & Gohl, 2005-2007, 247.369 Euro
7. Südöstlicher Atlantik und südwestlicher Indik: Rekonstruktion der sedimentären und tektonischen Entwicklung seit der Kreide – AISTEK II-: Mozambique-Rücken und -Becken. BMBF, Jokat, 2005-2006, 215.575 Euro
8. Interpretation of multichannel seismic data north of Svalbard. Norw. Petrol. Directorate, Jokat, 2006-2009, 180.000 Euro
9. Divalent Cations: Development and Validation of Proxy Relationships, “Proxycal”, DFG, Bijma, 2003-2006, 2 BAT2a positions + 80.000 Euro.
10. Calcareous Biocrystals, “BioCalc”, DFG, Bijma, 2006 – 2009, 1 BAT2a position + 74.300 Euro
11. Development, calibration and application of independent salinity proxies, „PaleoSalt“, DFG, Bijma, 2006-2009, 1 BAT2a position +189.618 €
12. Carbonate Chemistry, Carbon Cycle and Climate Change (a multidisciplinary view), „6C“, Bijma, 2002-2006, 1 BAT2a position + 269.203 €
13. Kooperation in den Meereswissenschaften zwischen dem Royal Netherlands Institute for Sea Research und den meeresforschenden Einrichtungen im Land Bremen, (NEBROC II), BMBF, Bijma, 2005-2008, 366.830,84 Euro
14. Climate Transitions: Forcing and Feedback mechanisms of glacial-interglacial and future climate change (DEKLIM Program): BMBF, 2004-2006; Lohmann, ca. 304.000 Euro
15. Decadal climate variability from high-resolution marine archives and model simulations, Research Center Ocean Margins at the University of Bremen, Project A7, funded by DFG, Lohmann and Pätzold, 2005-2009, 300.000 Euro
16. Neogene development and dynamic of the circum-antarctic ocean frontal system, IODP/ODP, BI 657/4-1, DFG, 2005-2007, Bickert and Lohmann, 200.000 Euro

17. Humboldt-Stipendium für Dr. Mihai Dima 2004-2006 (academic host: G. Lohmann)

List of expeditions

1. ARK-XX/3, RV Polarstern, 31 Aug – 3 Oct 2004, Northern Svalbard, 12
2. SO-182, RV Sonne, 06 Apr -18 May 2005, Agulhas Plateau/Transkei Basin, 8
3. SO-183, RV Sonne, 20 May - 07 July 2005, Mozambique Ridge/Basin, 6
4. ANT XXI/3 (Eifex), RV Polarstern, 2004, polar front, 2
5. ANT-XXII/4, RV Polarstern, 8 Apr - 22 May 2005, Scotia Sea, 3
6. ANT-XXIII/4, RV Polarstern, 10 Feb - 11 Apr 2006, Amundsen Sea and Pine Island Bay (West Antarctica), 6

List of external co-operations

1. ACD, NCAR, Boulder, USA (Jean Francois Lamarque, Sasha Madronich, Alex Guenther)
2. Analytical and Environmental Chemistry (ANCH) Vrije Universiteit Brussel, Belgium (Frank Dehairs)
3. British Antarctic Survey, Cambridge, UK (Robert Larter, Claus-Dieter Hillenbrand)
4. CGD, NCAR, Boulder, USA (Nathalie Mahowald)
5. DMI Copenhagen (Martin Stendel)
6. Geology Department, University of California, Davis, USA (Howard Spero).
7. Lab. IDES - UMR 8148, Bt 504 Geologie Université PARIS XI, France (Jean-Pierre CUIF)
8. National Institute for Polar Research, Tokyo, Japan (Yoshi Nogi)
9. National Oceanography Centre, Southampton, UK (Martin Palmer)
10. Norwegian Geological Survey (NGU), Trondheim, Norwegen (Carmen Gaina)
11. Royal NIOZ (Netherlands Institute for Sea Research), Texel, The Netherlands (Stefan Schouten, Geert-Jan Brummmer)
12. Statoil, Stavanger, Norway (Erik Lundin)
13. University of Amsterdam, Amsterdam, Netherlands (John O'Connor)
14. University of Bergen, Bergen, Norway (Rolf Mjelde)
15. University of Cambridge, UCAM-DES, UK (Henry Elderfield)
16. University of CapeTown, CapeTown, Rep. South Africa (Anton LeRoex, Maarten de Wit, John Compton)
17. University of Natal, Durban, Rep. South Africa (Mike Watkeys)
18. University of Oslo, Oslo, Norway (Jan-Inge Faleide)
19. Utrecht University, Utrecht, The Netherlands (Gert-Jan Reichart, Philip van der Capellen, Mariette Wolthers et al.)
20. WHOI (Woods Hole Oceanographic Institution), Woods Hole, MA, USA (J. Hayes, J. Bernard, R. Schneider)

List of co-operations in MARCOPOLI

POL6: there are common projects linked at the transition and comparison from old (Tertiary to Mesozoic) to young (Pleistocene and younger) time scales for climate change processes. Modelling results will be used for both packages.
POL2: on proxy development takes place. However, while the focus in MAR2 is mostly on calcareous remains and biomarkers, POL2 is more concerned with the silicious microplankton.

List of memberships in national and international committees

W. Jokat:	Interridge Working Group on Arctic Ridges Regional NAD Working Group on the Lomonosov Ridge Regional Coordinator for the Weddell Sea within the SCAR Seismic Database Library System Marine Arctic Sediment Thickness Project Review Panel for RV Sonne
K. Gohl:	Scientific Secretary of the German Committee for the International Polar Year 2007/08 International Coordinator of the IPY Lead Project "Plate Tectonics and Polar Gateways in Earth history" Pre-Site Survey Panel for Antarctic Drilling (ANDRILL) German ANDRILL Science Committee (D-ANDRILL)

J. Bijma: President of the Biogeosciences Division of the EGU
member of the Council and Programme Committee of the EGU
member of the Outreach Committee of the EGU
chair of the Scientific Committee of the ESF “Euroclimate” programme
editor of the Journal “Biogeosciences”

D.A. Wolf-Gladrow: Committee `European Doctoral School/PhD programme´ (three European Networks of Excellence: EUR-OCEANS, MarBEF, and Marine Genomics Europe)
Scientific Steering Committee of CARBOOCEAN (European Integrated Programme)
SCOR/IMAGES Working Group 124 on Analyzing Links Between Present Oceanic Processes and Paleo-Records (LINKS)
Scientific Board of the Institute for Baltic Sea Research in Warnemünde
Scientic Board of NEBROC (= NEtherlands BRemen OCeanography)

G. Lohmann: Spokesperson for the climate research programme DEKLIM
incoming President of the Climate Division of the EGU
member of the Council and Programme Committee of the EGU
Editor of the Journal “Climate of the Past”.

C. Kubatzki: Editor of the Journal “Climate of the Past”

Additional funding theme COM: Community Ocean Model
(Spokesman: Dr. Jens Schröter)

Academic results

As part of the Additional Funding Programme of MARCOPOLI a “Community Ocean Model” (COM) was proposed. The primary goal is to provide to the user community a second generation ocean model which overcomes many of the shortcomings of traditional numerical models.

Despite progress in general ocean circulation modelling most current state-of-the-art models use regular grids and work with stepwise coastlines and bottom topography. Increasing resolution in these models does not lead to a rigorous treatment of boundary conditions as the latter require lateral boundaries and bottom to be smooth. With growing resolution and focus on regional studies the impact of bottom and lateral boundaries and processes in their vicinity become increasingly important.

With the fast increase in computational power and storage and the advancement in numerical techniques it is now possible to apply unstructured meshes in realistic large-scale ocean modelling. Previous drawbacks such as an incorrect representation of the geostrophic balance terms have been solved in finite volume and finite element formulations of the equations of motion. The higher accuracy of the finite element formulation is accompanied by a higher computational cost. More neighbouring nodes are used for the numerical equivalent of differential operators, i.e. the “stencil” is larger. Furthermore large matrices are calculated explicitly and stored.

The major result achieved for the first two years of the project is the development of the finite element ocean model FEOM-1, a general ocean circulation model based on primitive equations. Its spatial discretisation offers the use of unstructured meshes (e.g. triangles/tetrahedra). This allows a more physical treatment of the boundary conditions, a better resolution of coastlines and also a refinement of local areas of interest while avoiding nesting of structured computational grids.

The development of the model is done in conjunction with running applications and designing tools which will facilitate its use. A particular focus is given to data assimilation systems which can be used together with the finite-element model or on their own. Inverse models which diagnose a stationary flow field from observations were developed for hydrographic sections (2D) and for ocean basins (3D). They are based on the variational approach and are used to assimilate satellite altimetry in conjunction with *in situ* ocean observations.

A finite-element dynamic-thermodynamic sea ice model was developed and coupled to FEOM-1. Its thermodynamic part is derived from the standard AWI sea-ice model that has been used before in several model coupling projects. The dynamic part is discretized in finite elements and features two alternative rheologies: the viscous-plastic and the elastic-viscous-plastic approach. The sea-ice model can also be run in a stand-alone configuration. This version is employed for data assimilation of satellite-derived ice drift fields in the Arctic basin with a mean horizontal resolution of 0.25^{O}.

In collaboration with members of the AWI Computing Center the Community Ocean Model has been implemented on different computer configurations. Solver libraries dealing with the solution of large sparse systems which is the numerically most expensive part were optimised. This led to an efficient reduction of the computation time. The interface package FoSSI (Family of Simplified Solver Interfaces) which has been developed at the AWI Computing Center allows for easy comparison of various solver configurations and adaptation to different computer hardware architectures.

The oceanic component of the COM project is augmented with an atmospheric unstructured module. In order to simulate multi-scale interactions between global and regional scales properly, the new self-adaptive atmospheric barotropic model PLASMA (Parallel LArge scale Self-adaptive Model of the Atmosphere) on high-performance computers has been developed. For that purpose, the adaptive Lagrange-Galerkin method, a combination of the finite element method and the semi-Lagrangian method for the spatial and temporal discretisation, has been applied to the spherical shallow-water equations.

Based on the experience gained within the COM project, a finite-element shallow-water wave propagation model was developed jointly by COM and German Indonesian Tsunami Early Warning System (GI-TEWS) project participants. It is employed currently in the GI-TEWS project for computing wave height and propagation time maps. Here the possibility of varying resolution is of exceptional value as the area of interest includes many islands and rapidly varying bathymetry.

State of achievements of deliverables

A full version of the model (FEOM-1) was developed, coded in Fortran-90 and optimized for different computer architectures. It uses a tetrahedral finite-element discretization. Beside the global model two regional versions have been studied in detail. One is focussing on the thermohaline circulation of the North Atlantic and the other one on the fresh water budget and sea-ice processes in the Southern Ocean.

The sea-ice component of FEOM-1 allows for two rheologies for ice dynamics: viscous-plastic and elastic-viscous-plastic. A stand-alone sea-ice model version which can be used with structured and unstructured meshes is available.

Stationary inverse model versions are developed for 2D and 3D applications.

The parallel data assimilation facility (PDAF) was built and optimized for parallel computer architectures. It offers a suite of reduced rank Kalman Filter algorithms and has been applied with FEOM-1. Its generalized interface allows for a simple use with other dynamical models.

The interface package FoSSI (Family of Simplified Solver Interfaces) which has been developed at the AWI Computing Center allows for easy comparison of various solver configurations and adaptation to different computer hardware architectures.

The finite element tsunami wave model has been implemented. Its resolution varies between 50m and 5km and the mesh covers the whole Indian Ocean.

Personnel

Personnel	Institutional funding	Third party funding
	Scientists / PhD / Technicians	Scientists / PhD / Technicians
AWI	4 / 1 / 0	0,5 / 2 / 0

Publication outcome numbers

Academic Publications Refereed only	2004-2006 publ./in press
ISI	8/2
non ISI	7/1
PhD theses	4/0
Master & Diplom Theses	0/0
Books	1/0
Book chapters	1/1

Key publications

1. Sidorenko, D., Danilov, S., Kivman, G., Schröter, J. (2006). On the use of a deep pressure gradient constraint for estimating the steady state ocean circulation from hydrographic data, Geophysical research letters. DOI: 10.1029/2005GL024716;
2. Danilov, S., Kivman, G., Schröter, J. (2005). Evaluation of an eddy-permitting finite-element ocean model in the North Atlantic, Ocean modelling, 10, 35-49.
3. Nerger, L., Hiller, W., Schröter, J. (2005). A Comparison of Error Subspace Kalman Filters, Tellus series a-dynamic meteorology and oceanography, 57A(5), 715-735. DOI: 10.1111/j.1600-0870.2005.00141.x;
4. Nerger, L., Danilov, S., Kivman, G., Hiller, W., Schröter, J. (2005). Data Assimilation with the Ensemble Kalman Filter and the SEIK Filter applied to a Finite Element Model of the North Atlantic, Journal of marine systems.
5. Losch, M., Sidorenko, D., Beszczynska-Möller, A .(2005). FEMSECT: an Inverse Section Model Based on the Finite Element Method, Journal of geophysical research-oceans, 110(C12), C12023.

List of guest scientists

1. Rainer Bleck, Los Alamos Natl. Lab.,USA, 10.-15.10.2005

List of running/accepted third party funding projects

1. Sea Level Variability, (SEAVAR), BMBF, J. Schröter, 2005-2008, 213 000 €.

2. GRACE-Level1 and Level2 Products and their validation (GRACE Level2), BMBF, J. Schröter, 2005-2008, 432 000 €.
3. Ozeanwirbeldynamik analysiert anhand von TOPEX/JASON Tandem Altimeterdaten und numerischen Zirkulationsmodellen (TANDEM), DFG, J. Schröter, 2005-2007, 70 000 €

List of expeditions

ANT XXII/3, Polarstern, 21.01.2005-06.04.2005, 1 scientist, 1 Ph.D. student

List of external co-operations

1. Imperial College London, Christopher Pain et al
2. LEGOS/CNRS Toulouse, Florent Lyard
3. Universite Catholique de Louvain, Eric Deleersnijder
4. Danish Meteorological Institute, Nicolai Kliem
5. University of Alberta, Paul Myers
6. TU Delft, Julie Pietrzak, Guus Stelling

List of co-operations in MARCOPOLI

POL1, POL2 and POL3: on sea-ice dynamics and fresh water budget in both the Arctic and the Southern Ocean. Assimilation of sea-ice velocities will provide more realistic estimates of sea-ice transports and rheology.
MAR1: the state-of-the-art data assimilation tools developed in COM are also used in MAR1 for ocean state diagnosis from hydrographic and remote sensing data. Furthermore, the COM model is used in MAR1 for the analysis of ocean bottom pressure fluctuations derived from in situ observations and GRACE gravity measurements.

List of memberships in national and international committees

J. Schröter: member, Principle Investigator und Co-Investigator Jason-1 Science Working Team (OSTST)
member, GRACE European Science Team
member, IAG Special Study Group SSG2.163 "Gravity field missions: calibration and validation".
co-chair, International Working Group on Ocean Modelling with Unstructured Meshes
member, IAG Special ICCT group on multiresolution
member, coordination of the DFG Programme SP 1257: „Mass-Transports“
member of coordination group and head of modelling in the Indian Ocean Tsunami Early Warning System (GI-TEWS).
editor of the journal “Ocean Science”

Topic CO: Coastal Dynamics and Causes of Change

(Spokesman: Prof. Dr. Franciscus Colijn, GKSS and Prof. Dr. Allan Cembella, AWI)

Report on the general development of CO

Coasts are highly dynamic environments acting as a boundary with wide transition zones extending from the marginal land mass to the shelf sea. As an interface between terrestrial and marine fluxes of energy, matter, and organisms, coastal zones comprise a diversity of complex ecosystems, such as tidal flats, rocky shores, reefs and islands. Coastal areas are often heavily exploited as human habitats, and for recreation, fisheries, aquaculture, sources of natural products, transportation and in some cases for energy generation, e.g. via windparks. In spite of efforts to stabilize coastal zones while optimizing resource utilization, the coast is subject to continuous geomorphological, hydrodynamic and meteorological changes. These physical stresses on the coasts are expected to increase in magnitude in response to Global Change expressed on a local and regional scale. Furthermore, human intervention linked to over-fishing, dredging and harbour construction, urbanization, pollution and eutrophication must be considered as additional stressors on already fragile systems.

A focal task of our coastal research programme is to provide a solid base of scientific knowledge on the stability, biodiversity, stressors, and potential of the coastal system. The coastal research programme is carried out as a joint initiative between AWI and GKSS, and involves scientists based in Bremerhaven (AWI), Helgoland (BAH) and Sylt (Wattenmeer Station), Geesthacht (GKSS) and Büsum (FTZ), as well as cooperation with universities, scientific institutions and technology companies.

The coastal programme has been partitioned into four Workpackages dealing with **Coastal Change (CO1)**, **Diversity and Food Webs (CO2)**, **Chemical Interactions (CO3)** and **Observation and Information for Coastal Management (CO4)**. The current institutional review presented here emphases primarily the role and contribution of the AWI partners to this research agenda. In addition to close linkages and interactions among the various elements of the Coast Programme, particularly with GKSS, AWI coastal scientists are collaborating actively with other components of the Marcopoli programme, specifically in comparative biological studies with POL 4, POL 5 and POL 7 and geomorphological work on polar versus temperate coastal regions.

The focus of our programme is on the coast and adjacent shelf areas of the North Sea and Wadden Sea coasts, but comparative studies are also conducted via cooperations in coastal regions of the Mediterranean Sea, eastern North America, Chile, Norway and France and other global areas including the tropics. We have already attained significant insights into the fundamental processes of coastal diversity and food web dynamics. Once a solid base of information is generated on the functioning and integration of coastal ecosystems is achieved, these processes can be modelled to generate scenarios and hypotheses of the consequences of accelerated or mitigated coastal changes. In our partnership with GKSS, we will be able to deliver the necessary tools and interpretation required by policy makers and society at large with a view towards Integrated Coastal Zone Management.

Workpackage CO1: Coastal Change: Long-term Trends and Extreme Events

(Spokesman: Prof. Dr. Hans von Storch, GKSS and Prof. Dr. Karsten Reise, AWI)

Academic Results

The AWI investigation of coastal long-term trends and extreme events is performed in close cooperation with the coastal research institute of GKSS. While GKSS focusses on modelling the physical and ecological processes, the AWI team is analysing ecological change. These studies will be combined in reconstructions and projections in an attempt to base options for coastal management on sound and broad insights into coastal change processes.

A) Coastal Change on Sandy Shores

Exposed sandy shores like those of the island of Sylt in the North Sea are particularly sensitive zones in the face of an accelerating sea level rise. Sequences of aerial photographs at high resolution have been assembled and analysed. These allow for a quantitative description of morphological changes of beaches and dunes. Sand is regularly replenished at eroding shores where they are exposed to the prevailing westerly storms. Part of this sand is drifting parallel to the shore and accumulates at the northern tip of the island. Other parts are lost to still unknown destinations. In the tidal zone, shifting channels and the dynamics of seagrass and mussel beds have been followed over the last few decades. The position of these biogenic structures is fairly conservative but recently decreased in extent. Below water, acoustic methods (RoxAnn) and side-scan sonar have measured sand waves up to seven meters in height. These dynamic structures arise in the deep inlets between barrier islands. They exchange sediment between the inner and outer coast. Storm-related sea level variations along the North Sea coast have now been simulated with numerical high-resolution modelling for the previous forty years. These hindcasts will be used to recognize relationships to sediment transport in the nearshore zone.

B) Abiotically Driven Changes on the southern North Sea Shelf

Besides sea level rise, temperature has also played a significant role in the long-term development of coastal and shelf processes. The long term data set from Helgoland Roads has been extensively analysed against the backdrop of Global Change. We have shown that there has been an obvious warming of 1.1 ^{o}C since 1962 and that the algal spring bloom and high diatom concentrations are occurring later in spring. This is opposite to what is observed with flowering plants on land. We have also demonstrated by analyses of the data series, as well as in experiments, that this is related to a warming of the autumn, which allows for an extended grazing of zooplankton. This explains the retarded start of algal bloom development in the subsequent spring. We have also analysed shifts in species composition and revealed a change in phytoplankton succession towards warm-water diatoms, e.g. *Guinardia delicatula*. This was tested by taking microalgae isolated *in situ* into the laboratory and studying their physiological adaptations and tolerances. These data are the first indication of a warming-related shift in phytoplankton succession, aftecting the timing of the spring bloom and foodweb dynamics. The consequences of this will be life cycle/food resource mismatches through to regime shifts in the North Sea ecosystem.

Shifts have also been observed in the salinity of the system, which has been steadily rising by an average of 1 unit in 40 years. This is probably related to a change in the water movements in the North Sea. With the help of models developed by GKSS, for the first time we have shown that salinity “events” often originate from an influx of water from the North Sea west of Helgoland and that events with low salinities are often related to the movement of water from the northeast to Helgoland. Unlike previously assumed, events of low salinity are not always directly attributable to the outflow of the River Elbe. This information is an important milestone in understanding changes in the water systems of the German Bight.

C) Changes related to invasive species

In addition to changes in the biota caused by climate change, anthropogenic nutrient supply and resource exploitation, there is evidence of direct introduction of exotic organisms via increased shipping traffic and ballast water exchange around the globe. Furthermore, the increase in aquaculture in the sea may contribute to and amplify the environmental consequences of such introductions. In the Wadden Sea, native oysters have been driven to extinction by overexploiting the natural stocks, therefore culturing of Pacific oysters (*Crassostrea gigas*) commenced twenty years ago. These have become ‘wild’ through dispersal of their larvae, which settled mainly upon mussel beds. At first this remained quantitatively rather unimportant. However, three extremely

warm summers in a row (2001 to 2003) initiated an unexpected invasion of these oysters. Throughout the entire Wadden Sea, mussel beds and artificial hard substrates became overgrown by the Pacific oyster.

What are the consequences of the shift from mussels to oysters for the ecosystem? Are the Pacific oysters an appropriate substitute for those oysters which once were native in the Wadden Sea? While warm summer temperatures triggered a high propagule production, our experiments have shown that high survival of the Pacific oyster is primarily due to a lack of predation. Crabs and seastars preferred mussels over oysters. Coastal birds were unable to take these oysters as prey because of the strong shell. The Pacific oysters thus constitute a dead end in the food web, while being voracious suspension-feeders consuming phytoplankton. Furthermore, Pacific oysters are not an ecological equivalent for the native oysters. Pacific oysters have invaded the intertidal zone, whereas the natives dwelled in deeper waters.

Other species, like the American slipper limpet *Crepidula fornicata* and an introduced *Spartina* cordgrass, spread and became more abundant recently because of milder winters and elevated spring air temperatures, respectively. Taken together, our investigations on the long-term developments at the North Sea coast indicate an acceleration of change, from geo- and hydrodynamics to a turnover in the ecological system. This has implications for the ecological quality targets aimed at with the EU Water Framework Directive for coastal water bodies.

State of achievements of deliverables

1. The historical ecology of the southern North Sea coast is an interdisciplinary field concerned with the reconstruction and understanding of past ecosystems and their changes through time. The ecological history of an ecosystem determines its present state and influences its path into the future. Thus, without knowing their past we cannot understand how ecosystems function today. Furthermore, we cannot predict future changes, and we cannot effectively protect and restore degraded ecosystems without historical baselines as reference points. During a multidisciplinary workshop held in 2004 at the Wadden Sea Research Station on Sylt, a comprehensive overview on the ecological history of the Wadden Sea was brought together and published in 2005. The results have also been disseminated to popular magazines (e.g. Der Spiegel 9/2004 and 7/2006) and in public talks. The Helgoland time-series data have been re-examined in the new light of global climate change. In an issue of *Helgoland Marine Research* an initial collection of eight publications relating to the Helgoland Roads time series has been published, representing only the beginning of the data mining that this time-series has still to offer.

2. Hindcasts of ecosystem development for the past five decades is in progress. This research is advanced in cooperation with GKSS, and is focussed on the ecological time series for Helgoland Bight. The northern Wadden Sea will follow when the Helgoland region is done.

3. Understanding cause-effect relations in relation to climatic trends and anomalies is progressing well via several lines of research. Based on six publications on the ecological effects of an anomalous severe winter in the Wadden Sea (*Helgoland Marine Research* 55), further research has focussed on the effects of a series of exceptionally mild winters (Thieltges et al. 2004: Too cold to prosper – Winter mortality prevents population increase of the introduced American slipper limpet *Crepidula fornicata* in northern Europe), on a row of exceptionally warm summers (Diederich et al. 2005: Introduced Pacific oysters *Crassostrea gigas* in the northern Wadden Sea: invasion accelerated by warm summers?) and warmer spring temperatures (Loebl et al. 2006: Is spread of the neophyte *Spartina anglica* recently enhanced by increasing temperatures?).

4. Contributions of CO1-members to the trilateral Wadden Sea Quality Status Report, published every five years, includes the chapters on eutrophication, introduced species, seagrass, subtidal habitat structures and synthesis of ecosystem developments. Since the mid-1990s, pressures from eutrophication are decreasing, while the impact of introduced species on the Wadden Sea ecosystem is dramatically increasing. The shellfishery in the intertidal zone has been largely phased out. However, in the subtidal zone almost all wild mussel beds have been turned into bottom cultures, but these have a significantly lower biodiversity than wild mussel beds. As an international conservation area, the Wadden Sea is improving with respect to birds, seals and seagrass but is still lacking a number of charismatic species which once were common in this region, i.e. pelicans, sturgeons and native oyster beds.

Personnel

Personnel	Institutional funding	Third party funding
	Scientists / PhD / Technicians	Scientists / PhD / Technicians
AWI	6,4 / 1,8 / 2,8	1,8 / 1,6 / 0

Publication outcome numbers

Academic Publications Refereed only	2004-2006
ISI	37
non ISI	52
PhD theses	5
Master & Diplom Theses	10
Books	1
Book chapters	5

Key publications

1. Wiltshire, K.H. (ed), 2004. Ecological long-term Research at Helgoland. Helgol Mar Res 58, 221-310.
2. Lotze, H.K., Reise, K. (eds), 2005. Ecological history of the Wadden Sea. Helgol Mar Res 59, 1-95.
3. Thieltges, D.W., Strasser, M., Beusekom, J.E.E. van, Reise, K. 2004. Too cold to prosper – Winter mortality prevents population increase od the introduced American slipper limpet *Crepidula fornicata* in northern Europe. J Exp Mar Bio Ecol 311, 375-391.
4. Wirtz, K., Wiltshire, K.H., 2005. Long-term shifts in marine ecosystem functioning detected by inverse modeling of the Helgoland Roads time-series. J Mar Systems 56, 262-282.
5. Buschbaum, C., Chapman, A.S., Saier, B., 2006. How an introduced seaweed can affect diversity in different coastal systems. Mar Biol 148, 743-754.

List of guest scientists (selection)

1. J. Coyer, RUG Groningen, Netherlands, 10.04.-17-04.04, 15.04.-20.04.05
2. E. Jackson, Plymouth, England, 23.03.-27.03.04
3. C. Muthama, Kenya, 31.08.-30.09.04
4. M. Wichorowski, Poland, 07.03.-18.03.04
5. G. Nehls, BioConsult SH, Husum, 02.05.-10.05.04, 01.09.-09.09.04, 21.05.-29.05.05
6. T. Reusch, MPI Plön, 20.10.-26.10.04,
7. A. Szczesinski, Univ Göttingen, 01.07.-11.07.04, 04.07.-14.07.05
8. A. Westphalen, Univ Göttingen, 14.04.-24.04.04, 12.08.-25.08.04
9. K. Ahrendt, CAU Kiel, 21.03.-28.03.05
10. T. Bartholomaeus, FU Berlin, 21.06.-30.06.05, 03.07.-14.07.05, 11.10.-21.10.05
11. S. Dietrich, Univ. Marburg, 19.09.-29.09.05
12. N. Eschweiler, Univ Göttingen, 04.07.-14.07.05
13. M. Gottschling, Inst. Vogelforsch., Wilhelmshaven, 31.07.-02.09.05
14. U. Irmler, CAU Kiel, 09.06.- 20.06.05
15. P. Schiek, Univ Bremen, 01.03.-31.03.05
16. K. Schwarzer, CAU Kiel, 16.06.-21.06.05
17. U. Smola, Univ München, 02.10.-14.10.05
18. G. Tröster, Univ Göttingen, 04.07.-14.07.05
19. A. Wehrmann, Senckenberg Wilhelmshaven, 27.01.-04.02.05
20. S. Cifuentes Pacheco, Univ Valdivia, Chile, 02.03.-02.04.05
21. A. O`Brien, Australia, 04.08.-15.10.05
22. N. Pope, England, 05.07.-17.07.05
23. J. Widdows, England, 05.07.-17.07.05
24. A. Siaulis, Klaipeda, Lithuenia, 31.01.-06.02.05
25. D. Wethey, Univ South Carolina, USA, 13.07.20.07.05

26. S.A. Woodin, Univ South Carolina, USA, 13.07.-20.07.05
27. Castrence-Gonzales, Philippines, 31.08.-30.09.05
28. C. Currie, Namibia, 21.02.-03.03.05
29. H.D. Viet, Vietnam, 22.02.-03.03.05
30. E. Pinto, Brazil, 20.02.-03.03.05
31. R. Kuhlemkamp, Uni Hamburg, 05.-10.04
32. M. Thiel, Univ Coquimbo, Chile, 25.07.-12.08.05
33. M. Pollüopüü, Univ. Tallin, Estonia, 3.2006
34. W. Kasyanov, Univ. Wladiwostock, Russia, 10.2005
35. H. Hummel, NIOO, Netherlands, 3.2005
36. E. van den Berghe, Univ. Gent, Belgium, 3.2005

List of running/acceptedthird party funded projects

1. BioFlow Network: flume facility cooperation network for biological benthic boundary layer research, EU, H. u. R. Asmus, 12.01-11.05, € 36,480
2. Monitoring Seegras-Makroalgen im SH Wattenmeer, NPA Schleswig-Holstein, K. Reise, 03.04-11.06, € 30,900
3. Seegras: Wasserrahmenrichtlinie, LANU Schleswig-Holstein, K. Reise, 02.04.-31.10.05, € 64,080
4. ELME: European Lifestyles and Marine Ecosystems, EU, K. Reise, 01.04.-02.07, € 30,259
5. Elektronische Neuerfassung der Referenzsammlung Makroalgen südliche Nordsee, BMBF, I. Bartsch, 01.04.-12.05, € 32,700
6. Wasserrahmenrichtlinie Klassifizierungssystem WK Helgoland, LANU Schleswig-Holstein, I. Bartsch, 05.-10.04, € 19,260
7. Revision of the Red Book of endangered animal species in Germany and adjacent marine waters: marine invertebrates, German Federal Agency of Nature Protection BfN, E. Rachor, € 3000
8. MarBEF, Network of Excellence on Marine Biodiversity and Ecosystem Functioning, EU DG XII. Buchholz: AWI-coordinator, member of Executive Committee, Theme 1 co-leader, 3.2004-2009, € 60,000
9. MarBEF, EU DG XII, Responsive Mode Project: LargeNet, F. Buchholz : coordinator, 3.2004, € 4000
10. MarBEF, EU DG XII, Theme 1 (Temporal and spatial patterns of biodiversity), F. Buchholz. Theme leader, 4.2006-2009, € 120,000
11. MARBENA, EU DG XII, (Creating a long term infrastructure for marine biodiversity research in the European Economic Area and the Newly Associated States), F. Buchholz: expert, 3.3004-4.2006, € 7,000
12. Restocking Programme Helgoland Lobster, State of Schleswig-Holstein, F. Buchholz, Leader, 8.2005-2008, € 80,000
13. Growth and development of Chilean sea spiders. Univ. Hamburg, F. Buchholz, Advisor of dissertation Tanja Hausen, 2.2004-2007, € 60,000

List of expeditions

1. HE 211 (RV Heincke) 24.04.04-28.04.04, North Sea, 2 scientists, Large-scale and long-term population dynamics of North Sea benthos
2. HE 218 (RV Heincke) 11.09.04-17.09.04, North Sea, 2 scientists, Large-scale and long-term population dynamics of North Sea benthos
3. HE 233 (RV Heincke) 09.07.05-13.07.05, North Sea, 2 scientists, Large-scale and long-term population dynamics of North Sea benthos
4. HE 236 (RV Heincke) 11.08.05-15.08.05, North Sea, 2 scientists, Large-scale and long-term population dynamics of North Sea benthos
5. HE 241 (RV Heincke) 10.10.05-17.10.05, North Sea, 2 scientists, Large-scale and long-term population dynamics of North Sea benthos
6. AHAB 2 (Alexander von Humboldt Angola-Benguela) Ship: RV Alexander von Humboldt in the Angola-Benguela upwelling system, 3.2004; Theme: Krill in the marine food web, WP-participant: F. Buchholz

List of external co-operations (selection)

1. CAU Kiel, Ökologiezentrum, FTZ Büsum, GEOMAR-IfM (U. Irmler, F. Colijn, M. Wahl)
2. MPI Bremen (D. de Beer et al.)
3. Dalhousie University Halifax, Canada (Bettina Saier, A. Chapman, H. Lotze)
4. Universidad Católica del Norte, Coquimbo, Chile (M. Thiel)
5. RUG Groningen, The Netherlands (W.J. Wolff, J. Olson, J. Coyer)
6. Univ. Hull, UK (M. Elliott et al.)
7. Univ. Arhus, DK (K.T. Jensen, D. Thieltges)
8. ICES Benthos Ecology Working Group, North Sea members (E. Rachor et al.)
9. Inha Univ., Inchon, South Korea (J-S. Hong et al.)
10. Nagasaki Univ., Japan (A. Tamaki)
11. IFREMER, France (C. Bacher)
12. NIOO, Yerseke, The Netherlands (H. Hummel, P. Herman, C. Heip)
13. IOPAS, Sopot, Poland (J.M. Weslawski et al.)
14. LOV, Villefranche-s-m, France (P. Mayzaud)
15. Littoral Station, Aguda, Portugal (M. Weber)
16. CICESE, Mexico (J. Faerber-Lorda)
17. Univ. Puerto Montt, Chile (K. Paschke)
18. Natural History Museum, London, UK (I. Tittley)
19. Royal NIOZ, Texel, Netherlands (J. van der Meer et al.)

List of co-operations in MARCOPOLI

1. CO1 has intricate linkages to CO2 by using habitat and biodiversity maps for interpretation of biodiversity change. Many scientists are involved in both Workpackages and research activities often cross the somewhat arbitrary boundary. For example, invasions of introduced species tend to be irreversible and are studied as long-term change in CO1, while implications for biodiversity and ecosystem functioning are studied in CO2.

2. CO1 linkages to CO3 are confined to a few cases. An example is cooperative work with respect to the interference of hydro-carbons with the olfactory performance of the Helgoland lobster of which the population is in long-term decline. Several pheromones and other scent-substances are to be described and effects tested.

3. CO1 has started cooperation with GKSS/CO4 in 2006 in order to link prognostic atmospheric models with temperature data at Helgoland Road for gaining a better understanding of expected temperature change on biological processes. Changes in current systems of the German Bight affect distribution and persistence of benthic species with pelagic larvae, e.g. Helgoland lobster and Pacific oysters. Modes of distribution are incorporated into modelling by GKSS.

3. CO1 scientists are involved in coastal studies all around the world and at polar coasts the efforts grade into the Programme topic POL. Several species of krill are used as indicators of effects of Global Change. Cooperative case studies are conducted from the Arctic via the upwelling regions off Namibia to the Antarctic.

4. CO1 is linked to MAR and POL by the common subject of sea level rise. The expected acceleration in sea level rise is a key factor in the long-term changes of the shoreline systems at the extremely shallow coast of the southeastern North Sea.

List of memberships in national and international committees

Editorial board *Helgoland Marine Research*: I. Bartsch, F. Buchholz, A. Cembella, H-D. Franke, E. Rachor, K. Reise:

H. Asmus Editorial board *Estuarine Coastal and Shelf* Science
Kuratorium Nationalpark Schleswig-Holsteinisches Wattenmeer:

E. Rachor: ICES Benthos Ecology Working Group
German Administrative (BLANO*) Working Group for Nature Protection in Coastal and Offshore Waters

	Environmental Expert Group for advice to the German Ship Average Command (Haveriekommando)
K. Reise:	Kuratorium Nationalpark Schleswig-Holsteinisches Wattenmeer Editorial board *Journal of Sea Research*: Editorial board *Journal of Experimental Marine Biology and Ecology* Editorial board *Senckenbergiana Maritima* Scientific advisory board Institut Vogelforschung, Wilhelmshaven Advisory board FK-Wind, Bremerhaven
F. Buchholz	Steering Group of Medium sized German Research Vessels: EU-Aquaculture Research, Ad-Hoc-Group of BMBF Otto Kinne Foundation, support of young environmental scientists in eastern Europe, member of the Board of Trustees

Workpackage CO2: Coastal Diversity: key species and food webs

(Spokesman: Prof. Dr. Karen Wiltshire, AWI and Prof. Dr. Franciscus Colijn, GKSS)

Academic results

The Workpackage Coastal Diversity specialises in the holistic scientific appraisal of coastal seas with particular emphasis on the ecological diversity of the North Sea, encompassing its habitats and the encumbering pressures of such an ecosystem. For the first time, in this programme we have successfully managed to network diverse disciplines, introduce innovative technology and model to answer fundamental ecological questions.

We place an emphasis on ecosystem function and key species (i.e. those species which have a pivotal role in ecosystem function) in our work. There are four sub-themes in this Workpackage: **Habitats and Biodiversity**, **Hidden Diversity**, **Adaptive Diversity** and **Foodwebs and Functional Biodiversity**. We collaborated across these sub-themes to maximise knowledge and to better integrate the information. One of the questions we asked was whether key organisms that have been assumed to be identical, based upon morphological criteria, are really the same, or do they occupy different niches (**Hidden Diversity**). This extends the information required to deal with the poorly explained "Paradox of the Plankton", where many phytoplankton taxa appear to be occupying the same ecological niche. To illustrate this, the diatom *Thalassiosira rotula*, an organism which plays a pivotal role in the food chain was isolated all over the North Sea and at different times of the year. The taxonomic, genetic, physiological and ecological relationships of this species were examined. This "one" organism is so diverse in its adaptations to different water conditions, in particular to temperature, that the species definition must be reconsidered. Strains of *T. rotula* were shown to express a range of temperature tolerances – both warm- and cold-water preferences were expressed among different isolates (**Adaptive Diversity**). The toxic aldehydes produced by *T. rotula* as a predator defence vary considerably depending on the nutrient status of the alga (**Adaptive Diversity & CO3 link**). This has significant consequences for interpreting predator defence mechanisms. We have shown that putative predator defence, mediated either by allelochemicals (e.g. aldehydes produced by certain diatoms), or by large prey size, may not always function as a viable defence strategy. An example of the latter is seen among North Sea dinoflagellates, which can successfully ingest diatom colonies much larger than themselves and thus control the growth dynamics of diatoms *in situ* (**Foodwebs and Functional Diversity**).

The ecosystem placement of key species, such as their relationship with other microorganisms, is also under active study. Analogous to larger organisms, we found that microalgae (including *T. rotula*) are "microplatforms" - micro-habitats for their own populations of bacteria. As an example of thus far hidden diversity, specific microalgae harbour different bacteria, potentially in symbiotic relationships. Such relationships might prove to be the limiting factor in microalgal uptake of nutrients.

Parasitism is another very interesting ecological relationship, which is considered in this Workpackage. Our studies showed that three times more parasite than host species are present in the Watt, albeit with variable infestation rates. Native parasites even adopt non-native bivalves introduced into the North Sea. Such relationships span many trophic levels. We intend to model aspects of our shallow coastal seas **(Hidden Diversity & Functional Diversity)**, by using, for example, network analysis (ENA). By this method, the differences in food chain length or biomass production in a system at different trophic levels can be determined. This has already proven useful in studies on different habitats in the Wadden Sea, to establish the level of organisation of different habitats. For example, mussel bank habitats and sea grass beds show a high degree of organisation (ascendancy), whereas sand banks and other areas with high hydrodynamic exposure are not so highly organised. This is partly related to the interactions and adaptations of the key species in these habitats (**Modelling** objectives in CO2).

We have shown that the survival and fitness of zooplankton are determined by what they eat. If the total carbon levels (food quality) of the food for zooplankton drop below a certain minimum level they will not feed. Thus, it is not just where they dwell in the water column, but the cohort species and abundance and quality of seston in their habitat that determines their survival and the success of the dependent stage of the food web. Similarly, in crustaceans, the enzymes required for digestion of food varies among species and depends on their eating habits. These adaptations are often analogous to the changes in "lifestyle" that these crustaceans must undergo in their life history; they often start off as plankton in the water column and end as adults in the benthos. How well these organisms are adapted to these extremely different "lifestyles" and habitats determines their success and in turn that of their predators (**Adaptive Diversity**). Often this difference is

comparable to an adaptation to living in an extreme habitat, such as in polar waters (**Habitat Diversity and Adaptive Diversity**).

Geographical comparisons are the subject of our comparability studies on key species, ranging from macroalgae to crustaceans. Key organisms are integrated into an ecosystem concept based upon characterization of the habitats, the organisms in these habitats and their adaptations. By looking at habitat changes in rocky shore benthic populations, we have differentiated changes in the occurrence of key species that are also related to changes in light penetration of the water column (**Habitat Diversity and Adaptive Diversity**). Via such information we are beginning to understand new and pivotal links of the food chain that are vital to successful ecosystem function. Such work has provided the foundation for the successful conceptualisation of ecosystem model modules for CO2 (together with **GKSS**. At AWI, we have developed, for example, new ways of looking at the impact of zooplankton grazing on phytoplankton blooms, so as to differentiate between the importance of top-down and bottom-up control of the spring bloom in the North Sea. Additionally, the role of phytoplankton cell size on growth rates and general photosynthetic efficiency has been recalibrated. This will help to provide explanations for the successional occurrence/ prevalence of specific microalgae in the North Sea pelagic system.

State of achievements of deliverables

1. Assessment of habitat-related biodiversity and their changes in the coastal waters of the North Sea.

This deliverable is fundamental to our interests in shallow coastal seas. Consequently it is represented by a working group straddling all the locations involved in Coast with a detailed organisational plan to acquire the information for this deliverable. Work from AWI with support from GKSS within Workpackage CO4 primarily involves comparisons of soft and hard bottom biotopes on Helgoland and Sylt. The spatial scales identified are 10 – 100 m² and 100 - >1000 m². Detailed cartography of the species distributions of Helgoland and in selected comparative areas has been carried out and this part of this work has already published in comparative studies of Helgoland and Sylt. Historical information has been gathered and added to the knowledge base in a co-project with CO1.The estimation of biotope-diversity has been identified as a requirement for assessing potential change. To this end, eulittoral areas have been mapped for Sylt and Helgoland. The sublittoral biotopes have mapped using the echosound system RoxAnn. By the end of 2006 we expect to publish the first sublittoral comparisons.

The evaluation of biotope change is only valuable if it is related to the organisms and their specific adaptations. Consequently, key species (eg. isopods and macroalgae) have been identified with key topics (eg. alien species, temperature, light) and experiments and *in situ* investigations have been carried out. For example, the known changes in light penetration at Helgoland over the last 40 years have been co-evaluated with the occurrence of macroalgae. We found distinct shifts in the populations and we have also published studies on how introduced species interact with indigenous species. Areas and organisms of interest have been identified for studies on the exchange of species between different habitats. The first experiments have been prepared to examine the impact of such exchanges.

The delivery of information for this goal is anticipated over longer time scales. The work is heavily dependant on collaborations and interactions between Foodweb studies in CO2 and long-term evaluations made in Workpackage CO1. The information acquired is already feeding into Network analyses and has allowed the first published comparisons of biotopes. Towards the end of Marcopoli, this work will culminate in unprecedented information-richness for the shallow waters of the North Sea, thus supporting management strategies envisaged in CO4.

2. Advanced knowledge of trophodynamic interactions in relation to biodiversity and ecosystem function.

This deliverable is fed by 80% of the science carried out in CO2, primarily by AWI scientists. The structure of the work supplying this deliverable has been set up such that key species are first identified in the system, both from biotope data from the Habitat Diversity studies in CO2 and Long-term data from CO1. These key species range from phytoplankton taxa, the base of the pelagic food chain, and zooplankton, to dominant macroalgae or introduced benthic species. The question of species identification and the recognition of new organisms is carefully examined, e.g. in the subtopic **Hidden Diversity** using modern techniques. A highly successful collaborative project has been started at the AWI on the diatom *Thalassiosira*.

The adaptations of these species to their environments are examined both *in situ* and under controlled conditions in the laboratory **(Adaptive Diversity).** This work has been related to geographical variability and forms valuable collaborations with the POL packages. Although the topics worked upon in this Adaptive Diversity package are highly varied, they have a common theme - understanding how marine animals and plants are adapted to their environments and their constraints. The information output is very large in this field and consequently in CO2, we strive to maintain the focus on the ecological relevance and to relate such work to *in situ* data.

This guarantees the link to trophodynamic interactions. In CO2 we place key organisms in their trophic hierarchy. For example, in bacterial-microalgal-zooplankton–fish studies, the interaction of bacteria with microalgae is already taken into consideration before the microalgae are fed to zooplankon in food quality or other experiments. We try to make sure that we relate these studies to the relevant genetic information of the organisms, the adaptations of these to their environments and the real data from outside.

We are aware that we are already producing large amounts of information (publications) for this deliverable. One of our imminent goals is to assemble the information into a at least a conceptual model and preferably into an ecosystem model (with GKSS).

3. Conceptual models integrating responses of key organisms to their physico- chemical environment and the interactions among major players

This work is mainly based in GKSS (>80%). However, in order to better understand our habitats we have set up the network analysis (ENA) working group at the AWI. Using this method, the differences in food chain length or biomass production in a system at different trophic levels can be determined. This method has already been useful in studies on different habitats in the Wadden Sea, whereby we determined the level of organisation of different habitats. This will be implemented in comparative studies between biotopes on Helgoland and Sylt in the near future and it is envisaged that the working group will link up with groups in POL.

In CO2 within AWI we also developed new ways of looking at the impact of zooplankton grazing on phytoplankton blooms, so as to differentiate between the importance of top-down and bottom-up control of the spring bloom in the North Sea.

A new methodology for defining algal blooms mathematically has been introduced, allowing for the first time the comparisons of growth rates and bloom dynamics in the North Sea based on real data. This will be extended to experimental data and probably will feed the ecosystem module to be developed towards the end of MARCOPOLI. All these modelling efforts are published or in press.

4. Modules for a biophysical ecosystem model of the coastal North Sea

A working group has been set up to devise the criteria required for delivery of ecosystem modules by the modelling group in GKSS. Core topics have been identified and are currently being evaluated. These core topics include the size spectrum of organisms and how this relates to predator-prey relationships in the pelagic. These include larval distribution mechanisms, the effects of bottom-up and top-down control of the spring bloom of phytoplankton and adaptations of phytoplankton to light. At the AWI we are already testing scenarios in the laboratory to corroborate the mathematical models and are also providing the urgently required *in situ* data for scenario testing.

Personnel

Personnel	Institutional funding	Third party funding
	Scientists / PhD / Technicians	Scientists / PhD / Technicians
AWI	12.3/4.0/9.0	3.6/12.8/2.0

Publication outcome numbers

Academic Publications Refereed only	2004-2006 publ. / in press
ISI	94 / 17
non ISI	60 / 12
PhD theses	12 / 1
Master & Diplom Theses	28 / 0
Books	0 / 1
Book chapters	4 / 3

Key publications

1. Augustin, C.B., Boersma, M. (2006). Effects of nutritional stressed algae on different Acartia species, Journal of Plankton Research, 28(4), 429-436.
2. Baird, D., Asmus, H., Asmus, R. (2004). Energy flow of a boreal intertidal ecosystem, the Sylt-Rømø Bight, Marine ecology-progress series, 279, 45-61.
3. Beer, D. de, Wenzhöfer, F., Ferdelman, T. G., Boeme, S. E., Huettel, M., Beusekom, J. E. E. van, Boetcher, M. E., Musat, N., Dubilier, N. (2005). Transport and mineralization rates in North Sea sandy intertidal sediments, Sylt-Rømø Basin, Wadden Sea, Limnology and oceanography, 50(1), 113–127.
4. Boersma, M., Elser, J. J. (2006). Too much of a good thing: on balanced diets and maximal growth, Ecology, in press.
5. Buschbaum, C., Chapman, A. S., Saier, B. (2006). How an introduced seaweed can affect epibiota diversity in different coastal systems, Marine biology, 148, 743-754.

List of guest scientists (selected from 35)

1. Hüttel, Markus, MPI Bremen/Florida State University, USA, 07.03. - 17.03.04, 12.07 - 30.07.04
2. Brinkmann, Bert, Netherlands, 02.06. - 05.06.04
3. Glud, Ronny, Denmark, 08.03. - 14.03.04, 12.07. - 24.07.04
4. Sokolowski, Adam, Poland, 07.12. -10.12.04, 06.06. -11.06.05
5. Titlyanov, Edouard, University of Vladiwostok, Russia, 01.01. - 14.03.04
6. Titlyanova, Tamara, University of Vladiwostok, Russia, 01.01. - 14.03.04
7. Wolowicz, Maciej, Univ. Gdansk, Poland, 07.12. - 10.12.04, 06.06. - 11.06.05
8. Middelburg, Jack, NIOO, Yerseke, Netherlands, 7.3 - 9.3.2004
9. Cook, Perran, MPI Bremen, 7.3. - 17.3.2004, 26.10. - 31.10.2004
10. Kotwicki, Lech, IOPAS, Sopot, Poland, 7.3. -10.3.2004, 12.7. - 18.7.2004
11. Baird, Daniel, Nelson Mandela University, South Africa, 06.05 - 08.05
12. Moniz, Monica, University of Lisbon, Portugal, 09.05 - 06.06
13. Reis, Mariana, University of Lisbon, Portugal, 11.05 - 07.06
14. Alvarez, Inmaculada, University of La Coruna, Spain, 01.02. - 19.04.06
15. Thiemann, S., DLR (Deutsches Zentrum für Luft- und Raumfahrt), 04.04 and 12.04
16. Wollgast, S., University of Essen 05.05 - 05.06
17. Hee, Young Yun, University of Bremen, 10.05 - present
18. Enge, A., University of Rostock, 10.05 - present
19. Karkosz, S., University of Köln, 05.06 - 11.06
20. Pollüopüü, M., University of Tallin, Estonia, 03.06

List of running/accepted third party funded projects (selected from 26)

1. PLANKTON*NET, EU project, duration 24 months, start 01.04.2006, 96,000 €
2. PLANKTON*NET, BIS (Bremerhavener Investitionsgesellschaft) project, duration 24 months, start 01.04.2006, 120,000 €
3. Ecological genetics in *Daphnia*: local adaptation and microevolution at intra- and interspecific level, DFG project, duration 2002 - 2005. AWI in co-operation with the University of Frankfurt, funds: one PhD student plus 25,000 €
4. Carotenoids and nutrients in zooplankton-phytoplankton interactions, DFG project, AWI in collaboration with the IFM-Geomar, 25,000 €

5. Interactions between phytoplankton- and zooplankton dynamics in relation to hydrography, BMBF project, duration 2002 - 2007, GLOBEC-GERMANY, 340,000 €
6. Programm zur Förderung anwendungsnaher Umwelttechnologien, BIS-PFAU project (2), duration 2004 - 2005, AWI, 94,000 €
7. MarBEF, NoE, (Marine Biodiversity and Ecosystem Functioning), EU DG XII, duration 3.2004 - 2009, 60,000 €
8. MarBEF, Responsive Mode Project LargeNet, EU DG XII, duration: 3.2004, 4,000 €
9. MarBEF, Theme 1 (Temporal and spatial patterns of biodiversity), EU DG XII, duration 4.2006 - 2009, 120,000 €
10. Restocking Programme Helgoland Lobster, State of Schleswig-Holstein, duration 8.2005 – 2008, 90,000 €
11. Effects of larval nutrition on growth of juvenile spider crab (Maja brachydactyla) reared in captivity, Centro de Acuicultura, Instituto de Investigación y Tecnología Agroalimentarias (IRTA) (Spanien), AWI, Project partner: Dr. Guiomar Rotllant, 100,000 €.
12. Development of Chilean king crab culture phase II: improvement of technology for seed production and development of growth out technology, Universidad Austral de Chile, Puerto Montt, Chile, AWI, Project partner: Dr. Kurt Paschke, 60,000 €
13. Praxistest für das Makrophyten- und Miesmuschel-Monitoring bei Helgoland im Rahmen der WRRL: Küstengewässertyp Helgoland (N5), LANU-Schleswig-Holstein, 15,600 €
14. Physiological acclimation of marine macrophytes along physico-chemical stress gradients, DFG Project BI 772/2-1 & BI 772/2-2, duration: March 2004 - February 2007, 94,100 €
15. Trophische Interaktionen im Pelagial: die Rolle des Zooplanktons, HGF Impuls- und Vernetzungsfonds des Präsidenten: Helmholtz-Hochschul-Nachwuchsgruppe, duration 2004 - 2007, 125,000 € per year (total 3 year funding)
16. Seapura: species diversification and improvement of aquatic production in seaweeds purifying effluents from integrated fish farms, EU project, duration 01.02.2001 -31.01.2004, 185,449 €
17. COSA: Coastal sands as biocatalytical filters, EU project, duration 01.11.2002 - 31.10.2005, 201,681 €
18. Freiland-Tankzüchtung von Nordsee-Makroalgen auf Sylt für den Nahrungsbereich, Deutsche Bundesstiftung Umwelt, duration 01.01.2002 - 31.12.2004, 99,659 €
19. Aquakultur von Nordsee-Makroalgen und der herbivoren Meeresschnecke Abalone, EU project FIAF, duration 01.01.2004 - 31.03.2006, 288,159 €
20. Mikrophytobenthos und Tannine, Projektbezogener Personenaustausch mit Argentinien, DAAD project, duration 2005 - 2006, 25,000 €

List of expeditions

1. AHAB 2 (Alexander von Humboldt Angola-Benguela) Ship: RV Alexander von Humboldt in the Angola-Benguela upwelling system, 3. 2004; Theme: Krill in the marine food web, 1 scientist
2. KOL 06, 6. – 29. Mai 2006, Kongsfjord, Spitsbergen, 1 scientist
3. King George Island (Antarctica, Jubany Station) & latitudinal gradient along the coast of Chile (Universities of Punta Arenas, Valdivia, Coquimbo, Biological Station Las Cruces), 1 PhD student
4. Zooplankton Foodwebs Nordsee - Deutsche Bucht, 1 PhD Student:
   Heincke: HE 214: 18.07.04 – 03.08.04
   Heinke: HE 219: 18.09.04 – 03.09.04
   Heincke: HE 235: 25.07.05 – 31.07.05
   Posedion: PS 329: 04.10.05 – 17.10.05
5. Globec-Germany-Expedition AL236, with M/SAlkor from Kiel, 07/05/-15/05/2004 German Bight/North Sea, participants: 2 scientists, 1 PhD student
6. Globec-Germany-Expedition HE 211, with M/S Heincke from Bremerhaven, 17/06/-25/06/2004 German Bight/North Sea, participant: 1 PhD student
7. Globec-Germany-Expedition HE 228, with M/S Heincke from Bremerhaven, 17/05/-28/05/2005 German Bight/North Sea, participant: 1 student

List of external co-operations (selected from 65)

1. PD. Dr. Klaus Schwenk, University of Frankfurt
2. Dr. J. Alheit (IOW), Prof. Dr. D. Schnack (Univ. Kiel), Prof. Dr. A. Temming (Univ. Hamburg)
3. Prof. Dr. W. Hagen (Univ. Bremen) and many others within the GLOBEC-Germany Project
4. Prof. D. O. Hessen et al. (University of Oslo, Norway). Carbon sequestration and stoichiometry
5. Prof. J. J. Elser (University of Arizona, USA). Stoichiometry
6. Dr. A. Iannora et al. (Stat. Zool. Napels, Italy), Prof. G. Pohnert (Univ. Lausanne, Switzerland), Dr. S. Poulet (St Biologique, Roscoff, France) et al. Influence of phytoplankton on herbivore reproductive success: impact of infochemicals and food quality
7. Dr. N. Aberle-Malzahn, Dr. C. Clemesen (Univ. Kiel) Effects of nutritional quality constraints on higher trophic levels
8. Dr. David Montagnes, University of Liverpool, UK
9. Dr. Ana Amorim, Universität Lisbon
10. Dr. Manfred Kaufmann, University of Madeira, Portugal
11. Dr. Barbara Meyer, Max-Planck Institut, Ploen
12. Dr. Paddy Patterson, Marine Biological Laboratory, Woods Hole, USA
13. Dr. Thomas Raabe/ Claus Duerselen, AQUAECOLOGY, Oldenburg
14. Professor Ulrike Feudel, Univ. Oldenburg
15. P.D. Dr Jan Freund, Univ. Oldenburg
16. Professor Ulrich Sommer, Univ. Kiel
17. Professor Helmut Hillebrand, Univ. Köln
18. Professor Bryan Manly, Western Systems Ecology, Wyoming US
19. Professor Jan Trondsen, University of Oslo, Norway
20. Dr. Daniel Vaulot, CNRS, Roscoff, France

List of co-operations in MARCOPOLI

CO2 has internal linkages to CO1 by providing habitat and biodiversity maps/data for interpretation of biodiversity change. The importance of diversity for ecosystem functioning is common surveys of biological and geological features. Co-operation with CO1 is conducted on long-term trends of organisms and introduced species. The hard-bottom fauna at Helgoland is compared at soft-bottom areas at Sylt. This also refers to modelling exercises in Network Analysis and case studies of mussel beds and single species, e.g. the Pacific oyster and the sand shrimp. Together with CO1 we use long-term data series for ecosystem modelling and hypothesis development.

CO2 works with CO3 scientists on chemical interactions in the plankton (e.g. production of aldehydes) and the interference of hydrocarbons with the olfactory performance of the Helgoland lobster. Several pheromones and other scent-substances are being described and the effects tested.

Co-operation with CO4 is focussed on Ferrybox development, optical sensors and microchip development. Changes in current systems of the German Bight affect distribution and persistence of several benthic species with pelagic larvae, e.g. the Helgoland lobster and the Pacific oyster. Modes of distribution are incorporated into modelling exercises in oceanographic and ecosystem models (GKSS).

Activities in CO2 relating physiological acclimation of marine macroalgae to abiotic stress are closely allied to corresponding studies in POL 4 on polar marine algae. Further collaborative work with POL4 and CO3 involves comparative analysis of the bacterial diversity in mussels of antarctic and temperate waters and comparative analyses of the bacterial diversity on marine macroalgae

CO2 projects are linked to POL5 via plankton community grazing experiments using dilution methods and investigation of intraspecific diversity in the key species *Thalassiosira rotula,* including ecological differences between different clones, particularly with respect to salinity
Other POL relevant projects are via diversity and succession processes of picoplankton as determined by PCR-DGGE and sequence analyses. Several species of krill are used as indicators of effects of Global Change on food webs. Cooperative case studies are conducted from the Arctic via the upwelling regions off Namibia to the Antarctic.

With respect to POL6/POL7, dinoflagellate cyst distributions around the island of Helgoland are being undertaken in CO2. Examination of sediment samples and hatching experiments are underway to examine the relationship between species diversity in the water column and sediments and to investigate the presence of cysts of potentially harmful algae.

List of memberships in national and international committees

M. Boersma:	Steering Committee of IMBER-Germany. member of ICES Working Group on Zooplankton
F. Buchholz:	MARSnet, European Network of Marine Research Stations, Representative for AWI OKF, Otto Kinne Foundation, in support of young environmental scientists in Eastern Europe, Member of the Board of Trustees
J. van Beusekom:	Bund Länder Messprogramm, AG Nordsee associate member of the DWK (German Scientific Commission for Marine science)
C. Wiencke:	Speaker Section Phycology, German Botanical Society
K.H. Wiltshire:	associate member of the DWK (German Scientific Commission for Marine science) Member of ICES working group on Phytoplankton Member of DFG working group on „Freiheit der wissenschaftlichen Meeresforschung

Workpackage CO3: Chemical Interactions: ecological function and effects

(Spokesman: Prof. Dr. Allan Cembella, AWI and Prof. Dr. Andreas Prange, GKSS)

Academic Results

The mission in this Workpackage is to determine the nature, extent, and function of chemical interactions of natural and anthropogenic substances with biota in coastal ecosystems. Natural and anthropogenic compounds play key roles in coastal ecosystems at the biomolecular level, but can also elicit effects at higher levels of biological organization. Effects and functional significance of chemical compounds are magnified in coastal zones because of the high contribution of these substances from anthropogenic sources, atmospheric inputs, and terrigenous run-off. To study these phenomena, we proposed a novel *marine ecological chemistry systems approach*, because it is necessary to move beyond a static quantitative and qualitative description of these substances in compartments of the coastal zone towards a dynamic perspective within which we define and model the *functional significance* of the interactions in food webs and coastal ecosystems. The AWI component of this Workpackage has been divided into five interlinked sub-themes: Effects of natural and anthropogenic toxicants on marine fauna (ST1); Molecular ecology and allelochemistry of protists (ST2); Dynamics of natural toxins in marine food webs (ST3); Marine microbiology and natural products (ST4); and natural substances from marine invertebrates (ST5). This knowledge is combined with ecological chemistry and ecotoxicological process studies linked to the effects of anthropogenic organic pollutants on marine food webs and ecosystem health from the molecular and cellular level to individuals within diverse populations. The combination of natural products and anthropogenic organic components research in an ecological content has created a unique programme for understanding the chemically mediated dynamics of our coastal ecosystems.

A) Natural Products for Marine Bacteria

Bacterial isolates from diverse marine habitats proved to be a rich source of novel marine bioactive compounds (ST4). Actinomycetes from mangrove areas have yielded a broad spectrum of natural products. The trioxacarcins, in particular, exhibited manifold reactions in bioassays, including high anti-bacterial, anti-tumour and anti-malarial activity. Screening of Arctic sea-ice bacteria revealed a bacterium affiliated to *Flavobacterium* that produced mono- and di-nitrophenol compounds, some of which may be effective as iron chelators – an important function in microbial loop dynamics.

B) Venoms and Endosymbionts from Marine Cnidaria

The Cnidaria (jellyfish and their allies) represent a major zooplanktonic fraction in North Sea coastal waters, acting as major planktonic predators affecting fish populations. Jellyfish can also cause dangerous stings after contact by humans. Our investigations are targeted towards determining the biochemistry and mode of action of the cnidarian toxins (ST5), and the role of bacterial endobionts (ST4). Cnidaria were collected from waters of the German Bight (Helgoland), the Hebrides and the Orkney Islands (cruises HE 209 in 2003; HE 230 in 2004). Tentacles from *Scyphozoa*, *Hydrozoa* and *Anthozoa* were used for isolation of venom containing capsules (cnidocysts) and the investigation of endobiotic bacteria. Cnidocysts were subjected to toxicity tests and the chemical structure analysis by LCMS and MALDI-TOF was performed by our GKSS partners. The first phylogenetic sequences of bacterial 16S rDNA derived from tentacles of the jellyfish *Cyanea capillata* (Helgoland) indicate the presence of marine species such as *Roseobacter* sp., *Ahrensia kiliense*, *Vibrio* sp. *and Sulfitobacter* sp., whereas the sea anemone *Metridium senile* (Helgoland & Orkney Islands) harbours *Pseudomonas saccharophilia)* and *Marinobacter* sp.

C) Natural Products and Chemical Ecology of Marine Invertebrates

The planktonic pteropod *Clione limacina* has evolved the ability to produce exceptional chemical compounds that enables it to survive the harsh conditions in polar regions (ST5). We found that this organism is able to very efficiently exploit its food resources to optimize storage of huge amounts of lipids and also to chemically protect itself. It synthesises large quantities of unusual ether-lipids with a considerable proportion of odd-chain fatty acids, formerly known only from bacteria. These lipids may protect the animal against epizootic fungi and bacteria.

A systematic investigation of the most abundant sponges of the North Sea (Orkney- and Shetland Islands), the Arctic (Spitsbergen), and the Caribbean Sea has revealed a broad spectrum of biological activities (ST5). The antibacterial, cytotoxic and enzyme-inhibitory effects of North Sea

and Arctic sponges were comparable to those of specimens of warmer habitats, but with some notable exceptions (ST1). A chemical ecological investigation of invertebrates from Spitsbergen indicated that only two species studied are chemically defended against predators (*Haliclona viscosa* and *H. nodosa*) and only the former species showed strong antimicrobial activity against five bacteria from the surrounding area. By comparison, our studies indicated that Caribbean reef sponges of the genus *Agelas* are chemically defended from fish predators by pyrrole-imidazole alkaloids. Chemical ecological studies also showed a feeding deterrent and antimicrobial activity of the Arctic sponge *Haliclona viscosa*. The responsible compounds, 3-alkylpyridinium alkaloids, were isolated and identified as new natural products via mass spectrometry. By comparison, stereochemistry of new natural products from the Caribbean sponge *Stylissa caribica*, including the stylissadines, complex pyrrole-imidazole alkaloids, were established by NMR-spectroscopy. Of special interest is that the feeding-deterrent effect of this class of compounds was associated with their activity as blockers of cellular calcium-ion channels.

Bromophenols are natural products (also produced industrially as flame retardants) found in many marine organisms, including fish, crustaceans, polychaete worms and even mammals. As suspected “endocrine disruptors“, bromophenols may disturb hormonal regulation in mammals. We have investigated feeding deterrent properties of pyrrole alkaloids from marine sponges (ST1, ST5). Both brominated pyrrole alkaloids and phenols alter intracellular calcium signals of neuroendocrine cells (hormone-producing type PC12). Pyrrole alkaloids reduce calcium ion inward currents through voltage-operated membrane channels, whereas brominated phenols release additional calcium ions from intracellular calcium stores. We have shown the potential of these substances to act as potent chemical signals in isolated cells and chemosensory organs of sea slugs and shrimps. The description of the functional anatomy of the chemosensory organs (rhinophores) the sea slug (*Aplysia punctata*) has also been completed.

D) Chemical Ecology of Toxic Marine Protists

Since the inception of Marcopoli COAST, the AWI research programme on chemical ecology of toxic marine protists can justifiably claim have emerged as the global leader in this field. Certain harmful algae (>200 species), associated with cell proliferation known as “Harmful Algal Blooms” (HABs), are capable of biosynthesis of potent marine phycotoxins with high bioactivity as enzyme inhibitors or ion-channel effectors. The aim of our CO3 contribution is to elucidate the processes supporting bloom formation mediated through toxins and other potential allelochemicals (ST2). Therefore we have combined approaches such as toxin analysis, physiology, and functional ecology for understanding the processes and functional role, with molecular genetics for elucidation of the regulation of growth and toxin synthesis.

The toxic marine dinoflagellate *Alexandrium* is of particular relevance to North Sea coastal ecosystems. By application of morphological criteria and various molecular methods, including fluorescence *in situ* hybridisation (FISH) in combination with solid-phase cytometry, and conventional and real-time quantitative PCR (RT q-PCR), we differentiated and quantified three *Alexandrium* species, namely *A. tamarense*, *A. ostenfeldii* and *A. minutum*. in field populations from the Scottish east coast.

North Sea populations of *A. tamarense* and *A. minutum* were found to produce tetrahydropurine neurotoxins (PSP toxins), whereas *A. ostenfeldii* yielded macrocyclic imine toxins known as spirolides, including novel derivatives (ST2). In addition to PSP toxins and spirolides associated with *Alexandrium* spp., field samples from the Scottish east coast also yielded other toxins, including DSP toxins, domoic acid and yessotoxins. We analyzed the yessotoxin composition of isolates of the dinoflagellate *Protoceratium reticulatum* from the Benguela Current off South Africa and compared the profiles to cultures of *P.reticulatum* and *Gonyaulax spinifera* from the east coast of Scotland by high performance liquid chromatography coupled with tandem mass spectrometry (LC-MS/MS). The data on the cultured isolates were then compared to the yessotoxin profiles found in natural phytoplankton assemblages from both locations.

We characterized the genetic structure and intra-population variation in *A. tamarense* from the Scottish coast from clonal isolates (>200), by phenotypic analysis of morphological characteristics and toxin composition, and complementary genotypic analysis with molecular markers. The work has revealed a surprisingly high intra-population variation in PSP toxin content and profiles, and this was confirmed with genetic markers, such as microsatellites and amplified fragment length polymorphism (AFLP). Yet there was no obvious correlation between the patterns of expression of known toxins, allelochemical activity and the genetic markers we have established. High allelochemical potency was expressed by some strains of *Alexandrium*, with very low effective concentrations (<100 cells ml^{-1}) required to lyse 50% of the target cells. Such deleterious consequences may be highly significant in explaining the formation and maintenance of

Alexandrium blooms, if they cause alterations in grazing behaviour and affect competitive outcomes.

Most phycotoxins produced by marine protists are polyethers, presumed to be polyketide-derived. Polyketide biosynthesis in both prokaryotes (bacteria) and eukaryotes (protists, fungi, plants and animals) is typically mediated by the enzyme polyketide synthase (PKS). In a bioinformatic study of PKS genes in protists, we identified a class of putative modular Type 1 PKS genes (formerly known only for bacteria and fungi) from newly sequenced genomes and expressed sequence tag (EST) data-bases that cluster into a unique protistan clade. These observations provide important insight into the evolution of polyketide metabolic pathways and suggest that PKS enzymes found in various lineages represent a conserved ancestral form derived from early eukaryotes.

In studies of the biosynthetic pathway to spirolide production in *A. ostenfeldii* by stable isotope NMR spectroscopy, in collaboration with the National Research Council, Halifax, Canada, we have effectively demonstrated that spirolides are polyketides. This work represents the first elucidation of a biosynthetic pathway to macrocyclic imines. We have adopted a limited genomic approach to functional gene expression for a number of protistan species in searching for the regulatory genes associated with growth and toxin biosynthesis. For example, in *A. ostenfeldii*, we detected several genes putatively related to toxin synthesis, including genes that appear to encode PKS. The low degree of sequence homology in *A. ostenfeldii* with known sequences continues to present a challenge for determining the expression and regulatory function of biosynthetic genes for dinoflagellate secondary metabolites, and specifically for spirolide biosynthesis in *Alexandrium.*

Our recent work on fish-killing algal blooms of raphidophytes and prymnesiophytes, which cause mass fish mortalities in coastal areas throughout the world, including the North Sea and the Mediterranean, has also yielded new insights. We investigated a mixed bloom event involving the raphidophytes *Chattonella* sp. and *Fibrocapsa* sp. on the Adriatic coast of Italy, including molecular genetic, morphological and ecological aspects. Light and electron microscopic observations revealed one of the species as *Chattonella subsalsa*, but genetic markers for nuclear and ribosomal DNA (LSU, SSU, ITS, psaA and RubisCo) differentiated this *Chattonella*, and with less distinctness *Fibrocapsa* sp., from other known strains of the respective genera. Phenotypic differences among the isolated clones were determined from profiles of polyunsaturated fatty acids (PUFAs) and the activity of reactive oxygen species (ROS), which are putatively responsible for ichthyotoxicity. However, toxicity bioassays based on fish erythrocytes and the brine shrimp *Artemia salina* failed to show an apparent relationship between toxicity and phenotypic and genotypic characteristics.

We are actively investigating the basis of toxicity and growth regulation in the key fish-killing prymnesiophytes, *Prymnesium parvum,* and *Chrysochromulina polylepis*, which are responsible for mass fish mortalities in brackish and marine waters of the North Sea, Baltic Sea and other global locations. *Prymnesium* toxins, known as prymnesins, are linear polyether compounds suggesting that are produced or at least partially modified via polyketide biosynthetic pathways. Therefore, our research focussed upon PKS genes. In our functional genomic approach based on a normalized cDNA library, we have categorized the EST sequences from *P. parvum* and are using this as the basis for oligonucleotide design of a microarray for gene expression analysis. Six potential candidate PKS sequences were identified among the ESTs based on similarity searches. This functional genomic approach to studying the chemical ecology of ichthyototoxic species has proven to be an ideal template for parallel gene expression studies of other protist and cyanobacterial species even when the toxic metabolites have not been completely characterized.

E) Biomarkers in Ecotoxicology

The development of diagnostic techniques based upon genetic and cellular properties, as well as biochemical and pathological markers, is a key issue for monitoring and risk assessment of global marine pollution. Our major goals of the past two years have been the identification of health effects of pollution in central metabolic organs of marine vertebrates and invertebrates using flatfish and mussels as indicator organisms (e.g., EU Project BEQUALM). By interlinkage of pathological events during toxic injury and carcinogenesis with genetic and metabolic changes during detoxification and biotransformation processes, and transport of chemical pollutants, a suite of biomarkers for integrated assessment of animal health has been implemented. We have extensively validated the so-called “core” biomarkers in different climate zones, in addition to developing novel stress tests. Crucially, because the data products are ranked, interpretation will be simple for environmental managers implementing the new EU Water Framework Directive.

State of achievements of deliverables

The general deliverables of this Workpackage are designed as staggered milestones and are stated as follows:

- Identification and characterization of hazardous anthropogenic and natural bioactive substances
- Attribution of ecological functions for chemically defined natural substances
- Novel tools for gene expression of toxic metabolites and bio-response monitoring
- Assessment strategies of cause-effect relationships for hazardous anthropogenic and natural bioactive substances

Some deliverables will thus not be fully realized until the end of the Marcopoli programme, but we have made significant progress on at least some aspects of each of these deliverables. Several publications have resulted from each of these deliverables.

1) Identification and characterization of natural bioactive substances has proceeded rapidly and successfully at AWI, whereas our GKSS counterparts have also included studies on hazardous anthropogenic substances. A host of new natural products have been isolated and characterized from marine sponges from sub-tropical, temperate and polar latitudes. These include new pyrrole-imidazole alkaloids (8) and 3-alkylpyridinium alkaloids (10) with bioactive properties. In addition analogues of both pyrrole-imidazole alkaloids (2) and 3-Alkylpyridinium alkaloids (5), including cyclostellettamine H, I, K und L, viscosaline B, C und E, and viscosamine have been synthesized. All of these compounds are of pharmacological interest as potential therapeutants. From Arctic sea-ice bacteria affiliated to *Flavobacterium*, a suite of 21 different mono- and di-nitrophenol compounds have been characterized. The protein cocktails produced as cnidaria venoms have for the first time been analysed in detail by colleagues at GKSS in a joint project. This protein and proteomic analysis could only have been accomplished with the acquisition of the new MALDI-TOF/TOF instrument in the Bioanalytical Chemistry group at GKSS.

Major progress have been made at the AWI with respect to the characterization of new algal toxin analogues by LCMS/MS. For example, several new derivatives of the macrocyclic imines spirolides have been described from the dinoflagellate *Alexandrium ostenfeldii*. Novel toxin profiles of the toxic dinoflagellates *Protoceratium reticulatum* and *Gonyaulax spinifera* have also been generated.

2) Attribution of ecological functions for the chemically defined marine toxins and other bioactive metabolites must be by inference and deduction, and therefore is a longer term deliverable with extended milestones. Clearly the cnidaria venoms serve a primary role in prey capture and defence and this has only been further substantiated in our chemical and histological investigations. We have not yet reached a conclusion on the role of the endosymbiotic bacteria in the tentacles with respect to venom production. The activity of the multiple di-nitrophenol derivatives in the sea-ice bacteria as natural iron chelators also remains conjectural.

In the pteropod *Clione limacina* the diacylglycerol ethers embedded in the integuments appear to assist in preventing microbial infections. Diacylglycerol ethers are known to exhibit bacteriostatic and fungistatic properties, and they are also believed to protect against radiation damage and may have some anti-tumour properties.

Our success with the functional genomic approach to gene expression of protist toxins suggests that we are on the right track to uncovering the ecological functions of these metabolites. For example, with *Prymnesium parvum*, which is known to synthesise the polyether toxins prymnesin – the putative fish-killing agent - we have randomly selected and sequenced about 9,000 clones from a normalized cDNA library, yielding approximately 15,000 ESTs. The resulting *in silico* analysis of ~6230 contigs and classification into functional categories revealed six candidate PKS sequences based on similarity searches. With our partners at GKSS, we have begun the identification of the prospective ichthyotoxic agents present in our toxic isolates. The evaluation of environmental factors on toxin production has been essentially completed from *P. parvum* as well as for most other toxic protist species under active investigation.

Initial suspicion that the known phycotoxins produced by a variety of toxigenic protists are involved in allelochemical interactions, such as inhibition of grazing by other protists or effects on inter-specific competition are not supported. Indeed we have found no simple correlation between toxicity due to PSP toxins or spirolides produced by *Alexandrium* species and lytic and static

effects on target cells. What is causing the allelochemical response? Unknown extracellular and relatively unstable substance(s), apparently unrelated to PSP toxins or to spirolide content, are responsible for the potent allelochemical effects.

3) Novel tools for gene expression of toxic metabolites and bio-response monitoring have already been developed within the Workpackage but more remain to be produced. We have optimized genetic probe methods (FISH, Q-PCR) with colleagues in CO2 and CO4 for application to field samples of toxic algae. A DNA-microchip based on the mouse genome has been successfully applied to study the up- and down-regulation of genes that may be associated with spirolide toxicity. We are developing DNA microarrays to examine toxin and growth gene expression for a suite of toxic algal species. We have extensively validated biomarkers for marine bivalves and fish with respect to anthropogenic pollutant stressors and this work will be extended to natural toxins. The use of sensory cell networks, such as the olfactory tissues of sea slugs, as a test of Ca++-channel activation or inhibition appears to be a useful system to evaluate bioactivity of many metabolites.

4) Assessment strategies of cause-effect relationships for hazardous anthropogenic and natural bioactive substances will not be generated until the end phase of Marcopoli because this essentially integrates the information produced in the rest of the Workpackage and also involves cross-cutting issues with other elements of the Coast programme. In 2007-2009, we will begin to assemble the elements of this deliverable. Nevertheless, we have already completed experiments on the detoxification processes related to the metabolism of PSP toxins and spirolides by bivalve shellfish, including publications on the comparative biotransformation processes in blue mussels (*Mytilus edulis*) and the soft-shell clam (*Mya arenaria*) and the cleavage of the cyclic imine ring – the toxic pharmacophore - of spirolides by mussels. The studies will be used a the basis of developing an ecotoxicological model of toxin metabolism in marine food webs.

Personnel

Personnel	Institutional funding	Third party funding
	Scientists / PhD / Technicians	Scientists / PhD / Technicians
AWI	8.0/6.0/5.6	0.1/2.0/0.4

Publication outcome numbers

Academic Publications Refereed only	2004-2006 publ. / in press
ISI	37 / 3
non ISI	19 / 4
PhD theses	3/ 1
Master & Diplom Theses	7 / 4
Books	0 / 0
Book chapters	6 / 2

Key publications

1. Cembella, A. D., John, U. (2006). Molecular physiology of toxin production and growth regulation in harmful algae, Ecology of Harmful Algae, E. Granéli and J. T. Turner (eds), Springer Verlag,339 pp.
2. Barenbrock, J., Köck, M. (2005). Screening enzyme-inhibitory activity in several ascidian species from Orkney Islands using Protein-Tyrosine-Kinase (PTK) bioassay-guided fractionation, Journal of Biotechnology, 117, 225-232.
3. Bickmeyer, U., Drechlser, C., Köck, M., Assmann, M. (2004). Brominated pyrrole alkaloids from marine agelas sponges reduce depolarization-induced celllar calcium elevation, Toxicon, 44, 45-51
4. John, U., Groben, R., Beszteri, B., Medlin, L. (2004). Utility of Amplified Fragment Length Polymorphisms (AFLP) to analyse genetic structures within the Alexandrium tamarense species complex, Protist, 155(2), 169-179

5. Tillmann, U. (2004). Interactions between planktonic microalgae and protozoan grazers, Journal of Eukaryotic Microbiology, 51(2), 156-168

List of guest scientists (selection)

1. Marco Schmidt, FU Berlin, 01.03.04 – 09.04.04
2. Natalia Wegner, TU München, 30.08.04 – 24.09.04
3. Prof. Dr. Carmen Gloria Seguel Neira, University of Tarapacá, Arica, Chile, 27.02.06 – 13.04.06
4. Susann Hiller, Universität Jena, 16.01.06 - 17.02.06
5. Jakob Pernthaler, Elke Allers, Cecilia Alonsoe, MPI Bremen, 2 - 3 times a year for about 1 week
6. Adrian Wertz, Universität Würzburg, 08.04 - 06.05
7. Thomas Hassenklöver, Universität Hamburg, 08.05
8. Kathleen Walther, Universität Hamburg, 08.05 - 05.06
9. Dr. Heiko Vogel, MPI Jena, 01.02. - 15.02.06
10. Dr. Gernot Glöckner, Fritz-Lippmann-Institute for Age Research, Jena, 01. - 08.03.06

List of running/accepted third party funded projects

1. Expressed Sequence Tags of Toxic Algae (ESTTAL), Prof. Dr. A. Cembella (Coordinator), 01.12.2004 - 30.11.2007, EU Project, 240,585 €
2. MARPLAN within MARBEF, Dr. U. John, AWI Representative, EU Project, 10,000 €
3. Antimicrobial activity of marine sponges, Dr. M. Köck, Beiersdorf AG Hamburg, 3,530 €
4. Screening for PKC activity of Caribbean sponges, Dr. M. Köck, Merck AG Darmstadt, 9,100 €
5. Structure elucidation of natural products, Dr. M. Köck, Aventis AG Frankfurt/Main, 10,000 €
6. Marine Naturstoffe V: Seltene marine Actinomyceten als biotechnologische Quelle für neue antivirale und anti-onkogene Wirkstoffe, Dr. E. Helmke, 2 years, BMBF, 36,000 €
7. BIS-PFAU Projekt (2) Programm zur Förderung Anwendungsnaher Umwelttechnologien, Dr. G. Gerdts, Dr. A. Wichels, 2004 - 2005, funds: 94,000 €
8. Marbef-Microbes, Dr. G. Gerdts, Dr. A. Wichels, EU Project, 2004 - 2007, 4,500 €
9. Biological effects of environmental pollution in marine coastal ecosystems (BEEP), Dr. A. Köhler-Günther, 01.01.01 - 31.01.04, EU Project, 153,580 €

List of expeditions

1. Heincke 209 (05/06 2004) to Scottish east coast and Orkney Islands. Two Scientists.
2. Adriatic coast Cesenatico/Rimini, 08.04, One Scientist
3. Bahamas Cruise, Prof. J. R. Pawlik, June 2004
4. ANT XXI/5, RV Polarstern, 07.05.2004 - 02.06.2004
5. ANT XXII/2, RV Polarstern, Ispol-experiments, 06.11.2004 - 19.01.2005, 1 PhD student
6. ARK XXI/1b, RV Polarstern, 13.08.2005 - 19.09.2005

List of external co-operations (selection from 45)

1. Dr. Vogel, Dr. Kroymann, MPI Chemical Ecology, Jena
2. Dr. Glöckner, FLI of Age Research, Jena
3. Prof. Dr. Moreau, CNRS, Banyuls sur Mer, France
4. Dr. deVargas, CRNS Roscoff, France
5. Prof. Dr. Edvardsen, University of Oslo, Norway
6. Prof. Dr. Read, CSUSM, USA
7. Prof. Dr. J. R. Pawlik, University of North Carolina at Wilmingtion, USA
8. Prof. Dr. T. Lindel, Universität München
9. Dr. F. Sasse, GBF Braunschweig
10. Prof. Dr. R. G. S. Berlinck, Universidade Sao Paulo, Brasil
11. Prof. Dr. M. Göbel, Universität Frankfurt/Main
12. Prof. Dr. M. Reggelin, TU Darmstadt,
13. Prof. Dr. H. Laatsch, Organic Chemistry, University of Göttingen
14. Prof. Dr. H. Fiebig, Oncotest GmbH, Freiburg

15. Prof. Dr. T. Schweder, Biotechnology, University Greifswald
16. Prof. Christa Schleper/Tim Urich, University of Bergen, Norway
17. Prof. Rudi Amann/Dr. Bernhard Fuchs, MPI Bremen
18. Prof. Ken Timmis/Dr. Peter Golyschin/ Christoph Gertler, GBF Braunschweig
19. Prof. Dr. Bernd Luckas/Dr. Bernd Christian, Universität Jena
20. Prof. Wolfgang Rössler, Biozentrum, Universität Würzburg
21. Prof. Konrad Wiese, Biozentrum Grindel, Universität Hamburg
22. Prof. W. Hagen, Marine Zoologie, Universität Bremen

List of co-operations in MARCOPOLI

Linkages are maintained from this Workpackage to many other components of MARCOPOLI. Among these the joint projects with collaborators in the GKSS Bioanalytical Chemistry group directed by Prof. Dr. A. Prange are among the most important. Two key joint projects are identification of the constituents of the protein cocktails in cnidaria venom and the characterization of ichthyotoxic substances from fish-killing microalgae.

Collaborations with CO2 are largely in the context of natural metabolites in marine food webs. Key examples are the identification of mussel metabolites involved in the aging process (D. Abele, CO2, POL4) and chemoreception of natural products by shrimps and copepods (K. Anger, M. Boersma, CO2).

CO3 has established internal linkages to POL5 and POL7 through joint projects on screening of bacteria from extreme environments for secondary metabolites, as well as cold adapted enzymes (E. Helmke). Other networking with POL, involves comparative analysis of the bacterial diversity in mussels of antarctic and temperate waters (D. Abele, G. Gerdts, A. Wichels, CO2,POL4) and comparison of bacterial populations on marine macroalgae (C. Wiencke, M. Molis, G. Gerdts, CO2,POL4). A project on molecular diversity and succession of picoplankton involves CO3 with both CO2 and POL5 (K. Metfies, L. Medlin, G. Gerdts, A. Wichels. Finally, linkages between CO3 and POL 5 have been developed via studies of exceptional lipids of key species in polar oceans (G. Kattner, M. Graeve).

The work on Harmful Algal Bloom species in CO3 is conducted in coordination with elements or CO2 related to the role of allelochemical substances in planktonic food web dynamics, and with CO4 in the context of development and application of molecular probes and biooptical sensors for operation systems for the study of HAB dynamics.

List of memberships in national and international committees

A. Cembella: International SCOR/IOC programme on the Global Ecology and Oceanography of Harmful Algal Blooms (GEOHAB): Founding Member of Scientific Steering Committee, Core Project Co-Leader – HABs in Fjords and Coastal Embayments
International Society for the Study of Harmful Algae (ISSHA): Vice President
International Committee for the Exploration of the Sea (ICES) Working Group on the Dynamics of Harmful Algal Blooms: Member
Intergovernmental Panel of the Intergovermental Oceanographic Commission (IOC) programme on Harmful Algal Blooms: German Representative
Editorial Board Member: *Harmful Algae* (Elsevier Journal), *Helgoland Marine Research* (Springer Journal), IOC newsletter *Harmful Algae News*)
Member of International Advisory Board of the International Conferences on Harmful Algal Blooms

U. John: MARPLAN within MARBEF, AWI Representative

A. Köhler: ICES Working Group on Biological Effects of Contaminants, Member

Workpackage CO4: Observation and Information for Coastal Management

(Spokesman: Prof. Dr. Roland Doerffer, GKSS and Dr. Justus van Beusekom, AWI)

Academic Results

The aim of this WP is to provide tools and scientific information for Integrated Coastal Management. The major challenge and main strategic objective of WP CO4 is to improve monitoring for such a complex environment by utilizing the synergy of very different but complementary data such as itime-series from fixed stations, remote sensing data, laboratory work and model simulations, and developing appropriate new observation techniques.

A) New Observation Techniques

Detection of Toxic Algae Blooms: The detection and quantification of toxic algae is traditionally based on microscopic investigations by specialized personnel and requires a relatively high level of taxonomic expertise. Within the EU-project ALGADEC a fully automated DNA-biosensor for detection and monitoring of toxic algae is being developed. This involves the parallel detection of up to 14 species based on molecular probes. The development of species-specific probes for the most relevant toxic algae of three European regions has been completed. A prototype of a multiprobe-chip and the microfluidics-chamber, which are at the heart of the DNA-biosensor, is now available.

Parallel development of biooptical *in situ* sensing technology for HABs has been implemented for aquaculture sites in coastal embayments in eastern Canada and along the Mediterranean coast of Spain. We have a complete continuous time-series of biooptical data related to seston distribution and plankton blooms (including periods where toxic species were present) over several months for these sites. The AWI has played a crucial role in the conception of the Science Plan for GEOHAB – the Global Oceanography and Ecology of Harmful Algal Blooms – and has developed technological linkages for comparative field studies on the North Sea coasts of Scotland and Norway.

Automatic Observatories: On Helgoland, the classical time-series were extended with an automatic device that registers salinity, temperature, nutrients and phytoplankton components (based on fluorescence) with high temporal resolution. These techniques allow for detection of short-term dynamics that remain unresolved with the manual daily sampling. Events such as sudden drops in salinity have been successfully analyzed with hydrographic models and show the importance of the north-frisian coastal zone as a source of low salinity coastal water.

Video Plankton Recorder: Zooplankton plays a crucial role in marine systems via controlling phytoplankton development and as an important food source for higher trophic levels. To detect zooplankton at small temporal and spatial scales a new plankton recorder has been developed. A new light-frame design (patent applied for) enables the quantification of zooplankton with video techniques. The high-resolution pictures allow an unprecedented taxonomic resolution.

By combining these and further observation techniques, it will be possible in the near future to observe pelagic ecosystems on different levels, ranging from bottom up factors such as light and nutrients, to top-down effects of phytoplankton and zooplankton interactions. By integrating these on-line data in models, short-term prediction of bloom development may become possible.

B) Managing the utilization of the coastal zone

During the next decades the sea floor will be increasingly used for offshore wind energy plants, pipelines, and aquaculture. This has prompted new requirements for a more detailed characterization of the seafloor. For the North Sea, an extensive data set of geochemical, geological and biological information were compiled, integrated in a Geodatabase and analysed by a Geo-Information-System (GIS). Thematic maps were derived, concepts for habitat mapping as EUNIS were considered, and zones along the seafloor were characterized by application of geostatistical techniques.

The mussel populations in the Wadden Sea have experienced low recruitment over the past few years, requiring the import of young mussels from elsewhere for aquaculture. One alternative is to collect mussel larvae on long-lines. Offshore wind parks offer the opportunity to attach these collectors. In the framework of a pilot project, the use of offshore windparks for aquaculture purposes is now being investigated. Special attention is given to the development of a Decision Support System that will help to guide future use of windparks for aquaculture purposes.

C) Assessment of the Wadden Sea Environmental Status: the Wadden Sea QSR 2004

In five-year intervals, scientists and coastal managers evaluate research and monitoring data to assess the present status of the Wadden Sea and trends. Major contributions by AWI scientist include the assessment of the eutrophication status, of seagrass and of the macrobenthos. In general, the Wadden Sea has been developing in a positive way. The eutrophication level is slightly decreasing. Introduced species are relevant issues for the future but thus far, they have not been a major threat. However, the next introduced species or an introduced species that is already there but has not developed its full impact may yet cause severe ecological change.

State of achievements of deliverables

During the past two years, the AWI team has successfully contributed to all deliverables. We focussed on the development and implementation of new observation techniques, on the development of GIS tools and GIS applications and on the assessment of the marine environment.

1. The growing need for automatic monitoring systems that allow for a rapid information delivery and processing on the present status of the marine environment is being addressed for the North Sea and Wadden Sea. We have implemented new automatic devices (stationary Ferry-Box) on Helgoland for measuring hydrographic parameters, nutrients and phytoplankton composition (Fluoroprobe). With this system, we have extended the classical time-series by adding data on the short-term variability of the pelagic system. We developed novel tools for the observation of toxic phytoplankton species with DNA probes and optical (video-based) systems for the detection of zooplankton species. We aim to integrate these systems with other automatic components like the above mentioned Ferry-Box and bio-optical devices. For the North Sea an extensive data set of geochemical, geological and biological information were compiled, integrated in a Geodatabase and analysed by a Geo-Information-Systems (GIS). The deliverables were in the form of thematic maps that incorporated habitat mapping concepts such as EUNIS (European Nature Information System), and seafloor characterised by application of geostatistical techniques.
2. Together with the GKSS, we decided on three demonstrations projects that focus on eutrophication, suspended matter dynamics and a sensitivity analysis of tidal flats. We developed several proxies to characterize the eutrophication status of coastal areas. In our estimation the coastal zone is about five times more eutrophic than under preindustrial conditions. Suspended matter dynamics in the Wadden Sea are linked to eutrophication. More intense eutrophication-related off-shore blooms would presumably enable a more efficient accumulation of organic matter and associated fine material into the Wadden Sea.
3. We have contributed to successful coastal management by sharing our data and our knowledge on coastal processes with coastal managers. Many data are transferred to local and international data bases (e.g. Helgoland Roads-data). At five year intervals, Dutch, Danish and German scientists cooperate with the Common Wadden Sea Secretariat to assess the status of the Wadden Sea. AWI scientist took the lead in three chapters and contributed to two additional chapters of this report. Our scientists are also contributing to several ICES Working Groups and Study Groups dealing with harmful algae blooms, eutrophication, and shellfish aquaculture impacts.
4. The ultimate goal of the Workpackage is the implementation of a hierarchically organized modular system in the form of an operational Decision Support System, which uses the synergy of various methods (SYMONIS). Work on this deliverable is in progress. An Important contribution has been the development of proxies, which allow for the characterization of the eutrophication status of the coastal zone.

Personnel

Personnel	Institutional funding	Third party funding
	Scientists / PhD / Technicians	Scientists / PhD / Technicians
AWI	2.1/0/ 0.6	1.0/2.0/0.2

Publication outcome numbers

Academic Publications Refereed only	2004-2006 publ. / in press
ISI	3 / 0
non ISI	5 / 1
PhD theses	0 / 0
Master & Diplom Theses	1 / 0
Books	0 / 0
Book chapters	1 / 0

Key publications

1. Beusekom, J.E.E. van, Bot, P.V.M., Goebel, J., Hanslik, M., Lenhart, H., Pätsch, J., Peperzak, L., Petenati, T., Reise, K. (2005). Eutrophication, In: Essink, K., Dettmann, C., Farke, H., Laursen, K., Lüerßen, G., Marencic, H. and Wiersinga, W. (Eds.), 2005. Wadden Sea Quality Status Report 2004. Wadden Sea Ecosystem No. 19. Trilateral Monitoring and Assessment Group, Common Wadden Sea Secretariat, Wilhelmshaven, Germany, 141-154
2. Gescher, C., Metfies, K., Medlin, L.K. (2005). Development of a DNA Microchip as a standard analytical tool for the Identification of Phytoplankton, Phycologia, 44, 37
3. Metfies, K., Huljic, S., Lange, M., Medlin, L. (2005). Electrochemical detection of the toxic dinoflagellate *Alexandrium ostenfeldii* with a DNA-biosensor, Biosensors & bioelectronics, 20, 1349-1357
4. Reise, K., Jager, Z., Jong, D. J., Katwijk, M. van, Schanz, A. (2005). Seagrass, In: Essink, K., Dettmann, C., Farke, H., Laursen, K., Lüerßen, G., Marencic, H. and Wiersinga, W. (Eds.), 2005. Wadden Sea Quality Status Report 2004. Wadden Sea Ecosystem No. 19. Trilateral Monitoring and Assessment Group, Common Wadden Sea Secretariat, Wilhelmshaven, Germany, 201-207
5. de Vlas, J., Brinkman, B., Buschbaum, C., Dankers, N. , Herlyn, M., Kristensen, P. S., Millat, G., Nehls, G., Ruth, M., Steenbergen, J., Wehrman, A. (2005). Intertidal blue mussel beds. In: Essink, K., Dettmann, C., Farke, H., Laursen, K., Lüerßen, G., Marencic, H. and Wiersinga, W. (Eds.), 2005. Wadden Sea Quality Status Report 2004. Wadden Sea Ecosystem No. 19. Trilateral Monitoring and Assessment Group, Common Wadden Sea Secretariat, Wilhelmshaven, Germany, 190-200

List of guest scientists

1. Marie Grieve, FRS Marine Laboratory, Aberdeen, UK, 08.11.04 - 11.11.04
2. Prof. Dr. V.N. de Jonge, Rijksuniversiteit Groningen, NL, 07.11.04 - 11.11.04

List of running/accepted third party funded projects

1. Development of a rRNA-Biosensor for the Detection of Toxic Algae (ALGADEC), EU FP6, Linda Medlin, 15.07.2004 - 15.07.2006, 122,877 €
2. Marines Geo-Informationssystem zur Visualisierung und Typologisierung meeres-geowissenschaftlicher Daten (MarGIS), BMB+F/DFG-Sonderprogramm Geotechnologien, Michael Schlüter, W. Schröder, L. Vetter, 01.01.2002 - 31.12.2002, 600,000 €
3. Coastal Futures-Zukunft Küste, BMB+F, Victor Smetacek, Bela H. Buck, 01.04.2004 - 31.03.2007, 133,545 € (partially also as non-Marcopoli research under New Technologies)
4. Entwicklung eines automatischen Planktonanalysesystems für unterschiedliche Einsatzbereiche, BIS Bremerhaven, Hans-Jürgen Hirche, 01.03.2004 - 31.12.2007, 210,000 €
5. Development of the COAST float – biooptical sensors for the detection of harmful algal blooms, BIS Bremerhaven, Allan Cembella with Optimare AG, 01.01.2006 - 31.12.2007, 150,000 €

List of expeditions

1. 24.05.05 und 26.05.05, AADE (Helgoland), Test Laser Optical Plankton Counter

List of external co-operations

1. Guido Drago, Managing Director, Gwent Electronic Materials, Applied Enzyme Technology Ltd.
2. Prof. J. Lewis, Research Centre Director, University of Westminster, School of Biosciences, UK
3. Thomas Hanken, Dipl. Ingenieur, ISITEC GmbH
4. Dr. Kees van Velzen, Palm Instruments
5. George Dubelaar, CytoBuoy
6. Prof. Dr. V.N. de Jonge, Rijksuniversiteit Groningen, NL
7. Medea AV, Erlangen
8. J.B. Jensen, Geological Survey of Denmark and Greenland
9. Prof. O. Zielinski, Applied University Bremerhaven
10. Waldmann, MARUM Bremen
11. Raytheon, Kiel
12. Marencic, de Jong et al., Common Wadden Sea Secretariat, Wilhelmshaven
13. H. Nies, H. Heinrich et al., Bundesamt für Seeschifffahrt und Hydrographie, Hamburg
    1. Kosmagh-Stephan et al., Nationalparkamt Schleswig-Holsteinisches Wattenmeer

List of co-operations in MARCOPOLI

CO4 cooperates with long-term ecological research carried out in CO1 by integrating knowledge on long-term trends and events in the assessment of the present status of coastal ecosystems.

CO4 cooperates with CO2 by developing and implementing technology required for the study of “ecosystem function”, hidden diversity and phytoplankton-zooplankton interactions. This allows for the proper interpretation of monitoring data within a wider ecosystem context.

CO4 has internal links to CO3 through the application of HAB-specific detection techniques, including the development and implementation of taxon-specific probes for HAB detection and combination with biooptical sensors.

CO4 cooperates with New Technologies by developing appropriate techniques for coastal monitoring, including relationships to aquaculture development and impacts

List of memberships in national and international committees

AllanCembella:	International SCOR/IOC programme on the Global Ecology and Oceanography of Harmful Algal Blooms (GEOHAB): Founding Member of Scientific Steering Committee, Core Project Co-Leader – HABs in Fjords and Coastal Embayments
Justus van Beusekom:	Member of the national AG Nordsee des BLMP (National Working Group on monitoring of the North Sea) Member of ICES SGEUT (Study Group on Eutrophication)
Bela H. Buck:	Member of ICES Working Group for Marine Shellfish Culture

Topic POL: Polar Systems

(Spokesman: Prof. Dr. Peter Lemke)

Report on the general development of POL

Global change is a result of external forcing and internal interactions, and it is a response to regional processes via large-scale dynamical mechanisms. Predominant areas in this regard are polar regions, and therefore the Programme Topic POL was established to improve our understanding of processes in polar regions and their role within the earth system. In order to achieve this we concentrate on:

1. *Quantification of lithosphere-ocean-cryosphere-atmosphere interaction*
2. *Identification of key processes responsible for recent changes*
3. *Reconstruction of global climate cycles from polar archives*
4. *Understanding the role of the changing polar environment for biogeography and biodiversity and definition of the mechanistic role of climate factors in evolution*

In POL the research activities are carried out by physical, biological and geological working groups at AWI. Many of the work packages are characterised by interdisciplinary collaboration between these working groups. The themes of the work packages are:

POL 1: Processes and interactions in the polar climate system
POL 2: Southern Ocean climate and ecosystem,
POL 3: Variations of the Arctic physical environment
POL 4: Benthic organisms in polar marine food webs
POL 5: Autecology of planktonic key species and groups
POL 6: Earth climate variability since the Pliocene
POL 7: From permafrost to deep sea in the Arctic

In addition to theses seven work packages POL includes the Additional Funding Theme: New Keys on polar climate archives (NEW KEYS).

The development of POL has proceeded as planned. By integrating physical, chemical, biological and geological disciplines and by interlinking field observations, experiments and modelling exercises considerable progress was made towards achieving the goals set. The data bases have been significantly enhanced, process understanding has improved, and the role of polar processes has been highlighted through coupling of various components of the Earth system. We expect that all milestones will be achieved in the remaining time.

The only area where we encountered difficulties was in the geological component of POL 3 because of political restrictions of relevant Polarstern cruises. To obtain the geological material necessary for this work a Polarstern cruise to the Russian Arctic was planned. In two consecutive years the permission was denied by Russian authorities.

Workpackage POL 1: Processes and interactions in the polar climate system

(Spokesman: Dr. Christof Lüpkes)

Academic results

A) Physics of processes in polar regions

The polar climate is strongly influenced by the interaction of sea ice and shelf ice with the ocean and the atmosphere. To obtain a better understanding of these interaction processes, during the first phase of MARCOPOLI our research concentrated on the modelling of Antarctic ocean-shelf ice interaction, on observations of the thickness, distribution, and surface topography of sea ice in different polar regions and on the modelling of the atmospheric flow influenced by inhomogeneous sea ice cover. Furthermore, the drift of Antarctic icebergs and their decay as well oceanic processes close to shelf ice regions have been modelled. The spectacular collapse in 2002 of the Larsen B ice shelf and its different phases were analysed in detail by means of satellite imagery.

Model results showed that the freshwater flux due to deep basal melting stabilizes the shelf water column in front of an ice shelf as well as downstream due to advection by the coastal current. If the freshwater from the caverns is absent, sea ice is thinner, shelf waters are warmer and saltier, and the Southern Ocean deep basins are flushed by denser waters (deliverable 1).

Expeditions to the Arctic, Antarctic and Baltic Sea were carried out using the helicopter-borne electromagnetic ice thickness sensor („HEM-Bird“) for sea ice thickness measurements. Comparison between helicopter-based observations and satellite radar imagery (SAR) revealed that the SAR signature can be used to distinguish between Antarctic first-year white (thin) and second-year (thick) ice regimes. This is an important step towards an analysis of Antarctic sea ice thickness variability. HEM-Bird thickness observations between Svalbard and North Pole and close to Ellesmere Island and their comparison with previous campaigns documented the strong variability in thickness trends for different Arctic regions. This shows the need of future continuous systematic thickness observations over wider areas of the Arctic and Antarctic (deliverable 2).

Ship- and helicopter borne measurements of atmospheric turbulence above Arctic leads were used to quantify the impact of thin sea ice on leads (nilas) on the energy fluxes. We found that fluxes of sensible heat are strongly reduced, but they may still reach values of up to 100 W/m^2 above nilas. Hence, it becomes important to detect thin sea ice from satellites. Furthermore, parameterizations of the lead effect on atmospheric fluxes have to be improved. A first step has been done during MARCOPOLI with the development of parameterizations of turbulence to be used in microscale non-eddy resolving atmospheric models. The model results show a strong variability of the flow and of the energy fluxes over leads and document the need to develop a parameterization of the lead effect on the entire atmospheric boundary layer for climate models (deliverable 3).

The weather forecast model LM of DWD was applied for the first time to Antarctic conditions, and the investigation of cloud and precipitation formation in Dronning Maud Land was started. It was found that the precipitation distribution on the plateau is due to a combined effect of topographical and synoptic forcing.

B) Atmospheric circulation structures and scenarios of polar climate changes

Several sensitivity studies were carried out with regional and global climate models to detect those key processes which need a better representation and parameterization for an improved prediction of the polar climate. A new sea-ice and snow albedo treatment has been investigated within the regional climate model HIRHAM, which results in a more realistic temperature simulation and changed regional circulation. With a global coupled model it has been shown that such changes of the Arctic radiative surface balance exert a strong influence on the mid- and high-latitude climate by modulating the strength of the mid-latitude westerlies and storm tracks.

A series of sensitivity experiments has been conducted with the coupled regional model in order to identify those model conditions that are essential for a realistic simulation of the Arctic sea-ice cover. One of the results was e.g., that a realistic reproduction of the sea-ice retreat during summer is substantially controlled by the ice thickness distribution at the beginning of the melting period. The simulated ice thickness distribution, in turn, depends on several model parameters, but particularly on the optimal choice of the lead closing parameter (see deliverable 4).

A new land-surface/soil scheme within HIRHAM improved the regional soil and atmospheric variables and also the large-scale circulation patterns over the Arctic Ocean with implications for global model simulations (deliverable 5). The choice of the new land surface scheme has a significant influence on the future projection of the Arctic temperature, precipitation and mean sea

level pressure. The projected surface air temperature changes differ by ~2 K, when the new scheme is applied, with a stronger warming of the Siberian coast compared to previous model estimates.

C) Trace constituents in the polar atmosphere

Our research during the first phase of MARCOPOLI concentrated on the observation of stratospheric ozone loss in both hemispheres, on the observation of stratospheric water vapour and on aerosol measurements. It was found that the severe Arctic ozone loss during the past decade occurred as a result of the anthropogenic increase in stratospheric halogens and long-term climate change. The winter 2004/05 showed the most severe ozone loss in the Arctic during the last decade. It was shown that maximum ozone reduction rates per sun light hour are the same for the Arctic and Antarctic stratospheres. In the Antarctic, ozone loss is observed over a larger region, and the reduction periods last longer than in the Arctic.

The stratospheric water vapour content influences the Arctic climate as well as ozone loss via Polar Stratospheric Cloud (PSC) formation. During an international intercomparison campaign, a modern, reliable balloon sonde was identified, which is used now for long term observations of water vapour at the Koldewey-Station.

Tropospheric aerosols in the polar region have several important effects on climate. During the campaigns ASTAR 2004 and SVALEX 2005 the origin, transport pathways, and the vertical structure of the physical and chemical properties of aerosols were studied with surface-based and airborne measurements. The first campaign lasted from May 10 to June 10, 2004, employing the two AWI aircrafts, which carried unique payloads, addressing both aerosol and cloud measurements. Simultaneous ground-based measurements took place in Ny-Alesund. The observations showed very clean aerosol summer conditions, reflecting an early shift from the spring to the summer season. The second campaign with the Polar 2 aircraft in April 2005 covered a period of high aerosol load and revealed the orographic dependence and temporal development of the Arctic Haze phenomenon on Spitsbergen.

D) Ice sheet dynamics, mass balance and lithospheric response

In cooperation with ESA the new Airborne SAR Interferometric Radar Altimeter System (ASIRAS), was installed and tested on Polar 4. Several AWI coordinated field groups of international institutions investigated the snow morphology during ASIRAS overflights in Greenland, Svalbard, and the Canadian Arctic. The validation activities yielded first results on penetration depth and scattering characteristics of the radar wave in the frequency range of future radar altimeter satellites like CryoSat2.

In order to assess the accumulation on polar ice sheets, internal horizons from ground penetrating radar measurements were analysed for the dry snow zone in Antarctica. Combined with imaging radar this yielded the first high resolution map of accumulation in the surrounding of the EPICA drill site at Kohnen station. Within the VISA program, the airborne ice thickness, earth magnetic and gravity measurements in Dronning Maud Land were continued. This program was combined with ground based reference measurements.

A 3-D time-dependent thermo-mechanical ice sheet/ ice shelf/ lithosphere model was integrated over the last 740000 years using the temperature forcing from the Dome C record. A remarkable feature of the forcing records is the apparent regime change prior to 450000 years (stage 11), with a less clear signature of glacial cycles with less warm interglacials. The model results indicate that this regime change did not only occur in the forcing, but also for the evolution of the Antarctic ice sheet: after stage 11 the Antarctic ice sheet shows a clear and more or less regular pattern of glacial cycles. But obviously, in the period before stage 11, the Antarctic ice sheet was staying mostly in glacial mode.

State of achievements of deliverables

1. Quantification of the freshwater budget in the Weddell Sea, the Arctic Ocean and the Greenland and Labrador Seas

Our research in POL1 concentrated mainly on the freshwater budget of the Weddell Sea. Model results suggest that due to ice shelf basal melting the net freshwater flux to the Weddell Sea is equal to ~50% of the annual mean net precipitation. The analysis of iceberg trajectories in the Weddell Sea revealed that the amount of freshwater released by iceberg melting strongly depends on export rate and route across the northern boundary. The freshwater flux may be as high as 60% of the NCEP reanalysis net precipitation and equivalent to the flux from the ice shelves. Our study also suggests that iceberg melt is released over a much broader area than previously assumed.

Hindcast simulations over the last 50 years have been conducted and analysed regarding the Arctic Ocean fresh water balance (see also MAR 1).

2. Estimation of sea ice changes and development of a technique for monitoring thin ice areas by means of remote sensing data

Since CryoSat could not be launched, the present observations at AWI of sea ice thickness changes are based on the helicopter borne system HEM bird. A comparison with previous in-situ thickness measurements along a Polarstern track between North Pole and Svalbard revealed a stagnation of the thickness between 2001 and 2004. Observations north of Ellesmere Island, a region with the largest sea ice thickness all over the Arctic, showed an increase of the average thickness from 2004 to 2005 by about 7 %. HEM bird was run for the first time also in the Antarctic, where it was used for an interpretation of SAR images in support of a new thickness classification based on SAR. We expect that SAR can be used also for a monitoring of thin ice areas. Depending on ESA funding, this will be tested during an aircraft based campaign SVALEX II planned for 2007 with two aircraft (AWI and DLR).

3. Quantification of the effect of ice characteristics on the structure of the atmospheric boundary layer over ocean and ice

During the first phase of MARCOPOLI both modelling and experimental studies have been carried out to investigate the influence of sea ice inhomogeneity on the atmospheric flow over the Arctic Ocean. Different processes have been considered, (i) the effect of rough sea ice in the marginal sea ice zones on the local fluxes of energy and momentum and their influence on remote processes in the inner Arctic, (ii) the effect of leads on the atmospheric boundary layer (ABL), (iii) the effect of ridges on ABL fluxes, and (iv) the impact of a modified sea ice surface albedo on Arctic circulation structures (see MAR1). The investigation of the effect of MIZ roughness was based on a new parameterization developed in POL 1, which could be implemented in the mesoscale model METRAS and in the regional climate model HIRHAM. It was shown that the increased roughness in the MIZ due to floe edges strongly influences the turbulent fluxes in the MIZ. There is also a slight influence on the Arctic flow regimes and the near-surface temperature even far from the MIZ. However, the effect is small compared with the impact of a modified sea ice albedo, but it can be expected that a modified surface roughness in the entire Arctic rather than only in the MIZ has a stronger effect. This will be investigated in the next phase of MARCOPOLI. Future work on this topic will be based on aircraft based observations (SVALEX 2005) of turbulence and simultaneous small scale radar observations (DFG funded).

4. Reconstruction of atmospheric circulation structures within the Arctic atmosphere-ice-ocean-land-snow system responsible for recent and future changes

By comparing the results of eight different regional climate models (RCMs) covering the western Arctic it was possible to identify key processes and parameters for the Arctic, since the models differed by their physical parameterizations while using the same horizontal resolution and domain. It was found that the parameterizations of the planetary boundary layer, of clouds and of the land-surface processes are essential. Simulations over one decade with the atmosphere-alone and coupled atmosphere-ice-ocean RCMs showed that the seasonal large-scale flow patterns are reproduced remarkably well by the models. Differences between the models are related to differences in the upward heat fluxes due to different ice thicknesses, open water fractions, and surface temperature forcing. The near-surface air temperature response shows a strong, seasonally dependent sensitivity to sea ice changes. The response is small in summer, but significant in winter. Changes in the marginal ice zone have the largest impact on the atmosphere. Vertical heat fluxes, but also dynamical responses affect the Arctic atmosphere through vertical and horizontal advection. The modelled sea-ice variability during summer is substantially controlled by the ice thickness distribution at the beginning of the melting period. It has been shown that the atmospheric and soil simulations depend on the soil parameterizations. The seasonal cycle of soil temperature is largely influenced by freezing and thawing of the soil moisture and the amount of snow on the ground surface.

5. Assessment of polar climate variability and change on the regional scale for the European North, Arctic and Antarctic and its impact on the ecosystem

Arctic downscaled projected temperature change for the mid 21st century has been calculated. It is largest during autumn/winter season and consists of a warming of up to 4 K in the Eastern part of the Arctic and a cooling of up to 2.5 K in Alaska and over the Bering Strait. However, the interannual variability in the Arctic climate is large (with a magnitude of up to 5 K in the monthly temperature variability). The general warming trend can be interrupted by colder years

or periods. It has also been shown that the landsurface/soil parameterizations exert a significant impact on projected future climate under greenhouse warming generating differences in the order of 2 K of the near-surface air and soil temperature by the mid of the 21st century. Therefore, the future projections of air and soil temperatures have an uncertainty of at least 2 K. The model results show that besides temperature also the summer precipitation and the mean sea level pressure may change significantly. Simulated projections of the Arctic atmosphere for the mid 21st century were used to drive a coupled hydrodynamic-ecological model of the Arctic Ocean and the Nordic Seas. The annual mean primary production has been calculated for the Nordic Seas. It shows a pronounced interannual variability depending strongly on ice cover, wind, and heat fluxes during the productive season (April-September) rather than on the winter NAO index which does not have a significant effect on the primary production.

6. Improved predictions of future ozone levels

The MATCH approach to precisely measure polar stratospheric ozone loss rates was further refined and a comprehensive study about its uncertainties was carried out. The sensitivity of polar ozone loss to climate change was quantified. It was found that coupled chemistry climate models underestimate the climate sensitivity of polar ozone loss by a factor of three. Based on a combination of data from MATCH and recent in-situ measurements of key species, the reaction kinetics in the model system was improved, which for the first time resulted in a good theoretical understanding of observed ozone loss rates. The model improvements also led to a reasonable representation of the climate sensitivity of polar ozone loss in a coupled model, largely improving predictions based on this model. A new model independent empirical approach to explore potential future scenarios for the Arctic ozone layer was developed.

A new balloon borne sounding system was developed with a small, light-weight (1.7 kg) optical sonde for measurements of ozone and various stratospheric trace gases. The new sonde measures the spectral irradiance during the ascent with a miniature grating spectrometer covering a large wavelength range (200-850 nm). The accuracy of the new sonde is increasing with higher altitude. That allows reliable measurements especially in altitudes above 30 km, where the uncertainty of the electrochemical sensors is increasing.

7. Quantification of aerosol and water vapour variability in polar regions

Aerosol variability for the Arctic spring summer transition was determined by a combined aircraft and ground based measurement campaign ASTAR 2004 (Arctic Study of Tropospheric Aerosols, Clouds and Radiation) in the vicinity of Spitsbergen. The project produced an observational over-determined aerosol data set for the assessment of the aerosol direct and indirect effects on the radiative balance. This campaign was followed by a smaller aircraft and ground based campaign in April 2005 (SvalEx 2005 participation), which observed the temporal and spatial development of an Arctic Haze event of increased spring time aerosol load.

The monitoring of the stratospheric water in the Arctic winter by balloon-borne hygrometers has shown variability due to dynamical processes at the polar vortex edge, but also local reduction of H_2O caused by phase change in connection with ice particle formation.

8. Improved 3D-thermomechanical models of ice dynamics

The existing 3D-thermomechanical ice sheet/ice shelf model for Antarctica has been improved by using a nested grid with an increased resolution over Dronning Maud Land. In this region, the horizontal grid size is smaller than the local average ice thickness of approximately 2700 m. This allows taking into account the special flow conditions near the ice divide, on which the deep ice core at Kohnen Station has been drilled. Aircraft based observations of ice thickness were used to reconstruct an improved surface topography. The modelled structure of the ice sheet compares well with internal layers of the ice sheet detected by airborne radio echo sounding.

9. New high resolution, high precision data sets on ice sheet geometry and its changes

Within the ESA CryoSat Calibration and Validation activities AWI measured surface elevation and internal horizons over several land ice profiles in the Arctic using the new ASIRAS (Airborne SAR Interferometric Radar Altimeter System) instrument. During the overflights extensive field measurements were conducted with partners from several international institutes. The data will yield invaluable information on the penetration depth and scattering characteristics of the Radar wave in various polar snow regimes.

10. Improved projections of change under different future scenarios

A 3D-thermomechanical ice sheet/ice shelf model driven by climate scenarios obtained from General Circulation Models was used to evaluate changes of the Antarctic and Greenland ice sheet

for the 20th and 21st century. High resolution anomaly patterns derived from ECHAM4 and HadAM3H time slice integrations have been scaled with a variety of lower resolution Atmosphere-Ocean General Circulation Models. As a general result, it is found that the effect of increased precipitation on Antarctica dominates over the effect of increased melting on Greenland for the entire range of predictions, so that both polar ice sheets combined would gain mass in the 21st century. Combining these results with the long-term background trend yields a 20th and 21st century sea-level trend from polar ice sheets that is, however, not significantly different from zero.

Personnel

Personnel	Institutional funding	Third party funding
	Scientists / PhD / Technicians	Scientists / PhD / Technicians
AWI	21.85 / 8.8 / 2.85	0/9/0

Publication outcome numbers

Academic Publications Refereed only	2004-2006
ISI	98
non ISI	28
PhD theses	2
Master & Diploma Theses	2
Books	1
Book chapters	9

Key publications

1. Dethloff, K., W. Dorn, A. Rinke, K. Fraedrich, M. Junge, E. Roeckner, V. Gayler, U. Cubasch, J.H. Christensen, 2004: The impact of Greenland's deglaciation on the Arctic circulation, Geophys. Res. Lett., Vol. 31, L19201, doi: 10.1029/2004GL020714
2. Huybrechts, P., Gregory, J. M., Janssens, I., Wild, M., 2004: Modelling Antarctic and Greenland volume changes during the 20th and 21st centuries forced by GCM time slice integrations, Global and Planetary Change, 42, 83-105.
3. Lüpkes, C., Birnbaum, G., 2005: Surface drag in the Arctic marginal sea-ice zone: a comparison of different parameterisation concepts, Boundary-layer meteorology, 117(2), 179-211.
4. Haas, C., Hendricks, S., Doble, M., 2006: Comparison of the sea ice thickness distribution in the Lincoln Sea and adjacent Arctic Ocean in 2004 and 2005, Annals of glaciology,44, in press.
   Rinke, A., and 18 co-authors, 2006: Evaluation of an ensemble of Arctic regional climate models: Spatiotemporal fields during the SHEBA year, Clim. Dyn., Vol. 26, No. 5, 459 - 472, DOI:10.1007/s00382-005-0095-3

List of guest scientists

1. Doz. Dr. Stanislav Ignatov, Department of Chemistry, University of Nizhny Novgorod (Russia), 28.6. – 27.8.04
2. Prof. Dr. Peter Sennikov, RAS Nizhny Novgorod (Russia), 28.4.-5.5.04
3. Dr. Sergey Khaykin, Central Aerological Observatory, Moscow, Russia; 17.11. - 22.12.04
4. Dr. Vladimir Gryanik, University of Moscow, January - December 2005
5. Dr. Timo Vihma, FMI Helsinki, November/December, 2005
6. Prof. Dr. Peter Sennikov, RAS Nizhny Novgorod (Russia), 16.6.-5.8.05; 20.11.-1.12.05
7. Dipl.-Chem. Lev Chuprov, RAS Nizhny Novgorod (Russia), 15.7. – 27.8.05
8. Dr. K. Shibata, Meteorological Research Insitute Tsukuba (Japan), January 2005
9. Dr. Paola Massoli, Institute of Atmospheric Sciences and Climate, CNR, (Italy), April 2005

List of running/accepted third party funded projects

1. CRYOgenic SATellite Office. Dr. C. Haas, 2001-2005, BMBF/DLR, 250 kEuro
2. Superimposed Ice, Dr. C. Haas, 2002-2004, DFG, 100 kEuro

3. Greenland arctic shelf Ice and Climate Experiment (GreenICE), Dr. C. Haas, 2003-2005, EU, 277 kEuro
4. Sea Ice THickness Observation System (SITHOS), Dr. C. Haas, 2003-2005, EU, 412 kEuro
5. Ice Ridging Information System for decision making in shipping operations (IRIS), Dr. C. Haas, 2003-2005, EU, 341 kEuro
6. Sea Ice Monitoring in the Polar Regions (ICEMON), Dr. C. Haas, 2003-2004, ESA, 70 kEuro
7. Information System on Sea Ice Dynamic for Climate Research (GlobICE), Dr. C. Haas, 2005-2008, ESA, 60 kEuro
8. Developing Arctic Modelling and Observing Capabilities for Long-Term Environmental Studies (DAMOCLES), (sea ice), Dr. C. Haas, 2006-2008, EU, 100 kEuro
9. Developing Arctic Modelling and Observing Capabilities for Long-Term Environmental Studies (DAMOCLES), (atmospheric boundary layer), Dr. C. Lüpkes, 2006-2008, EU, 177 kEuro
10. Developing Arctic Modelling and Observing Capabilities for Long-Term Environmental Studies (DAMOCLES specific support actions), EU, Prof. K. Dethloff, 2006-2009, 104 kEuro
11. CryoSat-Cal/Val, Dr. C. Haas, Miller, 2006-2009, BMBF/DLR, 750 kEuro (under discussion after CryoSat failure)
12. Marine Ecosystem consequences of climate induced changes in water masses off West-Spitsbergen (MariClim), Dr. C. Haas, 2006-2007, Norway, 35 kEuro
13. Airborne Synthetic Aperture Radar Altimeter System (ASIRAS), Dr. C. Haas, 2006-2008, ESA, 75 kEuro
14. Arctic Climate System Study (ACSYS), (hydrology of Greenland), Prof. Dr. P. Lemke, 2002 - 2005, 201 kEuro
15. Arctic Climate System Study (ACSYS), (effect of sea ice on regional arctic atmospheric processes), Dr. C. Lüpkes, 2002-2005, 187 kEuro
16. Arctic Climate System Study (ACSYS), (Influence of ocean/sea ice coupling on atmospheric variability), Prof. Dr. K. Dethloff/ Dr. A. Rinke, 2002 - 2005, 175 kEuro
17. Boundary Layer over Leads (BOLE), DFG Antarktisforschung, Dr. C. Lüpkes, July 2006-2008, ~55 kEuro
18. Mesoskalige Variabilität der atmosphärischen Strömung und Wolkenbildung in polaren Kaltluftaus-brüchen, DFG-Antarktisforschung, PD Dr. U. Wacker/Dr. C. Lüpkes, 2002-2004, 62.8 kEuro
19. Analysis and mesoscale modeling of cyclones causing precipitation on the Antarctic Plateau of Dronning Maud Land, DFG-Antarktisforschung, PD Dr. U. Wacker/Dr. G. Birnbaum, 2004-2006, 75 kEuro
20. Stratospheric-Climate Links with Emphasis on the Upper Troposphere and Lower Stratosphere (SCOUT-O3) , European Commission FP-VI, Dr. M. Rex/Dr. Maturilli/Prof. Dr. Schrems, 2004-2009, 404 kEuro
21. Validation, densification, and interpretation of satellite data for the determination of magnetic field, gravity field, ice-mass budget, and crustal structure in Antarctica using airborne and groundborne measurements (VISA), DFG, Dr. W. Jokat, 08/2003 – 07/2005, 201.3 kEuro
22. Validation, densification, and interpretation of satellite data for the determination of magnetic field, gravity field, ice-mass budget, and crustal structure in Antarctica using airborne and groundborne measurements (VISA), DFG, Dr. W. Jokat, 07/2005 – 06/2006, 119.6 kEuro
24. Enhanced Palaeoreconstruction and Integrated Climate Analysis through marine and ice core studies (EPICA-MIS-GEO), EU, Prof. Dr. H. Miller, 12/2004 – 11/2007, 257.3 kEuro
25. Sea ice roughness, DFG-Antarktisforschung, Dr. W. Dierking, July 2006-2008, ~55 kEuro
26. Quantification of Ozone Losses by Bipolar Investigations (QUOBI), European Commission FP-V, Dr. P. v. d. Gathen, 1.1.2002-31.12.2004, 253.3 kEuro
27. Chemical and Dynamical Influences on Decadal Ozone Change (CANDIDOZ), European Commission FP-V, Dr. P. v.d. Gathen, 1.4.2002-30.09.2005, 194.6 kEuro
28. Wasserkreislauf in einem regionalen Atmosphärenmodell der Antarktis, DFG-Antarktisforschung, Prof. K. Dethloff/Dr. A. Rinke, 2003-2006, 71 kEuro
29. Carbo-North, Quantifying the carbon budget in Northern Russia: past, present and future, EU, Dr. A. Rinke/Prof. K. Dethloff, 2006-2009, 143 kEuro
30. Pole - Equator - Pole: Variability of atmospheric trace constituents along a North-South Transect, virtual institute PEP, HGF, Prof. K. Dethloff, 2004-2007, 60 kEuro
31. Photochemische und physikalische Prozesse am Oberflächenschnee , DFG, Dr. H.-W. Jacobi, 2002-2004, 121,5 kEuro

List of expeditions

Ship

1. ANT XXIII/1 (Bremerhaven Kapstadt), Polarstern, 13.10. -17.11.2005, 3 scientists
4. ARK XX/2, Polarstern, August 2004, Fram Strait / Nansen Basin; 10 scientists
5. ISPOL (ANTXXII/2), Polarstern, Nov 2004 - Jan 2005: Western Weddell Sea; 2 scientists
6. IRIS 2005, March 2005, Aranda, Bay of Bothnia; 5 scientists

Aircraft and helicopter:

1. ASTAR 2004 (Arctic Study of Tropospheric Aerosols, Clouds and Radiation), Spitsbergen, 10. May – 9. June 2004, 8 scientists, 2 PhD students
2. IRIS 2004 (Ice Ridging Information System for decision making in shipping operations) March 2004, Hailuto (Bay of Bothnia), 5 scientists
3. GreenICE 2004 (Greenland arctic shelf Ice and Climate Experiment) May 2004, Lincoln Sea / Arctic Ocean, 2 scientists
4. GreenICE 2005, May 2005, Lincoln Sea / Arctic Ocean, 2 scientists
5. SvalEx 2005 (Svalbard Experiment), Spitsbergen, 4. - 21. April 2005, 8 scientists, 2 PhD students
6. ANT2003/04, 12/2003 - 02/2004, Dronning Maud Land, Antarktis, 2 scientists, 1 PhD student
7. ANT2004/05, December 2004 - February 2005 , Dronning Maud Land, Antarktis, 2 scientists
8. ANT2005/06, December 2005 - February 2006, Dronning Maud Land, Antarktis, 2 scientists, 1 PhD student
9. NGRIP (North Greenland Ice Core Project), June - July 2004, Greenland, 1 scientist
10. ASIRAS (Airborne Synthetic Aperture Radar Altimeter System), March 2004, Svalbard, 1 scientist
11. CRYOVEX 1b (CRYOSAT Validation EXperiment), 09 2004, Greenland, Svalbard, 2 scientists

Land:

1. Paramaribo (Surinam) 05. 09. - 16.11.04, 22.02. -10.03.05 EU-Projekt STAR, 2 scientists, 1 PhD student
2. Izana (Teneriffa) 01.06. -14.06.05 Internationale Gerätevergleichskampagne für UV Spektralradiometer; 1 scientist
3. AWIPEV Research base (Ny-Alesund, Spitsbergen), continuous operation and maintenance of long term measurements of atmospheric parameters, 6 scientists, 1 student
4. LAUTLOS (Sodankylä, Finnland) January/February 2004, Intercomparison of balloon borne water vapour soundings, 2 scientists
5. Kohnen meteorology, Antarctica, November 2005-February 2006, 1 scientist

List of external co-operations

1. DLR, Prof. Dr. Ulrich Schumann, Dr. Bernd Kärcher, Dr. Irena Hajnsek et al., Oberpfaffenhofen
2. University of Hamburg, Prof. Dr. Heinke Schlünzen, Prof. Dr. Burkhard Brümmer, Dr. Stefan Kern et al. Hamburg
3. University of Hannover, PD. Dr. Siegfried Raasch, Hannover
4. University of Trier, Prof. Dr. Günther Heinemann, Dr. Jörg Bareiss, Sascha Willmes, Trier
5. Forschungszentrum Karlsruhe, IMK, Dr. Gerd Hochschild, Karlsruhe
6. Forschungszentrum Jülich, ICG-I, Prof. Dr. Martin Riese, Jülich
7. University of Heidelberg, Prof. Dr. Ulrich Platt, Dr. Barbara Dix, Heidelberg
8. Monash University, Prof. Dr. Amanda Lynch, Melbourne, Australia
9. Antarctic CRC, Dr. Tony Worby, Hobart, Tasmania
10. Vrije Universiteit Brussel, Dr. Frank Pattyn, Belgium
11. Danish Meteorological Institute, Dr Jens Hesselbjerg Christensen, Denmark
12. Technical University of Denmark, Dr. Jorgen Dall, Dr. Henning Skriver, Lyngby, Denmark
13. Finnish Institute of Marine Research, FIMR, Dr. Jari Haapala, Jouko Launiainen, Finland
14. Finnish Meteorological Institute FMI, Dr. Timo Vihma, Prof. Esko Kyrö, FMI, Finland
15. Ifremer, Dr. Robert Ezraty, France
16. Laboratoire de Meteorologique et Physique, CNRS / Université Blaise Pascal, Prof. Dr. J.-F. Gayet, France
17. ANTSYO: National Institute for Polar Reseach, Prof. Dr. K. Shiraishi, Prof. Dr. Y. Nogi, Tokyo, Japan, Prof. Dr. S. Fujita, Tokyo, Japan

18. National Institute for Environmental Studies (NIES), Dr. Hideaki Nakajima, Tsukuba, Japan
19. Dr. Sebastian Gerland, Norsk Polar Institute, Norway
20. Dr. Jan Erik Haugen, met.no, Norway
21. Arctic and Antarctic Research Institute (AARI), Prof. Dr. Vladimir Romanov, St. Petersburg, Russia
22. Rossby Centre, SMHI, Dr. Ralf Döscher, Dr. Klaus Wyser, Norrkoeping, Sweden
23. University of Stockholm, Prof. Dr. Peter Kuhry, Prof. Dr. Michael Tjernstroem, Dr. G. Svensson, Sweden
24. Royal Netherlands Meteorological Institute (KNMI), Dr. Gé Verver, De Bilt, The Netherlands
25. European Space Research and Technology Centre (ESA-ESTEC), Dr. Mark Drinkwater, Dr. Malcom Davidaon, Dr. Rob Cullen, Noordwijk, The Netherlands
26. University of Reading, Dr. Jonathan Gregory, United Kingdom
27. Hadley Centre for Climate Research and Predictions, Met Office, Dr. Jeff Ridley, Exeter, United Kingdom
28. Jet Propulsion Laboratory (JPL), Dr. Ross Salawitch, ,Pasadena, Ca., USA
29. NASA, Dr. Bill Krabill, Dr. Bob Thomas, USA
30. NorthGRIP – Prof. Dr. D. Dahl-Jensen, University of Copenhagen, Copenhagen, Denmark, and other scientists from 10 nations
31. EPICA - Prof. Dr. J. Jouzel, Pierre Simon Laplace Institute and Research, Gif-sur-Yvette Cedex, France, EPICA = consortium of 10 nations

List of cooperations in MARCOPOLI

POL6: Use of the climate proxies for modelling work.
MAR1: Modelling of the polar fresh water budget.
POL4: Transfer of high precision UV- A & B solar radiation data (long-term series) for studies of the impact of variation in UV radiation on marine fauna and flora.
POL7: Supply of atmospheric columns/profiles of methane (long-term series) from FTIR measurements in Ny-Alesund.
POL7: POL 1 uses Arctic soil measurements for validation, and delivers pan-Arctic wide simulated soil temperature dynamics and atmospheric input for the determination of Siberian coastal retreat.
MAR1: Quantification of observed climate variability in the ozone field is used in MAR 1 for the analysis of decadal-scale climate variability.

List of memberships in national and international committees

O. Schrems: Member of the NDSC Steering Committee
Member of PASC Coordinating committee (PASC = Polar Atmospheric and Snow Chemistry)
Member of the Arbeitskreis Atmosphärenchemie of the German Chemical Society (GDCh)
K. Dethloff: Member of ISAC and ICARP
R. Neuber: Member Ny-Alesund Scientific Managers Committee, Member User Selection Panel of ALOMAR eARI
A. Rinke: Lead Author IPCC Fourth Assessment Report Climate Change 2007
C. Haas: Coordinator of WCRP/SCAR International Program for Antarcic Buoys, IPAB
H. Oerter: Member of SCAR Standing Scientific Group (SSG) of Physics
Member of EPICA Scientific Steering Committee
Sekretär Deutscher Landesausschuss SCAR/IASC
P. Huybrechts: Coordinator of ISMIP (Ice Sheet Model Intercomparison Project) (2003-), co sponsored by CliC/WCRP/SCAR
Panel member of the Numerical Experimentation group (NEG) of CliC (Climate and Cryosphere) (2004-)
Contributing Author of Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report on Climatic Change (2004-2007)
European Project Manager of EU FP6 EPICA-MIS (New paleoreconstructions from Antarctic ice and marine records) Work Package 7: Ice sheet dynamics and sea level (2004-2007)

Member of the Task Force of the WCRP COPES (Coordinated Observation and Prediction of the Earth System) activity 'Understanding Sea-level rise and variability' (2005-)

Member of the SCAR/ACE (Antarctic Climate Evolution) Committee on LGM to Holocene Antarctic ice sheet evolution (2005-)

C. Lüpkes: Task leader (atmospheric boundary layer) in the EU project DAMOCLES

Workpackage POL 2: Southern Ocean Climate and Ecosystem

(Spokesman: Dr. Volker Strass)

Academic Results

The overarching goal of the research conducted in work package POL-2 is to deliver improved scientific understanding of climate change resulting for instance from anthropogenic CO_2 emissions. Knowledge of the processes that govern the recurring patterns of CO_2 variations in the geological past is a prerequisite to forecasting future climate development. Our research effort is focussed on the Southern Ocean because of its crucial role in the global climate system. The complexity of interacting processes, which determine the internal and external forcing and feedback mechanisms are elucidated by integrating physical, chemical, biological and geological disciplines of the ocean sciences and by interlinking field observations, experiments and modelling exercises.

A) Experiments
Key to understanding the Antarctic paradox, the high nutrient - low chlorophyll (HNLC) situation of the Southern Ocean, is assessing the relative roles of the different limiting factors. Among the potentially important factors that can limit productivity, and hence the uptake of CO_2, are low light conditions due to prevailing deep wind mixing and lack of trace nutrients such as iron.
A powerful tool to elucidate the mechanisms that determine ecosystem response and the concomitant biogeochemical fluxes is provided with *in-situ* iron fertilization experiments, carried out as Lagrangian process studies in the open ocean. In order to conduct *in-situ* experiments even in the centre of the fast flowing and variable ACC, AWI scientists introduced with EisenEx the method of using transient mesoscale eddies as experimental sites. This method was very successful also with EIFEX, carried out with *Polarstern* January to March 2004, where it was possible to follow the developing bloom for over five weeks until its decline and the associated sinking out of biogenic matter.

B) Time series of daily to decadal variability in the kinematic, hydrographic and chemical properties are being recorded through continuation of long-term mooring measurements at repeat stations as well as by newly developed, ARGO-compatible, autonomous profiling floats. The latter instruments delivered the first ever undisturbed temperature and salinity profile measurements from below the sea ice. Pilot studies to collect geochemical trace substances have been conducted during Polarstern cruises ANT-XXIII/1 and -/3. They will be expanded during the IPY/GEOTRACES expedition ZERO & DRAKE for comparison with earlier work (GEOSECS) and in order to set the reference for sections to be performed later.

C) Ship-board sea ice research:
In November 2004, RV Polarstern conducted the Ice Station POLarstern (ISPOL) experiment in the Weddell Sea. Polarstern was anchored to an ice floe for 5 weeks to conduct biological, chemical, glaciological, meteorological, and oceanographic measurements in the air, ice and water. Ice thickness measurements showed the presence of two major ice regimes in the study region: two to four meter thick second-year ice to the West and East covered by up to one meter of snow and a south-north extending band of thinner first-year ice in-between. Despite spring/summer conditions and the low southern latitude of 67°30'S, ice and snow thickness only decreased by 20 to 30 centimetres over that expedition period. Low atmospheric and oceanic heat fluxes of a few Watts per square meter lead to warming of the ice to –2 to –1 °C. Chemical measurements showed that this increased the exchange of climatically relevant gases like Carbon Dioxide (CO_2) and Dimethyl-Sulfide (DMS) between ocean and atmosphere. Increased algal growth at the ice water interface supported large swarms of krill feeding under the ice and resulted in a continuous flux of dissolved and particulate Carbon into the water.

D) Modelling is an integral part of the research in POL-2. The modelling work comprises one-dimensional mixed-layer/ecosystem models, three-dimensional circulation models with biological modules, in part with schemes to assimilate measured data such as the data collected during the open-ocean perturbation experiments, and inverse models.

State of Achievements of Deliverables

1. Documentation of changes in physical, chemical and biological properties that are currently underway in the circumpolar Southern Ocean

The oceanographic measurements in the Weddell Sea indicate that the bottom water temperature increased steadily during the last decades. This is in contrast to the Warm Deep Water which enters from the Antarctic Circumpolar Current and after an earlier warming is cooling since 1996. The measurements indicate that climate related fluctuations from the upper layers reach the Antarctic deep sea and can affect the properties of the water which feeds the global thermohaline circulation.

An international study recently published in Nature showed that the uptake of anthropogenic CO_2 by the ocean will lead to significant decreases in the ocean's pH in the near future, especially in the Southern Ocean. The seawater acidification predicted by 13 different carbon cycle models will occur much faster than previously thought, and will result in undersaturation for the mineral aragonite in the Southern Ocean surface water by the year 2050. Within 50 to 100 years, there may be severe consequences for marine calcifying organisms, which build their external skeletal material out of calcium carbonate. Most threatened are cold-water calcifying organisms, including sea urchins, cold-water corals, coralline algae, and plankton known as pteropods - winged snails that swim through surface waters. And because these organisms provide essential food and habitat to others, their demise could affect entire ocean ecosystems.

2. Identification of major links between physical, chemical and biological variability

Both open-ocean perturbation experiments, EisenEx and EIFEX, have confirmed the fertilizing effect of iron additions, and have also demonstrated that phytoplankton blooms can develop in mixed layers as deep as 100 m under iron-replete conditions in the Southern Ocean. As vertical mixing influences biological activity, the mixed layer dynamics are investigated in detail by use of the measured microstructure turbulence data with emphasis on the discrimination between fossil mixed and actively mixing strata. In ocean models, mixing is parameterized and thus not always accurate. Mixing schemes and new mixing parameterizations have been tested against large eddy simulations in anticipation of improved mixing schemes for biological tracers.

The meso-zooplankton community showed an increase in species abundance by a factor of two to three during in the developing plankton blooms of both the EisenEx and the EIFEX iron fertilisation experiments. The aggregation of zooplankton within the bloom can in part be explained by superposition of the vertical current shear and the diurnal vertical zooplankton migration, which changed in response to the phytoplankton blooming.

With Polarstern cruise ANT-XXIII/2 we have collected a data set that allows us to study the effects of water mass circulation and sea ice on zooplankton and krill in the Lazarew Sea/eastern Weddell Sea. With the collected data set a contribution is made to the internationally coordinated programmes SO-GLOBEC (Southern Ocean - Global Ocean Ecosystems Dynamics) and CCAMLR (Convention on the Conservation of Antarctic Marine Living Resources).

A mechanism of lateral transport of remineralized carbon from the subsurface Weddell Sea into the abyssal world oceans has been detected. In the Weddell Sea interior, remineralization occurs at shallow depths from where the CO_2-charged water is isopycnally transferred to the abyssal world ocean waters and thus CO_2 is sequestered in the deep sea. The amount involved is at least 6% of the presently estimated world-wide natural CO_2 sequestration to the depths below 2000 m. It may also play a role on the glacial-interglacial time scale if during a glacial period the biological pump of carbon is reduced. The source/sink function of this region against the changing atmospheric CO_2 level has been investigated using contemporary CO_2 data from the subsurface Weddell Sea. It could be shown that the area turned into a CO_2 sink due to the rise of atmospheric CO_2 in recent times.

3. Development of new biological and geochemical proxies for improved interpretation of the palaeo-record archived in sediments

In order to reconstruct the glacial palaeo-environment various proxies are currently newly developed or improved. [$CaCO_3$ based proxies (foraminifera, coccolithophores: distribution, isotopic and elemental composition of Shells and coccoliths) are limited in large regions of the Southern Ocean by low calcification rates and limited preservation.]

In POL-2 research is focused on the following proxies:

1. Stable silicon isotopes in diatoms, radiolarian, and sponges ($\delta^{30}Si$) as a proxy for relative usage of silicic acid; 2 modelling studies have been published; a new laboratory for the analysis of $\delta^{30}Si$ is currently being set up by one of the world experts in this field (Dr.

Christina De La Rocha, hired in 2004). Field samples were collected during the iron fertilization experiment EIFEX, Polarstern cruise ANT-XXI/3.

2. Radio isotopes: $^{231}Pa/^{230}Th$ as a proxy of particle flux and ocean ventilation and ^{232}Th to quantify terrigenous flux into marine sediments; field studies will be used to improve the interpretation of these proxies.
3. Barite (BaSO4) has been proposed as a proxy for biological productivity. The population dynamics of acantharians, the major producer of barite, has been studied also during EIFEX.
4. The radiolarian *Cyladophora davisiana* has been identified as indicator for organic carbon export to mesopelagic depths (Abelmann et al., 2006).

4. Reconstruction of the palaeo-environment for selected time slices representing climate end-members as well as transitions during the last glacial-interglacial cycles

The cooperation between biologists and paleocenographers in POL-2 has distinctly increased our understanding of processes controlling the global CO_2 cycle and concentration of the greenhouse gas CO_2 in the atmosphere. Based on the combination of results derived from iron fertilization experiments and investigations of the distribution pattern of siliceous microorganisms in plankton and sediments, a last glacial scenario concerning the biological productivity and organic carbon export has been described; effective nutrient utilization leads to high primary production and high export of organic carbon during the last glacial that was at least tenfold higher than today. One basic requirement for understanding climate-governing processes is the compilation of oceanic parameters on specific time slices. A circum-Antarctic reconstruction of Southern Ocean sea-surface temperature and sea ice distribution based on the quantitative study of radiolarians and diatoms has been completed for the Last Glacial Maximum (LGM) at the international EPILOG time slice (23.000-19.000 cal. y). The LGM winter sea ice field was approximately 100% greater as compared to present and the Antarctic surface cold waters were expanded northward by 5-10° in latitude. For quantifying modern and past biochemical fluxes, the isotope ^{230}Th in surface sediments were used to derive the sedimentation rate of the bulk sediment and of a key component: biogenic opal. A similar analysis is planned on the time horizon of the last glacial maximum in cooperation with Bob Anderson, LDGO.

5. Contribution to quantifying modern and past global biogeochemical fluxes

The quantity and composition of particle rain to the seafloor is studied with the aid of sediment traps, with natural radionuclides, and using modeling. Scientists in POL-2 participate in attempts to reconcile the ^{234}Th- and sediment trap-based flux measurements (SCOR WG 116; Buesseler et al., submitted).

The following themes are investigated:

1. Depth pattern of POC remineralization in the ocean and its dependence on mineral composition of sinking particles:

The efficiency and time scales for oceanic CO_2 sequestration through the marine biota (the biological pump) depends critically on how much POC is transported below the winter mixed layer, but also on how POC is remineralized with depth. Recent studies have shown that systems dominated by $CaCO_3$ producers might be more efficient at exporting POC to the deep ocean than systems dominated by opal producers. Our purpose is to analyse sediment trap data and represent the relationship between mineral and POC export in coupled Global Circulation Biogeochemical Models in order to provide a better understanding of the relationship between biological productivity, POC export and time scales and efficiency of CO_2 sequestration through the marine biota.

2. Quantification of particle fluxes and ocean ventilation using natural radionuclides in the framework of GEOTRACES:

The measurement of export production with ^{234}Th can now be made with higher resolution through the development of an automated ^{234}Th analyser that has been tested and used on two expeditions. We evaluate the transfer of ^{210}Po in the food chain and the use of this tracer to quantify the organic content of export production.

We have collected large-volume water samples for a range of particulate and dissolved tracers in the framework of the new GEOTRACES program on sections across the Atlantic and in the Drake Passage (ANT XXIII/1, ANT XXIII/3, to be continued during IPY/GEOTRACES expedition Zero & Drake). Other tracers serve to estimate the input of waters that have been in contact with the shelf of the Peninsula (^{228}Ra as tracer for possible inputs of Fe) and to study particle flux (^{230}Th, ^{231}Pa) and deep upwelling (^{227}Ac).

6. Assessment of the feasibility and risks of large-scale iron- fertilization as a geoengineering option to mitigate the greenhouse gas problem

During the *in situ* iron fertilization experiment EIFEX (Polarstern cruise ANT-XXI/3) the increase of a iron-induced phytoplankton bloom and its subsequent decline could be followed over a period of more than five weeks. For the first time the sinking of the bloom together with faecal pellets and phytoplankton aggregates could be followed to mesopelagic and abyssal depths by various independent methods. These include the estimation of particle export from the euphotic zone by the Thorium 234 method, microscopic and pigment analysis, turbidity measurements, geochemical measurements at the sediment/water boundary layer as well as the analysis of the deep-sea sediment surface. A detailed calculation of carbon export flux to the deep ocean is in preparation. In order to synthesise all available data collected during EIFEX and to compute approximately closed budgets for all the observed properties and substances the combination of a physical (MITgcm) and ecosystem (REcoM) model is applied.

The iron-stimulated phytoplankton bloom moreover resulted in a concomitant increase in the local zooplankton assemblage. It could be shown that grazing of some mesozooplankton species on phytoplankton changed during the development of the bloom and that for some mesozooplankters the additional food resulted in enhanced egg production. The effect of the enhanced mesozooplankton grazing on the fate of the phytoplankton bloom is currently under investigation.

A three-dimensional model of the mixed layer has also been developed in order to determine the growth response of individual dominant or key phytoplankton species during a previous iron fertilization experiment, EisenEx. The purpose of this modelling study is to understand the effect of natural and artificial iron fertilization on the evolution of phytoplankton assemblages as well as the potential signature in the sediment record.

Personnel

Personnel	Institutional funding	Third party funding
	Scientists / PhD / Technicians	Scientists / PhD / Technicians
AWI	12.15 / 0.70 / 1.50	2.10 / 0.10 / 0.15

Publication outcome numbers

Academic Publications Refereed only	2004-2006
ISI	61
non ISI	16
PhD theses	6
Master & Diplom Theses	3
Books	-
Book chapters	4

Key publications

1. Fahrbach, E., Hoppema, M., Rohardt, G., Schröder, M., Wisotzki, A. (2004). Decadal-scale variations of water mass properties in the deep Weddell Sea, *Ocean Dynamics,* 54, 77-91.
2. Orr, J. C., Fabry, V. J., Aumont, O., Bopp, L., Doney, S. C., Feely, R. A.,Gnanadesikan, A., Gruber, N., Ishida, A., Joos, F., Key, R. M., Lindsay, K., Maier-Reimer, E., Matear, R., Monfray, P., Mouchet, A., Najjar, R. G., Plattner, G. -K., Rodgers, K. B., Sabine, C. L., Sarmiento, J. L., Schlitzer, R., Slater, R. D., Totterdell, I. J., Weirig, M. -F., Yamanaka, Y., Yool, A. (2005) Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. *Nature,* 437, 681-686.
3. Cisewski, B., Strass, V. H., Prandke, H. (2005). Upper ocean vertical mixing in the Antarctic Polar Front Zone, *Deep-Sea Research Part II - Topical Studies in Oceanography*, 52(9-10): 1087-1108.
4. Smetacek V, Assmy P and Henjes J (2004). The role of grazing in structuring Southern Ocean pelagic ecosystem and biogeochemical cycles. *Antarctic Science*, 16 (4), pp. 541-558.
5. Abelmann, A.; Gersonde, R.; Cortese, G.; Kuhn, G. and V. Smetacek (2006) Extensive phytoplankton blooms in the Atlantic sector of the glacial Southern Ocean. Paleoceanography 21, PA1013, doi:10.1029/2005PA001199.

List of guest scientists

1. Dr. Richard Bellerby, Bjerknes Centre for Climate Res., Univ. of Bergen, Norway (April 2005).
2. Prof. Valerie Franck, Department of Oceanography, Univ. of Hawaii, Honululu, USA (June 2005).
3. Dr. Marina Montresor, Stazione Zoologica Anton Dohrn, Naples, Italy (December 2004-January 2005, November 2005)

List of running/accepted third party funding projects

1. CLIVAR/marine-2 (Climate Variability and Predictability), BMBF, E. Fahrbach, A. Beckmann, J. Schröter, 2003-2005, 777.000 €.
2. LAKRIS (Lazarev Sea Krill Study) TP3, BMBF, M. Rhein (Univ. Bremen) and V. Strass, 2005-2008, 172.856 €.
3. CarboOcean (Assessment of the marine carbon sources and sinks: Quantification of anthropogenic CO2 uptake by the Southern Ocean), EU, M. Hoppema and C. Klaas (6 months), 2005-2009, 244.000 €.
4. NEBROC II (NEtherlands BRemen Oceanography), Netherlands-German Cooperation in Marine research, Theme: Carbon cycle of the Southern Ocean), BMBF and NOW, M. Hoppema and D. Wolf-Gladrow, 2005-2008, 91.455 €.
5. 'Actinium-227, Radium-223 and Radium-224 als Tracer für Stoffeinträge in die Tiefsee', DFG, W. Geibert, 2003-2004, 34.250 €.

List of expeditions

1. ANT-XXI/3 'EIFEX', *Polarstern*, 21 January - 25 March 2004, Atlantic Sector of southern Ocean, 11 persons.
2. ANT-XXII/2 'ISPOL', *Polarstern*, 06 November 2004 - 19 January 2005, Weddell Sea, 5 persons:
3. ANT-XXII/3:'WECCON', *Polarstern*, 21 January - 06 April 2005, Weddell Sea, 7 persons.
4. ANT XXIII/1 'GEOTRACES', *Polarstern*, 13 October - 17 November 2005, Atlantic meridional transect, 2 persons.
5. ANT-XXIII/2 'LAKRIS', *Polarstern*, 19 November 2005 - 12 January 2006, Lazarev Sea, 2 persons.
6. ANT XXIII/3, *Polarstern*, 14 January - 08 February 2006, Drake Passage, 2 persons.

List of external co-operations:

1. Department of Earth and Ocean Sciences, University of Liverpool, UK; H. Leach.
2. Bjerknes Centre for Climate Research, Bergen, Norway; R. Bellerby and S. Østerhus.
3. Observatoire Aquitain des Sciences de l'Univers, Arcachon, France; N. Savoye.
4. IfM-Geomar, Kiel, Germany; I. Peeken.
5. AAD as well as CSIRO, Hobart, Australia; G. Hosie and S. Rintoul.
6. Lamont Doherty Earth Observatory, Palisades, USA; A. Gordon and B. Anderson.
7. University of East Anglia, Norwich, UK; K. Heywood, D. Bakker and A . Watson.
8. National Oceanography Centre, Southampton, UK; R. Pollard, R. Sanders, M.Sparrow.
9. Royal Netherlands Institute for Sea Research (NIOZ), Texel, The Netherlands; H. deBaar.
10. Department of Geology and Oceanography, Univ. of Bordeaux, France; X. Crosta.
11. Dept. Earth Atmospheric and Planetary Sci., MIT, Cambridge, USA ; C. Wunsch et al..
12. JPL, California Institute of Technology, USA; D. Menemenlis.
13. Stazione Zoologica Anton Dohrn, Naples, Italy; M. Montresor.
14. Dept. Earth and Ocean Sciences, Univ. of British Columbia, Canada; E. Pakhomov.
15. British Antarctic Survey, Cambridge, UK; E. Murphy and C. Le Quéré.
16. University of Chicago, USA; David Archer.
17. University of Madison-Wisconsin, USA; Arne Winguth.
18. LPO/UBO UFR Sciences, Brest, France; Sabrina Speich

List of co-operations in MARCOPOLI:

MAR1: Close cooperation regarding the interaction of Southern Ocean processes with the global ocean.
MAR2: Cooperation aimed at the development of mechanistic models of palaeo-proxies.
POL1: Strong links regarding the research on sea ice and icebergs in the Weddell Sea; while POL1 is focussed on the physical aspects, POL2 addresses the biological and chemical processes associated with the ice.
POL5: Coordinated investigations and exchange of new findings with respect to the role of key species in structuring the Southern Ocean ecosystem.
POL6: Sharing laboratory facilities for the analysis of the fossil record in, cooperation in bi-polar aspects of climate change.
New Keys to Polar Climate Archives:
Exchange of information about new findings on climate-driving mechanisms and climate changes revealed from ice cores.

List of memberships in national and international committees:

E. Fahrbach: CLIVAR/CliC/SCAR Southern Ocean Implementation Panel
ASOF ISSG
SCAR/SCOR expert group on physical oceanography
IPY Joint Committee
R. Schlitzer and M.R. v.d. Loeff:
GEOTRACES Planning Group
M.R. v.d. Loeff: Member SCOR working group 116: Sediment Trap and Th-234 Methods for Particulate Organic Carbon Export in the Upper Ocean
C. De La Rocha: ASLO's Public Policy Committee
D. Wolf-Gladrow: Committee `European Doctoral School/PhD programme´ (regarding three European Networks of Excellence: EUR-OCEANS, MarBEF, and Marine Genomics Europe)
Scientific Steering Committee of CarboOcean (European Integrated Project)
SCOR/IMAGES Working Group 124 on Analyzing Links Between Present Oceanic Processes and Paleo-Records (LINKS)
Scientific Board of the Institute for Baltic Sea Research in Warnemünde, Germany
Scientific Board of NEBROC (= NEtherlands BRemen OCeanography)

Workpackage POL3: Variations of the Arctic physical environment

(Spokespersons: Dr. Ursula Schauer, Prof. Dr. Andreas Mackensen)

Academic Results

The work in POL3 aims at understanding the structure and the causes of the variability of the Arctic Ocean circulation and biogeochemistry in the present and past climate states. Besides investigating the causes of the variation of the Arctic-wide gyres, it addresses processes related to the thermohaline driven overturning in the Greenland Sea and on the Arctic shelves and their role in transport of dissolved and particulate matter and the effect of the latter on paleorecords in the Arctic.

The long term survey of the convection state of the Greenland Sea, maintained through hydrographic transects since 1995 and through moored CTD profilers since 2000, was continued with campaigns in 2004 and 2005. The resulting data enable the determination of the convection history by means of a newly developed multi-parameter criteria catalogue. This method showed that during the last decade convection depths were persistently limited to the upper part of the two-layered basin-wide structure which superseded the doming structure of the 1980s. Atlantic derived waters, intruding from the gyre's rims, play the dominating role for water mass modifications and convection. Deep water temperatures and salinities in the Greenland Sea continue to increase and reach now almost the values of the deep Arctic outflows. The repeated observations verified the multi-year lifetime of a small-scale eddy. Pacific Waters, formerly always found to exit the Arctic Ocean via Fram Strait, were completely absent above the shelf and slope northeast of Greenland during 2004 and 2005.

Shelf processes were investigated in two regions: in the Storfjorden in the western Barents sea and in the Laptev Sea. Both areas are dominated by persistent polynyas and our focus was on the related sea ice, oceanographic and geochemical dynamics.

The Storfjorden and its polynya is used as an easy-access study site and results can probably be extrapolated to other Arctic shelf polynyas. Here we found that plumes of brine–enriched shelf water - produced during freezing in winter - entrain large quantities of ambient waters when they are dense enough to sink to the deep sea floor and we quantify this downward transport of heat and salt to explain the Arctic deep water properties. Sinking rate, pathway and entrainment vary strongly with initial salinity and volume of the convected water in the polynya.

Polynyas play also a role in the Arctic methane cycle. Marine methane depends on microbial *in-situ* production and on oxidation in sea water and on sea-air exchange, which is influenced by ice-ocean dynamics. In the Storfjord polynya we observed during winter methane concentrations exceeding considerably marine background values. The vertical distribution points to a release of submarine methane due to resuspension of sediments caused by turbulence in the flow of dense brine-enriched bottom water. The isotopic composition shows that the methane originates from recent bacterial activities. Convective mixing transports the released methane to the sea surface and creates a sea-air flux of submarine methane during periods of open water. Thus, the coupling of biogeochemical and oceanographic processes forms a pathway for methane from sediments to the atmosphere. From summer observations showing anomalously high methane concentration in Storfjorden in the upper waters we conclude on bacterial in-situ production of methane in the euphotic zone.

The second focus of shelf studies lies in the Laptev Sea, which is the most productive sea ice formation site of the Arctic. Shelf polynyas in the Siberian Arctic are predominantly wind-driven and thus sensitive to variations of the atmospheric pressure field. Consequently the observed Arctic climate changes strongly affect the frequency and dynamics of polynya events. One example is the development of Laptev Sea polynya early in the year 2002, driven by anomalously strong poleward winds along the Siberian coast, which possibly caused the observed minimum Arctic sea ice extent in that year.

Change in the frequency of polynya events may also alter the physical and biological environment of the shelf seas. A problem with the understanding of possible effects is the scarcity of observational data. We have thus, in a Russian-German-US cooperation deployed two moorings in the range of the persistent Siberian Polynya.

Ice conditions and polynya processes north of the Lena delta in the region of the moorings have been monitored by means of satellite radar (SAR) imagery between October 2003 and June 2004. The data revealed numerous phases of ice breakup and new ice formation with implications for water mass modification and sediment redistribution. Ice drift and export was in good agreement with prevailing wind direction, but not well correlated with wind speed. A polynya ice

growth model showed that 50 * 10^3 km^3 of thin ice has been produced in the study region (approx. 200 km wide).

To investigate the use of benthic foraminifera as a means to document ancient methane release in the Arctic the stable isotopic composition of tests of live and dead specimens of epibenthic *Fontbotia wuellerstorfi* from an active methane-venting seep off northern Norway (Håkon Mosby Mud Volcano, HMMV) was determined. Because of its reliability in recording $\delta^{13}C$ values of bottom-water dissolved inorganic carbon (DIC) this species is preferentially used in paleoceanographic reconstructions. At the HMMV in 1250 m water depth, $\delta^{13}C$ values of *F. wuellerstorfi* are up to 4.4 ‰ lower than at a control site outside the volcano, thus representing the lowest values hitherto reported for this species. The comparison suggests that low test $\delta^{13}C$ values of *F. wuellerstorfi* are the result of incorporation of heavily ^{13}C depleted methanotrophic biomass that these specimens feed on, rather than due to low bottom-water $\delta^{13}C_{DIC}$.

Hindcast simulations with the coupled ice-ocean model NAOSIM support the observations of a new very warm pulse of Atlantic water intruding the Arctic Ocean since 2004. NAOSIM allows tracking of the signal from its origin in the southern Nordic Sea into the central Arctic. These studies allow better understanding of timing and dynamics of Atlantic Water intrusion to the Arctic and are first steps in exploiting the predictive potential. Simulations of the dispersion of oxygen isotopes and that of the anthropogenic radionuclide Technetium-99 have been used to trace river runoff and Atlantic water in the Arctic. The comparison with observed tracer data allows model validation, which is favorable for present experiments. The results serve as an important support in the interpretation of the sparse observational data. Our investigations prove a shift of the river-runoff pathways during the phase of high Arctic Oscillation index in the 1990s from the Transpolar Drift in the Eurasian Basin to the Makarov Basin with significant consequences for the export of freshwater to the North Atlantic. A theoretically derived hypothesis claiming the net potential vorticiy (PV) input as being responsible for the sense of rotation of the Atlantic Water layers in the Arctic Ocean was investigated. We could show that the net input of PV has a large influence on the movement of mid-depth Arctic water masses even in complex general circulation models. We found that water mass modification in the Barents Sea is essential for setting the high PV input to the interior Arctic and that the mid-depth circulation in the Arctic basins is further influenced by the atmospheric pressure fields via disturbances of the local halocline depth.

State of achievements of deliverables

1. Development and implementation of systematic observation systems for the ocean (HAFOS) and sea ice thickness.

The systematic observation system for the central Arctic Ocean is under development. Some components on the Laptev Sea shelf are already under operation:

In the Laptev Sea, we combine observations from oceanographic moorings with high resolution satellite data. In 2005, we have deployed two year-round observational arrays on the seafloor of the Laptev Sea shelf to study processes in the area of the recurrent Siberian Polynya in cooperation with the program "Nansen and Amundsen Basins Observational System" (NABOS). During winter, the polynya occurrence and extent as well as polynya processes were monitored with satellite measurements from the Envisat synthetic aperture radar (SAR) and the advanced microwave scanning radiometer (AMSR-E).

The moorings on the Laptev Sea Shelf monitor the variability of the current profile, the ice draft and the velocity and direction of ice drift and the temperature and salinity stratification. Meteorological data from the Laptev Sea will be provided through the Arctic and Antarctic Research Institute (AARI). The satellite imagery from the ENVISAT synthetic aperture radar and the advanced microwave scanning radiometer will be used to estimate across-shelf transport and sea-ice export into the central Arctic Ocean. A first analysis of the satellite imagery and the meteorological data has shown that the polynya near Severnaya Zemlya opened several times during the winter of 2005/2006.

2. Records of palaeo river discharge in key cores from the Eurasian marginal seas and sedimentary budgets of terrigenous input in relation to climate change

No achievements reached yet because of political restrictions of relevant Polarstern cruises. To obtain the geological material necessary for this task a Polarstern cruise to the Russian Arctic was planned. In two consecutive years the permission was denied by Russian authorities.

3. Reconstruction of extent and history of Northern Hemisphere glacial ice sheets
Also this task was affected by the cancellation of Polarstern cruises. Part of this deliverable was executed in POL6 and POL7.

Personnel

Personnel	Institutional funding	Third party funding
	Scientists / PhD / Technicians	Scientists / PhD / Technicians
AWI	5,85 / 0,5 / 1,3	1,2 / 0 / 0,5

Publication outcome numbers

Academic Publications Refereed only	2004-2006
ISI	31
non ISI	8
PhD theses	1
Master & Diplom Theses	-
Books	-
Book chapters	5

Key publications

1. Falck, E., G. Kattner, G. Budéus. Disappearence of Pacific Water in northwestern Fram Strait. Geophys. Res. Lett. 32: L14619,doi:10.1029/2005GL023400
2. Mackensen, A., Wollenburg, J., Licari, L.(2006). Low d13C in tests of live epibenthic and endobenthic foraminifera at a site of active methane seepage, Paleoceanography, (in press).
3. Ronski, S., Budéus, G.(2005). Time series of winter convection in the Greenland Sea, Journal of geophysical research-oceans, 110, C04015.DOI: 10.1029/2004JC002318
4. Hölemann, J., Schirmacher, M., Prange, A.(2005). Seasonal variability of trace metals in the Lena river and the south eastern Laptev Sea: Impact of the spring freshet, Global and planetary change, 48(1/3), 112-125. DOI: 10.1016/j.gloplacha.2004.12.008
5. Wegner, C., Hölemann, J. A., Dmitrenko, I., Kirillov, S., Kassens, H.(2005). Seasonal variations in Arctic sediment dynamics - evidence from 1-year records in the Laptev Sea (Siberian Arctic), Global and planetary change, 48(1/3), 126-140. DOI: 10.1016/j.gloplacha.2004.12.009

List of guest scientists

1. Dr. Sergey Pisarev, P.P. Shirshov Institute of Oceanology, RAS, Moskau 20. Okt. - 20. Dec 2004
2. Dr. Eva Falck, University of Bergen, Geophysical Institute, Bergen, Norway, 1 month in 2005

List of running/accepted third party funded projects

1. DAMOCLES (Developing Arctic Modelling and Observing Capabilities for Long-term Environmental Studies), European Union, Schauer, Rutgers vd Loeff (+ Fahrbach, Lüpkes, Haas, Gerdes in POL1 and MAR1), 2005 -2009, 1.107 k€ with contributions in POL1, POL3 and MAR1
2. SEARCH FOR DAMOCLES, European Union, Schauer (+ Dethloff in MAR1), 2006-2009, 104 k€ with contributions to MAR1
3. Benthische Foraminiferen und Methanquellen, DFG, Mackensen, 2004-2006, 201 k€

List of expeditions

1. ARK XIX/2, Polarstern, (24.04. bis 14.05.03), Greenland Sea, 6 scientists
2. ARK XX/1, Polarstern, (16.06. bis 16.07.04), Greenland Sea, 4 scientists
3. ARK XXI/1, Polarstern, (21.07. bis 13.08.05), Greenland Sea, 4 scientists
4. ARK XXI/2, Polarstern, (13.08. bis 18.09.05), Storfjord, Fram Strait, 1 scientist

5. NABOS 2005, Kapitan Dranitzyn, 5-27 September 2005, northern Laptev Sea, Nansen and Amundsen Basin. Participants: 1 scientist / 2 Ph.D. Students

List of external co-operations

1. Eva Falck, University of Bergen, Geophysical Institute, Bergen, Norway
2. NABOS (Nansen and Amundsen Basins Observational Systems) Igor Polyakov, IARC Fairbanks,USA
3. Igor Dmitrenko, IARC Fairbanks,USA
4. Leonid Timokhov, AARI, St. Petersburg
5. Carolyn Wegner, IFM-GEOMAR, Kiel
6. Louis Fortier, Laval University, Quebec, Canada
7. Justin Gwynn, NRPA, Tromsoe, Norway
8. Andrey Proshutinsky, John Toole, WHOI, Woods Hole, USA
9. Elisabeth Hunke, LANL, Los Alamos, USA
10. Jinlun Zhang, APL, University of Washington, Seattle, USA
11. Sirpa Häkkinen, GSFC, Nasa, Maryland, USA
12. Bob Newton, Peter Schlosser, LDEO, Palisades, NY, USA
13. Igor Yashayaev, BIO, Dartmouth ,Canada
14. Jacqueline Grebmeier, University of Tennessee, Knoxville, Tennessee, USA
15. Bert Rudels, Finnish Institute of Marine Research, Finland
16. Sergey Pisarev, P.P. Shirshov Institute of Oceanology, RAS, Moskau, Russia
17. Wieslaw Maslowski, Naval Postgraduate School, Monterey, California, USA
18. Paul Wassmann, University of Tromsø, Norway
19. Jinping Zhao, Ocean University of China, Qingdao, China
20. Jean-Claude Gascard, Universite Pierre et Marie Curie, Paris, France
21. Ron Kiene, Dauphin Island Sea Lab, Alabama, USA

List of co-operations in MARCOPOLI

1. POL3 has very strong internal linkages to POL1, POL6 and MAR1.
All observations of Arctic sea-ice change are treated in POL1. The modelling of fresh water and sea-ice circulation is reported in MAR1 while the variations of the deeper layers (below ca. 150 m) are treated in POL3. While the observation of longterm changes in the Arctic Ocean and the Greenland Sea are dealt with in POL3, the observation and modelling of the fluxes between both areas are subject of MAR1. The distinction of the fresh water fluxes into their components by use of δO-18 are however part of POL3.

List of memberships in national and international committees

U. Schauer: National IPY-Committee
Steering committee of EU- Project “Arctic-Subarctic Ocean Flux Array for European Climate: North” (ASOF-N) and there speaker of WP “Heat flux through Fram Strait” 2002-2006
Steering committee of AOSB-Programm ISAC (International Study of Arctic Change)
member of ICARPII (International Conference on Arctic Research Planning II) working groups “Gateways and Margins” und “Deep Basins”
chair of WP “Ocean” and steering committee of EU-funded Integrated Project “Developing Arctic Modelling and Observing Capabilities for Long-term Environmental Studies” (DAMOCLES)
Chair of “Arctic ships coordination during IPY” (ASCI)
Steering committee of SEARCH FOR DAMOCLES
Steering committee of Verbundvorhaben „Der Nordatlantik als Teil des Erdsystems“, proposal for BMBF funding

M. Karcher: Member of the steering committee of “Arctic Subarctic Fluxes Study” (ASOF) and chair of its WG7 “Numerical Experiments”

P. Lemke: Chairman of the Joint WMO/ICSU/IOC Scientific Committee for the World Climate Research Programme (WCRP) (since 1995 Member; since 1999 Officer, 2000-2006 Chair)

Coordinating Lead Author: IPCC Fourth Assessment Report, Chapter 4: Observations of snow, ice and frozen ground.
Chairman des Scientific Advisory Board of the Bjerknes Centre, Bergen, Norway
Chair of the German National Member Organisation for the International Institute for Applied Systems Analysis (IIASA, Laxenburg, Austria)
Chair of the IIASA Program Committee, Member des IIASA Executive Committee
Member of the Environmental Monitoring Expert Group of ESFRI (European Strategy Forum on Research Infrastructures (since 2005)
Member of the Earth Science Advisory Committee (European Space Agency) (since 2003)
Member of the Scientific Advisory Group des ESA Satelliten CryoSat

Chair of the Science Advisory Board of the Max Planck Institute for Meteorology, Hamburg (since 2002)
Vice-Chair of the Science Advisory Board of the GKSS Research Centre
Vice-Chair of the National Committee for Global Change Research (since 2003)
Member of the Science Advisory Board of the Institute for Tropospheric Research, Leipzig
Member of the Science Advisory Board of the Deutscher Wetterdienst (since 2003)
Member of the DFG Senate Commission for Oceanography
Member of the Board of the Potsdam Institute for Climate Impact Research

A. Mackensen: member of IMAGES (IGBP/PAGES) Executive Committee
chair of Southern Ocean WG in IMAGES
German national representative in IMAGES
editor-in-chief of Marine Micropaleontology (Elsevier)

Workpackage POL4: Benthic organisms in polar marine food webs

(Spokesman: Prof. Dr. Hans-Otto Pörtner)

Academic results

A) Trophic relations in polar marine food webs

In the light of the extremely rich species inventory and the extraordinary number of feeding linkages of the Weddell Sea shelf food web the traditional view of a rather simple Antarctic food web becomes obsolete. Our actual food web model which consists of 491 compartments connected by 16200 feeding links indicates that the Weddell Sea system is outstanding in terms of ecosystem descriptors based on general ecosystem network analysis: (i) there are more species and feeding links than elsewhere; and (ii) the value of mean linkage density is higher than usually reported. Given the high dietary overlap and generalist feeding nature of most Antarctic species, plus the well-documented capacity of diet switching, it appears that there are few trophic links of particular exclusivity and strength. The observed “loose” connectivity of the Antarctic network leads towards stability, albeit there are different ways of being robust related to different types of perturbations.

Bouvet Island is one of the few remote islands within the open ocean of Antarctica, about 1600 km away from the nearest land mass. The structure of the coastal food web is rather uncommon. The system is centred on one single primary food source, i.e. suspended particulate organic matter. The pelagic part of the food web does not exhibit any specific coastal features but resembles the self-sustaining open ocean system. The benthic part of the food web consists of filter feeders and their predators, while deposit feeders and infauna are completely missing. Thus Bouvet Island constitutes a shallow water “oasis”, where the fast flowing Antarctic Circumpolar Current prevents sedimentation and soft bottom formation. The benthic fauna just tries to get their share from the food drifting by, in direct competition with the pelagic consumers.

Pelagic ecology and energy flow in the Arctic Kara Sea are much more complex than previously thought. Riverine input and advection from the Arctic Ocean as well as the Barents Sea define four distinct faunistic regions. Current estimates of primary production appear much too low to balance food requirements of the whole system as derived from biomass and metabolic rates of zooplankton, benthos, and bacteria. Either primary production is seriously under-estimated, or other sources of food input, e.g. advection, play a more significant role than previously thought. From these findings we can draw one major conclusion: Food requirements of the Kara Sea shelf ecosystem are so high in itself that little will be left for export towards the central deep basins of the Arctic Ocean.

B) Role of temperature, oxygen and CO_2 in evolution

The general validity of the concept of oxygen limited thermal tolerance in animals is supported by recent findings in the European cuttlefish *Sepia officinalis*. We demonstrated for the first time that in a cephalopod the capacity for oxygen transport by the circulatory system and by the blood pigment (haemocyanin) becomes limiting at the border of the thermal envelope.

Separation into physiologically distinct populations supports a wider geographical distribution of a species, e.g. of Atlantic cod (*Gadus morhua*). Cod populations differ in their level of optimum performance, which is co-defined by circulatory capacity. As shown by comparison of venous oxygen tensions, Arctic cod from the Barents Sea displays a lower thermal optimum than North Sea cod, even when both populations were acclimated to 10°C. At low acclimation temperature, Arctic cod display a higher capacity of mitochondrial respiration than the respective North Sea population. At the same time gene expression capacity of mitochondrial enzymes in muscle tissue is enhanced in Northeastern Arctic cod, with an as yet unidentified mechanistic background. Activity of hypoxia inducible transcription factor (HIF-1) responds to cellular redox status and may play a role during temperature adaptation through triggering expression of mechanisms causing improved blood oxygen supply. HIF-1 has been sequenced from fish species of the North Sea and the Antarctic.

Specialization of Antarctic animals in a narrow thermal window in the cold can be found on all levels of biological organization. Windows are somewhat wider at low hierarchical levels, as seen in a comparison of isolated Antarctic fish liver cells or mitochondria with the whole organism. Growth rate depends on protein synthesis capacity, which is cold compensated in the Antarctic eelpout (*Pachycara brachycephalum*). This is not achieved through increased RNA contents but through higher translation capacity. Accordingly, maximum growth of the stenothermal Antarctic eelpout occurs at 4°C, while the eurythermal species (*Zoarces viviparus)* grows maximally only at 12°C.

The Antarctic eelpout displays a higher food conversion efficiency associated with an increased contribution of lipid metabolism.

Oxygen radicals contribute to lifespan limitation and are destroyed by antioxidants like glutathione. Glutathione levels are higher in long-lived polar bivalves (*Adamussium colbecki*, ~45yrs, *Arctica islandica* <=375yrs) than in boreal species (*Aequipecten opercularis,* ~8-10yrs).

C) Response of polar marine life to recent change

Ecological models indicate that short distance dispersal of early life-stages of Antarctic macrobenthos maintains the high biodiversity evaluated from field data. By minimizing the risk of loss through drift, this strategy saves energy and is considered advantageous in a homogeneous environment exposed to climate-related disturbances. High species richness within ecological guilds cannot only be explained by the occupation of distinct niches, but also by mechanisms that suppress competition between species and by pure chance.

Hard and soft bottom succession experiments at 20m depth in the coastal Arctic (Kongsfjorden, Spitsbergen) and in the Pacific Humboldt Current (Antofagasta, Chile) confirmed that diversity increases with time. Early succession does not display the same pattern every year, indicating the importance of larval supply. Development of Arctic macrobenthic communities appears to be extremely slow compared to warmer regions, making these communities extremely sensitive to anthropogenic disturbances.

Conceptual analysis suggests an interaction of the effects of changes in temperature and CO_2 level on marine ecosystems. In the brachyuran crab *Cancer pagurus* elevated CO_2 levels cause in fact a narrowing of the window of thermal tolerance as characterized by limitations in the capacity of oxygen supply to tissues.

The thermal window of the lugworm *Arenicola marina* was found to shift dynamically between seasons. Windows were identified from patterns of oxygen consumption, ventilation and protein synthesis monitored in an artificial burrow. At the same acclimation temperature thermal windows were narrow in winter associated with lower rates of energy turnover and a very high response to warming compared to the wider windows found in spring.

UVB tolerance was investigated in seaweeds and amphipods from shallow coastal areas of Spitsbergen and the Western Antarctic Peninsula. The upper depth distribution limit of Arctic kelps is determined by the UV susceptibility of their zoospores. Carnivorous Arctic amphipods are less resistant to UVB than herbivores with sun-screening pigments, they experience severely bleaching and antioxidant enzymes are photo-inhibited by UV-light. Exposure to UV-radiation led to increased oxygen uptake in Antarctic amphipods. The effect was more pronounced under UVB than UVA exposure.

State of achievements of deliverables

1. Key trophic traits in polar ecosystems with emphasis on differences between the two polar systems

Food web structure of both Antarctic (Weddell Sea, Bouvet Island) and Arctic (Kara Sea) shelf systems has been analysed. With close to 500 compartments, our Weddell Sea food web model is the most complex marine web established so far. Owing to the large number of “weak” links, the identification of key trophic traits is a non-trivial task and will require extensive balanced energy flow modelling. Corresponding energy flow modelling, albeit at much lower resolution, of the Kara Sea system already indicated serious imbalances, thus casting some doubt on central flow estimates.

2. Polar food web response to continued climate change and/or anthropogenic impact

According to modern ecosystem theory, “loose” connectivity of a food web, i.e. the existence of many “weak” trophic links, leads towards system stability, as most links can easily be substituted functionally. Thus, high-Antarctic food webs can cope better, to a certain extent, with slowly changing environmental conditions that lead to a shift of equilibrium trophic structure. But if global warming causes dramatic short-term disturbances such as the loss of large shelf ice sheets that affect most of the species simultaneously, this will have significant impacts on predator-prey relationships, with profound consequences for ecosystem functioning. We intend to test this hypothesis by dynamic energy flow modelling.

3. Cause and effect understanding, how climate factors, molecular and cellular design as well as physiological and ecological performance are interrelated

Current evidence supports the hypothesis that the narrowest windows of thermal tolerance are set at the highest level of organizational complexity, the whole organism, with a key role of

oxygen supply pathways. High and low limits of thermal tolerance are likely to be interdependent and the width of the thermal window relates to the level of organismic energy turnover, as seen at cold temperatures. Investigations have revealed individual patterns of temperature dependent gene expression or different capacities of protein synthesis between eurytherms and stenotherms. The picture currently emerges that all of these processes have ecological implications by shaping energy budget at various organisational levels, e.g energy availability to cellular energy consumers or to organismic growth. However, the regulatory and mechanistic background of climate dependent adaptation remains insufficiently explored. Accordingly, these relationships require further conceptual and experimental analyses.

4. Development of organismic energy turnover and associated macro-ecological patterns

Aerobic performance depends on climate as indicated by temperature dependent as well as seasonal patterns of aerobic performance and energy metabolism in different taxa (e.g. annelids, cephalopods, pectenids, fishes) in a latitudinal gradient.

A conceptual model has been elaborated of how the principle mechanisms of thermal adaptation and climate patterns have led to rising levels of energy turnover over evolutionary time and have finally led to the evolution of warm blooded animals. Our data support the development of hypotheses of how oxygen limitation at extreme temperatures and the thermal sensitivity of ion regulation might interact and finally define the geographical geographical distribution limits of species and their populations. These relationships require further conceptual and experimental analyses.

5. Principal factors that determine habitat selection, pace of succession, biodiversity and complexity

We developed the first ever spatially explicit numerical model for simulation of marine benthic diversity pattern dynamics and testing of hypotheses on the effect of habitat fragmentation. The model will be used to identify not only particular ecological processes but also complex physical-biological interactions, and to predict climate-induced changes in polar environments.

6. Common principles that support mechanistic and numerical modelling of marine ecosystem dynamics, scenarios and predictions of the responses of marine life to change

Progress towards this long term goal was slow due to its complexity and the need for broad scale approaches in various disciplines from molecular biology via cellular and organismal physiology to ecology. First steps of model construction have recently been started at the borderline between ecology and physiology and have led to a numerical description of temperature dependent performance in relation to abundance data. The numerical simulation of benthic diversity widens the basis for future, more integrative analyses of ecosystem dynamics.

Personnel

Personnel	Institutional funding	Third party funding
	Scientists / PhD / Technicians	Scientists / PhD / Technicians
AWI	Positions 19.3 / 11.9 / 12.1	2.0 / 11.6 / 1.4

Publication outcome numbers

Academic Publications Refereed only	2004-2006
ISI	89
non ISI	45
PhD theses	10
Master & Diplom Theses	9
Books	5
Book chapters	5

Key publications

1. Brose U, Cushing L, Berlow EL, Jonsson T, Banasek-Richter C, Bersier LF, Blanchard JL, Brey T, Carpenter SR, Cattin Blandenier MF, Cohen JE, Dawah HA, Dell T, Edwards F, Harper-Smith S, Jacob U, Knapp RA, Ledger ME, Memmott J, Mintenbeck K, Pinnegar JK,

Rall BJ, Rayner T, Ruess L, Ulrich W, Warren P, Williams RJ, Woodward G, Yodzis P, Martinez ND, 2005. Body sizes of consumers and their resources, Ecology: 86: 2545.
2. Eastman J, Gutt J, di Prisco G. (eds), 2004. Adaptive evolution of Antarctic marine organisms. Antarctic Science 16 (Special issue): 1-93.
3. Philipp E, Brey T, Heilmayer O, Abele D, Pörtner H-O, 2006. Physiological ageing in a polar and a temperate swimming scallop. Marine Ecology Progress Series 307: 187-198.
4. Pörtner H-O, Langenbuch M, Michaelidis B, 2005. Synergistic effects of increased CO_2, temperature and hypoxia on marine animals. Journal of Geophysical Research – Oceans 110: C09S10
5. Wiencke C, Roleda MY, Gruber A, Clayton MN, Bischof K, 2006. Susceptibility of zoospores to UV radiation determines upper depth distribution limit of Arctic kelps: evidence through field experiments. Journal of Ecology 94: 455-463.

List of guest scientists

1. Rainer Kiko, Institut für Polarökologie, Christian-Albrechts-Universität, Kiel
2. Dr. Simon Morley, British Antarctic Survey
3. Prof. Lloyd Peck, British Antarctic Survey
4. MSc. Aitor Albaina Vivanco, Marine Research Division, AZTI Foundation, Pasaia, Spain
5. Prof. Dr. Angela Wulff, University of Gothenburg, Sweden
6. Dr. Michael Roleda, University of Manila, Philippines
7. MSc. Cheryl Tosh, University of Pretoria, South Africa
8. Dr. Maritza Palma, Universidad Concepcion, Chile
9. MSc. Carlos Rios, Universidad de Magallanes, Punta Arenas, Chile
10. MSc. Erika Mutschke, Universidad de Magallanes, Punta Arenas, Chile
11. Dr. Ivan Gomez, Universidad Austral de Chile, Valdivia, Chile
12. Dr. Fernanda Covacevich, Argentina

List of running/accepted third party funding projects

1. The impact of climate variability on aquatic ecosystems (DFG AQUASHIFT) (Pörtner) 66.000 Euro
2. Influence of CO_2 on gene expression in marine fishes (University of Bremen fellowship) (Pörtner) 65.000 Euro
3. Role of CO_2 in metabolic depression in marine invertebrates (DAAD) (Pörtner) 65.000
4. Ecological and Physiological Investigations about the Impact of UV Radiation (UVR) on the Succession of Benthic Primary Producers in Antarctica (Wiencke) 31.000 Euro
5. Physiologische Anpassungsmuster polarer Algen an abiotische Stressfaktoren und ihre Bedeutung für die Struktur polarer Felsküstenökosysteme" (HGF) (K.Bischof) 375.000 Euro
6. Trophische Interaktionen im Pelagial: die Rolle des Zooplanktons (HGF) (Niehoff) 375.000 Euro
7. Whole Genome Sequencing Ectocarpus siliculosus (Valentin) 500.000 Euro
8. Network of Excellence Marine Genomics (Valentin) (80.000.- Euro)
9. Whole Genome Sequencing of a Sea Ice Bacterium (Valentin) 200.000 Euro
10. Genetische Struktur benthischer Invertebraten innerhalb und außerhalb der Hochantarktis (Held) 120.000 Euro

List of expeditions

1.	FS “Polarstern”	ANT XXI/2
2.	FS “Polarstern”	ANTXXIII/2
3.	FS “Polarstern”	ANTXXIII/3
4.	Dallmann Laboratory	Jubany Expedition 2003/04,
5.	Dallmann Laboratory	Jubany Expedition 2004/05,
6.	Dallmann Laboratory	Jubany Expedition 2005/06,
7.	Koldewey-Station	Langzeitprogramm KOL 06 04/2004 - 09/2004
8.	Koldewey-Station	Langzeitprogramm KOL 06 03/2005 - 11/2005
9.	Koldewey-Station	Langzeitprogramm KOL 06 04/2006 - 09/2006

List of external co-operations

1. British Antarctic Survey, Cambridge UK (L. Peck, S. Morley)
2. Department of Zoology, Cambridge University UK (C. Ellington)
3. Laboratory of Animal Physiology, Department of Biology, University of Turku, Finland (M. Nikinmaa)
4. Institut für Polarökologie, Christian-Albrechts-Universität Kiel (I. Werner)
5. Marine Zoologie, Universität Bremen (W. Hagen, H. Auel)
6. Universität Rostock (U. Karsten)
7. Universität Hamburg (D. Hanelt)
8. University of Gothenborg (A. Wulff)
9. Department of Global Ecology, Stanford University, Stanford, USA (K. Caldeira)
10. Hopkins Marine Station, Stanford University, Pacific Grove, USA (G. Somero)
11. Oregon State University, Corvallis, USA (C.B. Miller)
12. Biology Department, University of North Carolina at Charlotte, USA (I. Sokolova)
13. Graduate School of Oceanography, University of Rhode Island, Narragansett, USA (E.G. Durbin)
14. University Melbourne, Australia (M. Clayton)
15. Zoological Institute Russian Academy of Scieces, St. Petersburg, Russia (A. Sukhotin)
16. Kol´tsov Institute of Developmental Biology; Russian Academy of Sciences; Moskau (N.D. Ozernyuk)
17. Instituto Antartico Argentino, Buenos Aires, Argentina (R. Carlini)
18. Universidad de Concepcion, Chile (M. Palma)
19. School of Pharmacy and Biochemistry, University of Buenos Aires, Argentina (S. Puntarulo)
20. Mammal Research Institute, University of Pretoria, South Africa (M.N. Bester)

List of co-operations in MARCOPOLI

1. □□ POL5	Antarctic copepod ecology
2. □□ POL3	Use of hydrograhic, meteorological and Ice data
3. □□ POL6/MAR1	Use of climate proxies & macroorganism climate archives
4. □□ CO2	Coastal diversity - key species and food webs
5. □□ CO3	Chemical Interactions - ecological function and effects

List of memberships in national and international committees

Schiel, S.:	Census of Marine Life
Pörtner, H.O.:	Special report of IPCC (Intergovernmental Panel on Climate Change): Carbon dioxide capture and storage (Environmental Impact) (2003 - 2005)
	OSPAR intersessional correspondence group: Ocean acidification
	Committee member and editor: SCOR/IOC sponsored symposium and special volume: „Oceans in a high CO_2 world“ 2004/2005 (J. Geophys. Res.-Oceans)
	Advisory council “Evolutionary physiology” IUPS (International Union of Physiological Sciences)
	DZG representative IUBS council for International Conferences in Comparative Biochemistry and Physiology
	Society for experimental Biology, Thermal Biology Group Convenor
	ESF Scientific Programme: Thermal adaptation in ectotherms: Linking life history, physiology, behaviour and genetics
	Editorial boards: J. comp. Physiol., Physiol. Biochem. Zool., Comp. Biochem Physiol.
Valentin, K.:	Editor for Molecular Biology, European Journal of Phycology
	Rapporteur for the European Science Foundation ESF on Plant Life in Extreme Environments.
Knust, R., Pörtner, H.O.:	Deutsche Wiss. Komm. für Meeresforschung (DWK)
Abele, D.:	Kuratorium Forschungszentrum Terramare, Wilhelmshaven
Wiencke, C.	National SCAR committee
	Spokesman, Sektion Phykologie in der Deutschen Botanischen Gesellschaft
	Deutscher Koordinator des Dallmann-Labors

Bischof, K.:	Organizing committee, European Phycological Congress, 2007, Oviedo, Spain
Bornemann, H., Plötz, J.:	SCAR Expert Group on Seals
Plötz, J.	Life Science SCAR Standing Group (LSSSG)
Bornemann, H.	Ethikkommission des Landes Bremen nach § 15 Tierschutzgesetz
Bock, C.	Gründungsmitglied der Deutschen Sektion der ISMRM

Workpackage POL5: Autecology of planktonic key species and groups

(Spokesman: Prof. Dr. Ulrich Bathmann)

Academic results

Key species shape the structure of pelagic ecosystems in relation to biogeochemical fluxes
Biogeochemical cycles are driven by trophic interactions among a yet unknown range of species
Key species have evolved mechanical and chemical defense systems

The pennate diatom *Fragilariopsis kerguelensis* is among the dominant diatom species in the water column of the ACC. The thick frustules are remarkably resistant and have likely evolved as mechanical protection against crustacean zooplankton and ensure long-term persistence in the surface layer. *F. kerguelensis* contributes up to 90% of the diatom shells in the ooze making up the Antarctic opal belt, which is the largest depot of biogenic silica in the world ocean. Thus its ecological properties make *F. kerguelensis* by far the most important diatom in the global silicon cycle and an indicator species of a silica-sinking regime in an otherwise iron-limited ecosystem.

Due to its global significance in the silicon cycle the following studies are being carried out on *F. kerguelensis* at the Alfred Wegener Institute: Characterisation of its life cycle, the mechanical properties of its frustules, genetic variability within the population, physiology, in particular adaptation to extreme environments and grazing by zooplankton. Here we have strong collaboration with POL2: *F. kerguelensis* in Southern Ocean sediments and its response to iron enrichment during two in situ iron fertilization experiments (EisenEx and EIFEX).

Research in the sea ice group in POL 5 is centred on the question, which adaptations enable sea ice diatoms to thrive in such an extreme habitat as the Polar Regions. Thus, contributing significantly to polar primary production and biogeochemical fluxes. *Fragilariopsis cylindrus* was chosen as a model organism, since it is a very abundant species in the open water column and sea ice. In recent years molecular genetic methods and procedures have been increasingly employed to elucidate physiological processes and their regulation. As a basis for further quantitative expression analysis, two cDNA libraries have been established under induced cold and salt stress, the major environmental constraints in sea ice. Almost 2100 high quality sequences were retrieved from the salt stress library. A comparison with the already known genomes of the mesophilic diatoms *Thalassiosira pseudonana* and the pennate *Phaeodactylum tricornutum*, revealed that about one third of the sequences remained unique to *F. cylindrus*. This provided insight into the potential role of these genes in the adaptation to extreme habitats. Functional characterization of the sequences revealed a large number of proteins involved in stress response, e.g. heat shock proteins, reactive oxygen detoxifying proteins, ion antiporters and stress signalling proteins. Furthermore, all genes relevant for the metabolism of proline, the main organic osmolyte synthesized upon salt stress, could be identified and subjected to a further detailed expression analysis using quantitative real-time-PCR (Q-PCR) techniques. This analysis showed that ornithine was used as a substrate if exposed to salt stress, contrasting to higher plants where glutamate is preferred. With the construction of a third cDNA library under CO2 limiting conditions, the genetic basis will be broad enough (ca. 5000 genes) to carry out expression analysis using microarrays. A technique currently established here at the institute.

Antarctic krill, *Euphausia superba*, plays a key role in the ecosystem of the Southern Ocean and occupies a central place in commercially valuable resources. Population size of krill seems to be driven by recruitment, rather than by predation pressure on postlarvae. Therefore understanding the mechanisms that influence recruitment success (starvation tolerance, overwintering strategies) are the main objectives in the krill research within MARCOPOLI.

For larval krill resistance to starvation is important with respect to this critical autumn-winter transition period. Experiments conducted in our group have shown that lipid utilisation in starving furcilia does not seem to be linear but a more exponential process over time. We concluded from these results, that the amount of body lipids in freshly caught larvae does not provide reliable information on their survival time and hence on their population success.

In adult krill, the reduction in metabolic rates is one of the most energy saving mechanism during winter but the principle behind this reduction is under great debate. We found that changes in the environmental light regime have an important effect on physiological parameters of krill such as feeding and metabolic rates. Further studies will focus on the question which substance (e.g. Melatonin, Serotonin) in krill is triggered by changes in the photoperiod and might influence its physiology.

Distribution and reproduction of the atlantic copepod *Calanus finmarchicus* and the arctic species *C. glacialis* reflect the distribution of the Atlantic and arctic water masses. In the laboratory

temperature response of egg production was very similar in both species. In the field, however, stage composition and in-situ experiments indicate reproductive failure of *C. finmarchicus* in arctic waters. In the future the increasing temperatures predicted for the Arctic could facilitate successful colonization by *C. finmarchicus*. This would strongly affect trophic relationships and carbon flux.

Many key species in cold-water habitats, particularly copepods, convert phytoplankton with relatively low lipid levels, into large lipid stores and hence provide large amounts of energy-rich compounds fuelling the marine food web. A considerable variability in lipid content and compounds has been detected. Some species are very effective in utilising food and are able to survive extremely long periods of food scarcity.

During all processes within the marine food web dissolved organic matter (DOM) is produced contributing considerably to the biogeochemical cycles. Transformation processes convert bio-molecules into complex molecular structures which are characterised by modern, high resolution ion cyclotron resonance mass spectrometry to gain information on origin and fate of DOM as well as on transformation processes and bio-availability.

State of achievements of deliverables

1. An improved understanding of factors shaping the structure of pelagic ecosystems in relationship to biogeochemical fluxes extreme anomalies and climate change

Phytoplankton blooms play a crucial role in pelagic food webs, transfer of organic matter to the sea floor and ocean biogeochemistry. Phytoplankton biomass build-up is a function of growth rates of species populations, dependent on light and resource availability, growth regulation mechanisms, but also of mortality rates due to cell death, pathogens and predators (grazers). The two in situ iron fertilization experiments EisenEx and EIFEX conducted by the Alfred Wegener Institute in collaboration with several national and international partners have revealed the central role of iron in controlling growth rates of individual phytoplankton species in the land remote Southern Ocean. Further studies on cosmopolitan key diatom and Haptophytes species (phaeocystis and coccolithophores) are being carried out at the Biologische Anstalt Helgoland, in parallel to the established time-series study, in order to investigate other factors (environmental conditions and mortality) affecting seasonal dynamics of key species.

Several experiments with different approaches, with the focus on both phytoplankton and zooplankton contribute to the accomplishment of this deliverable.

Two in situ iron fertilization experiments EisenEx and EIFEX have revealed a central role of iron in controlling growth rates of individual phytoplankton species in the land remote Southern Ocean. Further studies on cosmopolitan key diatom and Haptophytes species (phaeocystis and coccolithophores) are being carried out at the Biologische Anstalt Helgoland, in parallel to the established time-series study, in order to investigate other factors (environmental conditions and mortality) affecting seasonal dynamics of key species.

Samples of the long-term moored sediment traps in the "HAUSGARTEN " reveal a change in key species (i.e. *E. huxleyi, C. pelagicus*, ice algae, *Chaetoceros* resting cells, feacal pellets, swimmers) flux patterns. More detailed microscopical work in the coming two years will show whether this change is due to a climatic change in the Fram-Strait area.

An analysis of expressed sequence tags (ESTs) at different time-points of viral infection of *E. huxleyi* revealed a significant change of gene-expression in the host-cell. In the course of the viral infection more an more viral genes are expressed until after 24 hours the transcription in the host-cell is dominated completely by viral transcripts.

Experiments on Antarctic krill, *Euphausia superba*, exposed to simulated Antarctic summer autumn, winter light conditions and constant high food conditions have demonstrated that changes in the environmental light regime have an important effect on physiological parameters of krill such as feeding and metabolic rates. Krill exposed to summer and autumn condition showed an increase in feeding activity and metabolic rates while in krill exposed to winter condition no evident change was recorded. This relationship is of importance for krill survival during the Antarctic winter when food supply is low and its population dynamic has a strong effect on higher trophic levels in the Southern Ocean.

2. Data to improve the predictive ability of coupled earth system models

The population size of Antarctic krill, Euphausia superba , a key species in the ecosystem of the Southern Ocean is driven by recruitment. The main objective of the krill physiology group at AWI is therefore to understand the mechanisms that influence recruitment success such as starvation tolerance and overwintering strategies.

To improve the predictability of recruitment success and krill population dynamics through the use of models the DFG funded project “A biochemically based modeling study of the growth

and development of Antarctic krill (*Euphausia superba*)“ was implemented. It uses krill physiology data collected in the past years to parameterize this individual-based model of krill. Furthermore experiments were designed to fill data gaps that were conducted during research cruise ANTXXIII-2+6 on RV Polarstern.

3. Development of new biological proxies for interpretation of sediment archives

The study of the diversity and the function of larger protozooplankton in pelagic food webs, despite the extensive use of their mineral skeletons as proxies for palaeoceanographic reconstructions, has started only fairly recently. An important group, which comes to the fore as a biological proxy, are the acantharia. These delicate, free living, microphagic organisms are exclusively marine microzooplanktonic protozoa, ranging in size from 50 µm to 5 mm in diameter and form barium-enriched celestite (Ba/Sr SO4) skeletons. During the iron fertilization experiment EIFEX acantharia showed very high abundances (50 ind. L-1) already prior to the first fertilization and their temporal development resembled the temporal development of the phytoplankton bloom. Hence acantharia have the capability to respond to enhanced biological productivity with population growth This is of major interest since acantharia play a unique role in the barium and strontium cycle of the oceans and it has thus been suggested that these organisms influence barite (BaSO4) deposition in the sediments although the mechanisms leading to its formation are still under debate. The degree of barite deposition in the sediments is used as a proxy for biological productivity of the overlying water column.

Personnel

Personnel	Institutional funding	Third party funding
	Scientists / PhD / Technicians	Scientists / PhD / Technicians
AWI	7.5 / 5 / 5	1 / 4 / 0.2

Publication outcome numbers

Academic Publications Refereed only	2004-2006
ISI	42
non ISI	19
PhD theses	4
Master & Diplom Theses	6
Books	-
Book chapters	1

Key publications

1. Lee, R. F., Hagen, W., Kattner, G.(2006). Lipid storage in marine zooplankton, *Marine Ecology-Progress Series, 307,273-306
2. Pakhomov, E. A., Atkinson, A., Meyer, B., Oettl, B., Bathmann, U.(2004). Daily rations and growth of larval krill Euphausia superba in the Eastern Bellingshausen Sea during austral autumn. *Deep-Sea Research Part II, 51, 2185-2198.
3. Smetacek, V., Assmy, P., Henjes, J.(2004). The role grazing in structuring Southern Ocean pelagic ecosystem and biogeochemical cycles, Antarctic Science, 16, 541-558.
4. Smetacek, V., Nicol, S.(2005). Polar ocean ecosystems in a changing world, *Nature*, 437, 362-368.
5. Medlin, L.K. and Zingone, A. 2006. A Review: The genus Phaeocystis and its species. Biogeochemistry, in press.

List of guest scientists

1. Dittmar, Thorsten Florida State University, Dep. of Oceanography, Tallahassee, Florida, USA (2 month in 2005)
2. Jung Hee Levialdi Ghiron, Marine genomics fellowship for women Study on phylogenetic relationships among-and cryptic diversity within Pseudo-nitzschia, Stazione Zoologica Anton Dohrn Villa Comunale 80121 Naples Italy, 30.04. 2005-11.06.2005

3. Kosobokova, Ksenia Shirshov Institute of Oceanology, Moscow 1,5 month a year from 2004- to 2006
4. Montresor, Marina Stazione Zoologica "A. Dohrn", Naples/Italy, Nov. 28th - Dec 3rd 2005
5. Pasternak, Anna Shirshov Institute of Oceanology, Moscow
6. Richard Lee, Skidaway Institute of Oceanography, Savannah, USA (3 month in 2004, 2 month in 2005) in connection with the Hanse Wissenschaftskolleg
7. Ying Wu, East China Normal University, State Key Laboratory of Estuarine and Coastal Research, Shanghai, China (3 month in 2004)
8. Yuishiro Yamada, Ocean Research Institute, University of Tokyo, Japan (1 month in 2005; 1 year in 2006)
9. Zhuoyi Zhu, East China Normal University, State Key Lab. of Estuarine and Coastal Research, Shanghai, China (2 month in 2005)

List of third party funding projects

1. BMBF Krill Verbund Project 1.3 Mill. € (Prof.Dr.U. Bathmann)
2. DAAD exchange with Argentinia (Dr. B. Meyer)
3. DAAD exchange with Australia (Dr. B. Meyer)
4. DAAD, PPP Norwegen: Lipids in an Arctic marine food chain represented by the ctenophores Beröe cucumis and Mertensia ovum. Partners: Haakon Hop, Stig Falk-Petersen, Norsk Polar Institute (2.420 € in 2005; 2.420 € in 2006,) (Dr. M. Graeve)
5. DAAD, PPP USA: Molecular characterization of sources and formation processes of marine dissolved organic matter. Partners: Thorsten Dittmar, Bill Cooper, Florida State University (7.000 € in 2005; 7.000 € in 2006) (Prof. Dr. G. Kattner)
6. DFG Antarctic Research Krill Model A 25.312 (Dr. B. Fach)
7. DFG Antarctic Research Krill Model B 63.918€ (Dr. B. Fach)
8. DFG Antarctic Research on polar Prymnesiophyte spezies Phaeocystis antarctica" 28.560€ (Dr. L. Medlin)
9. DFG Antarctic Research. Key factor 60.756,00 (Dr. B. Koch)
10. DFG (Postdoc + extras) 13.320€ für 3 Jahre (Dr. B. Fach)
11. DFG project: Salps in Antarctic ecosystems (1 PhD + extra) (Prof.Dr.U. Bathmann)
12. DFG travel fund, ASLO conference, Santiago/Spain (Drs. P. Assmy u. J. Henjes)
13. DFG workshop grant: Marine zooplankton lipid workshop in Delmenhorst, Germany (6.270 €) (Dr. M. Graeve)
14. DFG, Antarktis-Schwerpunkt: Microbial-derived dissolved organic matter in the polar environment - a key factor for global carbon flux? (1 year Postdoc) (Dr. Boris Koch)
15. DFG, Antarktis-Schwerpunkt: Refraktäre gelöste organische Substanzen im Ozean: Bildungsprozesse unter marinen antarktischen und kontinental beeinflussten arktischen Bedingungen (3 years Postdoc) (Prof. Dr. G. Kattner)
16. DFG, und China: Gastaufenthalt von Dr. Ying Wu (6.900 €,)
17. EU DIATOMICS 133.091€ (Dr. L. Medlin)
18. EU MARINE GENOMICS 200.000€ (Dr. L. Medlin)
19. EU MARPLAN 700 Euro travel fund, sabbatical at the Stazione Zoologica "A. Dohrn", Naples/Italy (Dr. P. Assmy)
20. HWK workshop grant: Marine zooplankton lipid workshop in Delmenhorst, Germany (4.000 €) (Prof. Dr. S. Schiel)
21. WTZ-IB mit Argentinien 9.200€ (Dr. B. Meyer)
22. WTZ-IB project South Africa 16123€ (Dr. B. Meyer)
23. WTZ-IB, Argentinien: Food web structure at Potter Cove, Antarctica. Partner: Ricardo Sahade, University of Cordoba (5.520 €) (Dr. M. Graeve)
24. WTZ-IB, China: Terrigenous molecular tracers in contrasting marine environments. Partner Ying Wu, East China Normal University (Prof. Dr. G. Kattner)

List of expeditions

1. ANT 21/1
2. ANT 21/3 EIFEX
3. ANT 21/4 LAKRIS autumn
4. ANT 22/2 ISPOL
5. ANT 22/4
6. ANT 23/2 LAKRIS summer

7. ARK 20/1
8. ARK 21/1b
9. KOP 92-2005
10. KOP 92-2006

List of external co-operatons

1. Australian Antarctic Division, krill and zooplankton studies, personal exchange PI + PhD, Dr. Steve Nicol, Dr. Graham Hosie
2. Biochemical Oceanography, Villefranche Sur Mer, France, Patrick Mayzaud, Prof. Luis Legendre
   British Antarctic Survey, Dr. E. Murphy
3. East China Normal University, State Key Lab. of Estuarine and Coastal Research, Shanghai, China, Ying Wu, Jing Zhang, Zhuoyi Zhu,
4. Florida State Univ., Dep. of Oceanography, Tallahassee, USA, Thorsten Dittmar,
5. GSF, Neuherberg, Germany, Norbert Hertkorn, Philippe Schmitt-Kopplin,
6. Institut de Ciencies del Mar, Barcelona, Spain, Dr. Renate schark, Dr. M. Lakassa
7. Limnological Institute, Siberian Branch of the Russian Acadmy of Sciences, Irkustk, Russland 1995-2007, Dr Yelena Likhoshway,
8. Max-Planck-Institut für Marine Mikrobiologie, Bremen, Germany, Jens Harder,
9. National Research Institute of Fisheries Science, Yokohama, Japan, Hiroaki Saito,
10. Natural history Museum, London. 1990-2007, Miss Pat Sims,
11. Norsk Polar Institute, Tromsø, Norway, Stig Falk-Petersen, Haakon Hop, Prof. Paul Wassmann
12. Shirshov Institute of Oceanology, Moscow, Dr. Ksenia Kosobokova,
13. Skidaway Institute of Oceanography, Savannah, USA, Richard Lee,
14. Stazione Zoologica "A. Dohrn", Naples/Italy, diatom studies, personal exchange
15. Univ. Brest, Prof. P. Treguere
16. Univ. British Columbia, Prof. Evgeny Pakhomov
17. Universität Bremen, Marine Zoologie, Bremen, Germany, Wilhelm Hagen,
18. University of Wales, Bangor (UWB), North Wales, UK, Dr. David Thomas
19. University of Washington, Chemical Oceanography, Seattle, USA, Kenia Whitehead, Susan Lang

List of memberships in national and international committees

Ulrich Bathmann:	IGBP-Project ICED (Integrated Circumpolar Ecosystem Dynamics) scientific steering committee European Polar Consortium – Scientific Advisory Board EPC-SAC German representative in SCOR
Siegried Schiel:	Deutsche Wissenschaftliche Kommission (DWK) ICES Working Group of Zooplankton Ecology (ICES WGZE) Census of Marine Zooplankton (CMarZ), (Steering Group and European secretariat)
Linda Medlin:	1998-now: SCOR subcommittee on evolutionary biology of Antarctic organisms 1999-now: Algal commission for molecular biology and evolution of the Algae, Göttingen Algae collection 1999-2005: SCOR working group on Phaeocystis 2003-now: Journal of Plankton Research, editorial board WKNCT, Oceanography Committee and Baltic Committee. Phycological Society of America Award of Excelllence Committee.

Workpackage POL6: Earth climate variability since the Pliocene

(Spokesman: Dr. Rainer Gersonde)

Academic results

Central to the studies in POL6 is the generation and inter-correlation of well-tuned climate records from polar continental ice, permafrost, lake and marine sediments to document past climate change at seasonal to millennial time scales. The combination of marine, atmosphere and land data is needed to decode mechanisms driving and amplifying Earth's climate variability, an essential prerequisite for the establishment of realistic numerical simulations of past and future climate and sea level development.

Paleoclimate reconstructions from polar ice cores concentrated on the two multinational deep ice core drilling projects, the North Greenland Ice Core Project (NGRIP) and the European Project for Ice Coring in Antarctica (EPICA), which both achieved milestone results in ice core research. With the NGRIP ice core it became for the first time possible to reconstruct Greenland temperatures of the penultimate interglacial, the Eemian. Based on the stable isotope record it was revealed that the Eemian was approximately 5°C warmer than today. The high annual layer thickness of the NGRIP ice core also allowed for climate reconstruction in unprecedented resolution over the last glaciation. The EPICA Dome C (EDC) ice core, located in the Indian Ocean sector of Antarctica, extended the time interval covered by ice core records for the first time to more than 740,000 years, a near doubling versus the previous record, from the Vostok core. The most enigmatic features of the new EDC record are the lukewarm interglacials encountered in the time interval 740,000-450,000 years BP, which are significantly cooler than our current interglacial, the Holocene. This is also supported by sea salt and mineral dust aerosol records from Dome C showing a reduced glacial/interglacial amplitude at that time. In contrast, marine biogenic sulfur shows no significant variation in the biogenic production of marine sulfur aerosols over the last 800,000 years. Based on the analogue of Marine Isotope Stage (MIS) 11, a warm period at around 400,000 years BP, we estimate that (even without human interference) our current warm period would last for another 15,000 years. High-resolution analysis of glacial terminations reveals a slight decoupling between temperature in central East Antarctica and dust, revealing tight sensitivity of this proxy to the whole process of deglaciation that occurred at high Southern latitudes, involving sea ice, atmospheric circulation, as well as climate and environmental conditions on land. The second EPICA drilling, carried out by AWI in Dronning Maud Land (EDML), provides the first deep ice core from the Atlantic sector of Antarctica. Preliminary dating of the basal ice at EDML yields an age of around 350,000 years BP. The EDML core represents a direct Antarctic counterpart to the Greenland ice core records and provides high-resolution climate records over the last 80,000 years. This allows for the first time to document the one-to-one connection, via the bipolar seesaw, of all Dansgaard-Oeschger events in Greenland and the slower Antarctic warmings. The highly synchronized time scales of the records reveal that all major climatic changes led to synchronous changes of dust flux for EDML and EDC. This, coupled with the fact that the ratio of dust concentration at EDML and EDC is moderately variable (i.e. by a factor of 3), suggests that either different dust source areas varying independently in strength exist for the two sites or that atmospheric transport efficiency from one source to the two sites varies in time.

Marine climate records have been generated on Holocene and Pleistocene sediment sections from the Arctic Ocean, the Sea of Okhotsk, the Pacific and Atlantic sectors of the Southern Ocean and the Nordic Seas. Our study of Ocean Drilling Program (ODP) Leg 177 sedimentary sequences from the Atlantic sector of the Southern Ocean provides the first records documenting Holocene and Pleistocene climate variability at high-resolution over the past 650,000 years from a transect across the Southern Ocean. The reconstructed parameters include sea surface temperature, sea ice extent, nutrient utilization, and changes in biological productivity and carbon export. The records represent ideal marine counterparts to the climate records obtained from the ice cores. Sea surface temperature records of the past 650,000 years compare remarkable well with atmospheric temperatures obtained from Antarctic ice cores (e.g. EDC), including the shift from lower to higher interglacial temperature regimes 450,000 years ago. This supports the use of temperature for the correlation of marine and ice core records. The reconstructed extents of maximum winter and summer sea ice coincide with coldest ice core temperatures and increased dust deposition. Sea ice is a major player in global climate development because of its impact on planetary albedo, oceanic water mass production and atmospheric CO_2 concentrations. The Antarctic sea ice field expanded during glacials to twice its present extent, restricting atmosphere/ocean exchange, enhancing glacial dust generation, and acting as a storehouse of dust-Fe for seasonal release into a stratified water column, which

launched a biological productivity regime characterized by high carbon export efficiency. The high-resolution studies combining marine and ice core records document the in- and out-of-phase periods of northern and southern high latitude climate development that can be related to the complex interplay of processes involving insolation, physical properties of the water column and water mass circulation (e.g. via melt water injections), atmospheric circulation and biological export of organic carbon. This results in non-uniform amplitudes and sequences of events at the glacial/interglacial transitions and hemispheric/regional differentiation of climate development. We documented an unexpected glacial increase of Agulhas Current activity around 350,000 years ago, which allowed intensified Agulhas spillover into the Atlantic, flushing the glacial South Atlantic Ocean with heat previously accumulated in the Indo-Pacific tropics. Further enhancement of the understanding of the complex bipolar processes comes from our study of new sediment cores recovered 2005 during Integrated Ocean Drilling Program (IODP) Leg 306 at key locations in the North Atlantic. These records represent a benchmark to extend the present knowledge of North Atlantic millennial-scale climate variability over the last few million years. The studies done in the Atlantic are now extended to the little explored Pacific polar regions. This work started with paleoceanographic reconstructions of Pleistocene sediments in the eastern Pacific sector of the Southern Ocean, the preparation of future marine-geological cruises with RV *Polarstern* and RV *Sonne* to the southern and northern polar Pacific, and the generation of an IODP proposal (#625) for the drilling of high-resolution Pleistocene and Neogene records in the Pacific Southern Ocean.

Reconstruction of the landscape development and permafrost dynamics in the northern-hemispheric periglacial realm focused on climate-sensitive key regions in eastern Siberia and permafrost tunnels in Barrow (Alaska). The latter for the first time document the winter climate amelioration from the Bølling-Allerød to the Younger Dryas cold event. Paleoecological and geocryological studies on permafrost sections exposed along the Arctic Laptev Sea coast of Yakutia show that permafrost aggradation prevailed during the cold stages of the past 200,000 years, while the Eemian and the Holocene warm stages were characterized by permafrost degradation. First results of an offshore drilling transect in the Western Laptev Sea (COAST I) clearly show the existence of up to 100 ka old terrestrial permafrost in the near-shore zone of the Laptev shelf. Seismic investigations of the deposits and crater structure of Lake El'gygytgyn (Chukotka) exhibit up to 420m of undisturbed sediments of the last 3.6 Mio years. The results formed an important input to a successful proposal for deep drilling within the framework of the International Continental Drilling Program (ICDP). Physical properties of a 16m long core from the lake show a complex record of sedimentary events derived from slope failure superimposed on climatically induced cycles of the last 300,000 years. Permafrost drill cores and ground-ice features in frozen ground from the impact crater rim of Lake El'gygytgyn yielded insights into climate-related slope dynamics during the late Pleistocene-Holocene. The reconstruction of ancient slope stability is essential for the interpretation of sediment records from Lake El'gygytgyn, to be accomplished in the frame of IDCP. The paleoenvironmental investigation of lake sediment and peat records, and ice wedges in central Yakutia (eastern Siberia) point to pronounced climate variations during the past 10,000 years (Holocene). The period between 8,000 and 4,500 years before present was characterized by less severe winters and warmer summer temperatures than today. Marked fluctuations of thermokarst lake levels document repeated changes in summer humidity. This variability is likely related to high-frequency seesaw effects and teleconnections in the global climate system (e.g. Arctic Oscillation, sun-spot cycles). The effort to significantly increase our knowledge of polar Holocene climate development is augmented by the study of an ice core recovered from the Akademii Nauk ice cap (Severnaya Zemlya) that began to accumulate only after a warm period about 2,700 years ago and thus documents climate evolution during historic time at high sensitivity. After a warming around 400 BC, coldest temperatures were reached around 1800 AD, the late "Little Ice Age". The stable isotope derived temperatures calibrated with a 150-year air temperature record from northern Norway (Vardø) indicate a 1.6°C temperature increase since 1800 AD until the 1930s.

As part of the ESF Program EUROMARGINS the extent of the Yermak Slide at the Svalbard continental margin (Arctic Ocean) has been revised based on new echo sounding and bathymetric data. With an affected area of at least 10,000 km^2 and more than 2400 km^3 involved sedimentary material this megaslide ranges among the largest exposed submarine slides worldwide, comparable to the Storegga Slide off central Norway. AMS^{14}C dating places the main slide event around 30,000 years BP, which coincides with the build-up phase of the Svalbard-Barents Sea Ice Sheet (SBIS).

State of achievements of deliverables

1. Generation of polar climate proxy time series at millennial to decadal resolution covering the past 8 climate cycles (past 800 ka) and selected time slices

- Climate proxy time series (stable isotopes, dust, sea salt, marine biogenic and volcanogenic sulfur) at millennial to decadal resolution based on **polar ice cores** (EDML, EDC, NGRIP, Severnaya Zemlya) have been reconstructed for up to 8 climate cycles (past 800 ka).
- Climate proxy time series (e.g. sea surface temperature, salinity, sea ice, nutrient utilization, marine productivity, terrigenous input, ice rafted debris) at millennial to centennial resolution based on **marine sediment cores** from the Atlantic and Pacific sector of the Southern Ocean, the Arctic Ocean, the Sea of Okhotsk have been reconstructed for up to 650 ka. These studies will be further extended in the Pacific and Indian sectors and the Scotia Sea.

- **Lake sediment records**: Between 2003 and 2005, limnoecological studies were made in Central Yakutia (East Siberia) to characterize sedimentary and biogenic responses to modern climatic and limnological summer conditions. The goal is to establish statistical transfer functions, which can be used for the quantitative reconstruction of vegetation history, summer temperatures, and hydrological conditions derived from long sediment cores. Several sediment cores for late Pleistocene to Holocene age were recovered from thermokarst lakes and deep mountain lakes.

- **Permafrost sequences:** Along the East Siberian Laptev Sea coast, ground-ice-bearing sedimentary sections were studied by a multi-proxy approach, covering the late Quaternary since the Eemian warm stage. Sedimentological data and fossil bio-indicators (pollen, plant macro fossils, ostracods, chironomids) were used to infer paleoecological summer conditions, vegetation history, and the regional periglacial landscape development. The stable-isotope geochemistry of ground ice provided data on former winter climate conditions.

2. Generation of data sets documenting the behaviour of the polar ice sheets during glacial and interglacial periods

Estimation of surface water salinity (based on combined oxygen stable isotope and surface water temperature records from diatoms) and ice-rafted debris (IRD) deposition in Pleistocene sediments from the Indian, Atlantic and Pacific sector of the Southern Ocean was used to establish insight into the stability of Antarctic ice during glacial and interglacial periods. Preliminary results show strong melt water deposition not only at glacial terminations but also during glacial maximum conditions.

3. Collection of seismic and bathymetric data and sediment cores from the Pacific and Atlantic sectors of the Southern Ocean, and from the Arctic Ocean for palaeoceanographic investigations and the generation of deep sea (IODP) drilling proposals

- During IODP Expedition 306 (2005), new sites were drilled at key locations in the **North Atlantic**. The preliminary data indicate that glacial/interglacial and submillennial cycles of excellent quality are preserved in these sediments, allowing for detailed research on high-resolution environmental variability (e.g. ice-sheet-ocean interactions, deep circulation changes, sea-surface conditions) over the last few million years. These records are similar to those obtained from the Southern Ocean (ODP Leg 177) and give the chance for studying the Northern-Southern Hemisphere interrelationship in short-term climate variability together with the polar ice core records.
- During RV Polarstern expedition ANT-XXII/4 (2005) systematic multi-beam and sub-bottom profiler mapping in **the Scotia Sea** provided excellent sampling sites for long piston cores with high resolution Holocene and Late Pleistocene sediment sequences for studies of the evolution, spatial, and temporal variations of the Antarctic Circumpolar Current.
- New seismic, sub-bottom profiler and multi-beam data were acquired from the **Amundsen Sea and the Pine Island Bay** area in early 2006 during RV Polarstern expedition ANT-XXIII/4. The data will be used together with analyses of sediment cores for reconstructing the glaciation/deglaciation history of the highly dynamic West Antarctic ice-sheet.
- RV Sonne expedition SO178 (2004) recovered new Holocene and Pleistocene records in the **Sea of Okhotsk** used for reconstruction of the marine paleoenvironment and land-ocean climate connections
- The **IOPD proposal** Cenozoic **Southern Ocean Pacific** (CESOP, #625-Pre2, Gersonde et al. 2005) has been rated by the IODP evaluation panels as scientifically unique. The preparation of a full proposal including bathymetric, seismic and sediment survey data has been highly recommended. The proponents have submitted further proposals for RV Sonne (SOPATRA), RV

Marion Dufresne (COPASO) and RV Polarstern (HIPAS, TecSed-HIPAS) to collect the requested pre-site survey and paleoceanographic data in the Pacific sector.

4. Drilling of new ice cores from Greenland and Antarctica

In **Antarctica** the EPICA-DML ice core project reached bedrock in January 2006 (depth: 2774 m). New shallow ice cores were drilled to reconstruct the temperature history over the last millennium from the borehole temperature and to study the process of air entrapment in polar ice at low accumulation sites. In cooperation with the Antarctic Research Centre at the Victoria University, Wellington, New Zealand, two shallow ice cores (200 m) were drilled on the Evans Piedmont Glacier and the Mount Erebus Saddle in the Ross Sea area.

5. Generation of new proxies for palaeoclimate reconstruction.

- Periglacial land and lake environments: New approaches in paleontological methods were directed towards the establishment of modern ecological reference data sets for pollen, diatoms, ostracods, and plant macro remains in Central Yakutia, as a basis for the reconstruction of palaeoecological conditions. A new geochemical proxy tool for the inference of palaeo lake temperatures and hydrology is being developed by the application of stable-isotope signals in fresh-water diatoms from Siberian and Greenland lacustrine sediment records. Progress was achieved by using geocryological methods for the monitoring of modern ice-wedge formation processes. The calibration of stable-isotope signals in modern ice wedges against modern climate data serves as a tool for the quantitative reconstruction of precipitation sources and winter temperatures in the past ("paleothermometer"), as derived from fossil ice wedges.

- Facilities have been set up for measuring **δ^{30}Si, δ^{15}N, and δ^{13}C of biogenic opal** and isolating specific biological fractions (e.g., centric versus pennate diatoms) from sediments. In the next 2 years, the first opal stable isotopic records of silica cycling will be generated based on these more specific biological fractions, eliminating isotopic variability associated with shifts in species composition and giving a clearer picture of silicic acid use and Si to N uptake ratios of diatoms in the Southern Ocean over glacial interglacial cycles and with the climatically variable availability of the micronutrient, iron.

Personnel

Personnel	Institutional funding	Third party funding
	Scientists / PhD / Technicians	Scientists / PhD / Technicians
AWI	12 / 5 / 8	11 / 4 / 3

Publication outcome numbers

Academic Publications Refereed only	2004-2006
ISI	88
non ISI	29
PhD theses	3
Master & Diplom Theses	2
Books	2
Book chapters	8

Key publications

1. EPICA, community members, 2004. Eight glacial cycles from an Antarctic ice core, Nature, 429, 623-628. Nature, 440, 491-496, doi:10.1038/nature04614
2. North Greenland Ice-Core Project members, 2004. High-resolution record of the Northern Hemisphere climate extending into the last interglacial period, Nature, 431, 147-151.
3. Wolff, E. W., Fischer, H., Fundel, F., Ruth, U., Twarloh, B. et al., 2006. Southern Ocean sea-ice extent, productivity and iron flux over the past eight glacial cycles, Nature, 440, 491-496, doi:10.1038/nature04614
4. Kienast, F., Schirrmeister, L., Siegert, C., Tarasov, P.(2005). Palaeobotanical evidence for warm summers in the East Siberian Arctic during the last cold stage, Quaternary Research, 63(3), 283-300.

5. Bianchi, C., Gersonde, R., 2004. Climate evolution at the last deglaciation: the role of the Southern Ocean. Earth and Planetary Science Letters 228, 407-424

List of guest scientists

1. Bolshiyanov, Dmitry, AARI, St. Petersburg, 05.02. - 04.03. 04, 17.01 - 16.02.05, 24.01 – 23.02.06 (AWI)
2. Bobrov, Anatoly, Moscow State UniverityUniversity, 15.04. - 15.07. 04 (DFG)
3. Derevyagin, Alexander, Moscow State University, 10.02. - 10.03.04, 24.01 - 23.02.06 (DFG)
4. Dorofeyuk, Nadezhda, Moscow State University, 02.02 - 30.04.06 (DFG)
5. Fedorov, Grigory, AARI, St. Petersburg, 12.03. -12.04.2004, 01.06. - 31.08.2005 (DFG)
6. Heuser, Heather, University of Washington, Seattle/USA, 15.11. - 20.12. 05 (AWI)
7. Kalugin, Ivan, RAS, Inst. Geol., Novosibirsk, 08.11.04 - 07.02.05 (DFG)
8. Kholodov, Alexander, RAS, Institute of Soil Science Pushchino, 01.11 - 31.12.05 (INTAS)
9. Khursevich, Galina, Moscow State University, 10.10. - 10.12. 04, 09.11. - 09.12.05 (DFG)
10. Kunitski, Viktor, RAS, Permafrost Institut Yakutsk, 10.02. - 10.03.04 (BMBF), 23.01. – 23.02.2006
11. Kuznetsova, Tatiana, Moscow State University, 07.10. - 06.11. 04 (BMBF), 23.03 - 30.04.06 (DFG)
12. Matul, Shirshov Institute of Oceanology, Moskow, 22.03.-20.05.2004, 11.10.-09.12.2004, 19.9.-17.12. 2005 (AWI)
13. Minyuk, Pavel, NEISRI, Magadan, 06.03. - 05.04.2004 (DFG)
14. Nazarova, Larissa, Kazan State University, 01.01.05 - 31.05.06 (Humboldt Foundation)
15. Pestryakova, Ludmila, Yakutsk State University, 18.03. - 01.05. 04, 03.03 - 28.04.06 (AWI)
16. Razina, Victoria, St. Petersburg State University, 10.12. - 20.12.05 (AWI)
17. Rudaya, Natalia, RAS, Institute of Archeology and Etnography, Novosibirsk, 01.09.05 - 31.05.06 (DAAD)
18. Spektor,Valentin, RAS, Permafrost Institute Yakutsk, 06.12. - 31.12. 04 (DFG)
19. Subetto, Dmitry, RAS, Inst. Limn., St. Petersburg 01.09. - 30.11. 04 (DAAD)
20. Xingqi, Liu, CAS, Institute of Limnology and Geography, 03.01. – 28.02.06 (AWI)

List of running/accepted third party funded projects contributing

1. „Climate variations in Antarctica since the last glacial maximum using stable isotope records (2H, 18O) of the EPICA ice core from Dronning Maud Land“, DFG, H. Oerter (OE 130/5-1,2), 1.7.2003 - 30.6.2005, 95.000,-€
2. „Investigating and revealing the nature and origin of electromagnetic reflections in polar ice by combinations of numerical forward modeling techniques, ice core measurements, and radar field surveys“ DFG, F. Wilhelms (WI 1974/2-1), 11.12.2003-10.12.2004, 45.000,-€
3. „KOMEX II Kurilen Ochotskisches Meer Experiment (BMBF-Verbundvorhaben 03G0568A), TP 5: Kieselige Mikrofossilien im Ochotskischen Meer – Ökologische und biogeochemische Aspekte für paläozeanographische Rekonstruktionen in polaren Meeresgebieten“, BMBF (Förderkennzeichen: 03G0568C), TP proponent: A. Abelmann, 01.06.01-31.05.04, 139.057,- €
4. „Sediment dynamics of megaslides along the Svalbard continental margin“, DFG, R. Stein, 2003-2006, 150.000,-€
5. „Short-term variability of sea ice and surface-water characteristics in the Late Neogene North Atlantic Ocean: A biomarker approach“, DFG, R. Stein, March 2006-2008, 100.000,- €
6. „SO-182 AISTEK-I: Südöstlicher Atlantik und südwestlicher Indik: Rekonstruktion der sedimentären und tektonischen Entwicklung seit der Kreide. AISTEK-I: Agulhas Transect”, BMBF, G. Uenzelmann-Neben, 01.03.2005-31.05.2007, 247.369,- €
7. “Cenozoic development of the depostitionaldepositional environment in the northern Cape Basin in relation to the Initiation of Northern Hemisphere Glaciation,”, DFG, G. Uenzelmann-Neben, 22.07.2004- 21.07.2007, 62.864,- €
8. “Biogenic silica in the Southern Ocean and adjacent ocean marginal sediments. Biogeochemical processes, budgets, and temporal variations”, DFG Research Centre FZT 15 (RCOM) Project B4, R. Gersonde, M. Schlüter, 1.7.2001-30.6.2005, 360.000,-€
9. “Linking high to low latitude nutrient cycling to Quaternary climate cycles: a joint geochemical-paleobiological process study”, DFG Research Centre FZT 15 (RCOM) Project B4, R. Gersonde, C. De La Rocha, 1.7.2005-20.6.2009, 370.000,- €

10. “Innovatives Nordpazifik Experiment (INOPEX)”, BMBF RV Sonne cruise, R. Gersonde, ?2009-2010, ca. 1.550.000;- €
11. “Enhanced palaeoreconstruction and integrated climate analysis through marine and ice core studies (EPICA-MIS)”, EU 6th Framework, Workpackage 8 Carbon cycle and paleoproductivity, R. Gersonde, 1.12.2004-30.11.2007, 119.000,-€
12. “Siliceous Paleoceanography at Pleistocene Glacial/Interglacial Transitions in the Southern Ocean: a combined Micropaleontological and Stable Isotope Approach”, German-Israeli Foundation for Scientific Research and Development (G.I.F. grant G-649-154.8/1999), R. Gersonde, 1.1.2001-31.12.2004, 67.000.- €.
13. Prozessstudie zur Dynamik des Permafrostes in der Laptevsee, TP Stadien der Permafrostentwicklung, BMBF FKZ 03G0589, H.-W. Hubberten, 1/2003 –12/2005, 53.916.- €.
14. Permafrost im periglazialen Umfeld des El´gygytgyn-Sees (BMBF-Verbundprojekt FKZ 03G0586A, Sedimentation im El´gygytgyn-See (NO-Sibirien) seit dem Pliozän - Vorstudie für eine angestrebte Tiefbohrung im Rahmen des ICDP), BMBF, H.-W. Hubberten, 2/2002-12/2005, 207.673,- €.
15. Quartäre Vegetationsentwicklung und Klimarekonstruktion in Nordsibirien anhand botanischer Großreste aus Permafrostsequenzen (Quaternary Vegetation history and climate reconstruction in North Siberia using botanical macro remains in permafrost sequences); DFG; F. Kienast, 1/2004-1/2007, 188.774,- €
16. Interstadiale und interglaziale Perioden der spätquartären Umweltgeschichte der Arktis rekonstruiert aus Bioindikatoren in Permafrostsequenzen NE-Sibiriens *(Interstadial and interglacial periods of the Arctic Late Quaternary environmental history reconstructed from bioindicators in permafrost sequences of NE Siberia)*; DFG; L. Schirrmeister, 4/2006 – 3/2008, 120.000.- €
17. "Developing and maintenance of the observational network of the Subarctic Scientific Center as the base for educational and scientific activity in environmental studies in Western Siberia", H. Meyer, INTAS IA 04-87-689, 6/2005 – 5/2007, 43.400,- €.
18. Jungquartäre Klima- und Landschaftsentwicklung im Werchojansker Gebirge und in der Zentraljakutischen Tiefebene (*Late Quaternary Climate and Landscape Development in the Verkhoyansk Mountains and the Central Yakutian Low Lands*). DFG; Prof. Dr. H.-W. Hubberten und Dr. Bernhard Diekmann, 6/2002-5/2005, 106.280,- €.
19. “East Antarctic Ice-Sheet Dynamics during the late Quaternary inferred from marine sediment records of the Indian sector of the Southern Ocean”. DFG; B. Diekmann, DFG, endorsed by DFG Antarktis-Schwerpunktprogramm
20. “Permafrost im periglazialen Umfeld des Elgygytgyn-Sees und geophysikalische Erkundung der Sedimenttfüllung im Elgygytgyn-See und der Kraterstruktur”. BMBF-Verbundvorhaben, H. Hubberten, F. Niessen, 10/2002 – 12/2005, 516.000,- €.
21. “Three-dimensional geometry and quantification of the sedimentary fill of Lake El’gygytgyn (Chukota, NE Siberia)”. DFG, C. Gebhardt, 2/2006 – 1/2007, 51.000,- €.

List of expeditions (scientists/students)

North polar

1. ARK-XX/3, RV Polarstern, 31.08.-03.10.04, Fram Strait/Yermak Plateau/East Greenland continental margin, (2/1)
2. IODP Leg 306, JOIDES Resolution, 03.03.-26.04.05, North Atlantic, (2/0)
3. SO178, RV Sonne, Mass exchange processes and balances in the Okhotsk Sea, 22.7.-15.9.04, Pusan, Vladivostok, Sea of Okhotsk, Vladivostok, Pusan, Jakarta, (1/0)
4. ALASKA 2004/1, 20.04 -11.05.2004, Fairbanks, Barrow, (3/0)
5. YAKUTIAN LAKES 2004, 15.07 - 10.08.2004, Yakutsk area, (1/1)
6. Yakutsk-Tiksi 2004, 16.08.-09.09.04, Yakutsk area, Lena Delta, (1/0)
7. YAKUTIAN LAKES 2005, 05.04 - 08.05.2005, Yakutsk, Verkhoyan Mountains, (2/0)
8. CENTRAL Yakutia 2005, 03.07 – 28.08.2005, Central Yakutia, Verkhoyan Mountains, (2/1)
9. LENA DELTA 2005/2, 01.08 - 07.09.2005, western Lena Delta, (3/1)
10. LENA DELTA 2005/3, 01.08 - 07.09.2005, Central Lena Delta, (1/0)
11. ALASKA 2006, 18.04 – 08.05, Fairbanks, Barrow, (2/0)

South polar

12. EPICA-DML, 1 Dec. 2003 -– 16 Feb. 2004, Dronning Maud Lland (Antarctica), (7/2)
13. EPICA-DML, 6 Nov. 2005 -– 7 Feb. 2006, Dronning Maud Lland (Antarctica), (9/1?)

14. Evans Piedmont Glacier, 10 Oct. 2004 -– 15 Dec. 2004, (Antarctica), (1/0?)
15. ANT-XXII/4, RV Polarstern, 8 Apr -22 May 2005, Scotia Sea, (2/0)
16. ANT-XXIII/4, RV Polarstern, 10 Feb - 11 Apr 2006, Amundsen Sea and Pine Island Bay (West Antarctica), (2/0)
17. SO-182, RV SONNE, 4 Apr – 18 May 2005, Kontinentalrand, Transkei-Becken (Südindik) **(**2/2)

List of external co-operations

1. Université de Quebéc á Montréal (Anne de Vernal)
2. Tongji University, Shanghai (P. Wang)
3. Univ. Bordeaux (Xavier Crosta)
4. Fraunhofer Institut für Techno- und Wirtschaftsmathematik, Kaiserslautern (K. Schladitz)
5. Freie Universität Berlin, Institute of Geoscience, (Frank Riedel, Pavel Tarasov)
6. Geopolar, University Bremen (B. Zolitschka)
7. Geoscience Center, University of Göttingen (H. von Eynatten)
8. Humboldt University Berlin, Institute of Geography (Wilfried Endlicher)
9. IfM-Geomar, Kiel (Henning Bauch, Heidemarie Kassens)
10. Institute for Analytical Sciences, Berlin (Christian Lüdke)
11. Institut für Umweltphysik, Universität Heidelberg (I. Levin, D. Wagenbach)
12. Leipzig University, Institute of Geography (Jürgen Heinrich)
13. Leibniz Laboratory for age determination and isotope studies, Kiel (Piet Grootes)
14. RWTH Aachen, Institute of Geography (Frank Lehmkuhl)
15. Saxonian Academy of Science (Matthias Krbetschek)
16. University Bremen (Thomas Frederichs, Thilo von Dobeneck, Christoph Vogt)
17. University Hamburg, Institute of Soil Science (Eva-Maria Pfeifer)
18. Univ. Leipzig, Geowissenschaften, Leipzig (Werner Ehrmann, Martin Melles)
19. Weizmann Institute of Science, Rehovot (Aldo Shemesh)
20. Nagaoka University of Technology (N. Azuma)
21. Korea Institute of Geology and Mineral Resources (Seung-Ill Nam)
22. Univ. Utrecht (Henk Brinkhuis)
23. University of Bergen (U. Ninnemann)
24. Norges Geologiske Undersøgelse, Trondheim (Jochen Knies)
25. Norsk Polar Institute, Tromsø (N. Koc)
26. Univ. Tromsø, Department of Geology, (Forwick, Matthias, Mienert, J.)
27. Antarctic Research Centre, Victoria University, Wellington (N. Bertler)
28. Academy of Science / Siberian Branch (TSOGU), Tyumen (Anna Nikolaevna Kurchatova)
29. Arctic and Antarctic Research Center St. Petersburg (Dimitri Bol'shiyanov)
30. Moscow State University, Geological Faculty (Tatyana Kuznetsova)
31. Pacific Oceanological Institute, Vladivostok (S. Gorbarenko, A. Salyuk, V. Soshnin)
32. Permafrost Institute Yakutsk, Russian Academy of Science (Victor Kunitski)
33. Shirshov Institute of Oceanology, Moskow (Alexander Matul)
34. Yakutsk State University, (Paraskovya Gogoleva, Ludmilla Pestryakova)
35. Department of Geology, University of Salamanca (Jose-Abel Flores)
36. British Antarctic Survey, Cambridge (Claus-Dieter Hillenbrand, Joann Johnson, Robert Larter)
37. University College London (Mike Kaminski)
38. International Permafrost Association, Woods Hole (Jerry Brown)
39. Lamont Doherty Earth Observatory, Palisades, (R. Anderson, S. Goldstein, G. Winckler)
40. University of Massachusetts, USA (Mark Altabet)
41. University Washington, USA (A. Ingalls, Ron Sletten)
42. University of Alaska, Fairbanks (Kenji Yoshikawa)
43. EPICA and EPICA-MIS community
44. NGRIP community
45. TalDice community

<u>List of co-operations in MARCOPOLI</u>

1. MAR1 and MAR2 have internal linkages to POL6 by making use of the climate proxy data for modelling work.
2. POL 6 and MAR 2 are closely linked at the transition and comparison from young to older (Tertiary) time-scales for climate change processes.

3. POL6 marine environment reconstructions are closely based on the study of physical and biological processes governing the generation of siliceous microfossil signals conducted in POL2
4. The permafrost cores of the offshore drilling transect in the Western Laptev Sea (COAST I) are jointly studied by POL 6 and POL 7/1 scientists
5. Very close connection exists to the additional funding theme NEW KEYS where new quantitative climate proxies in polar ice cores are developed.
6. Close cooperation exists between MAR 1 and POL6 on interactions between mineral "ballast" and sinking aggregates of marine snow and their impact on the biological carbon pump and atmospheric concentrations of CO_2.
7. POL6 and POL1 are linked about the work concerning the chemical composition of aerosols in polar regions.

List of memberships in national and international committees

C. De La Rocha:	Member of ASLO Policy Committee
H. Fischer,	Member of the NGRIP steering committee Head of the EPICA lab consortium working on gases in ice cores Member of the "International Partnerships in Ice Core Sciences (IPICS)" steering committee Initiator of the DFG SPP "INTERDYNAMICS"and member of the INTERDYNAMICS steering group
R. Gersonde:	Member of SCAR Standing Scientific Group on Geosciences (SSG-GS) Member of German Committee for the International Polar Year 2007/08 Member of EPICA-MIS Steering Committee Vorstand DFG Research Center FZT "Ocean Margins-Research Topics in Marine Geosciences for the 21st Century" (RCOM), University Bremen
K. Gohl:	Scientific secretary of German Committee for the International Polar Year 2007/08
H. Hubberten	Member of the Executive Committee of the International Permafrost Association (IPA) Advisory board of the German national committee Permafrost (DNP/IPA)
G. Kuhn:	MASIC national representative (McMurdo ANDRILL Science Implementation Committee)
H. Meyer:	Co-Chair of the IPA working group "Isotopes and Geochemistry of Permafrost"
H. Miller:	Executive of Deutsche Gesellschaft für Polarforschung e.V. German representative in Council of Managers of National Antarctic Programs Member of NAD Nansen Arctic Drilling Program, Site Survey Panel Member of Academia Scientiarium et Artium Europaea Member of Forschungskollegium Physik der festen Erde Member of DFG-Senatskommission für Ozeanographie Member of Kommission für Glaziologie der Bayerischen Akademie der Wissenschaften Spokesman of HGF-Forschungsbereich „Erde und Umwelt", Programm 3 „Meeres-, Küsten- und Polarforschung" Member of SCAR Group of Specialists on Environmental Affairs and Conservation Member of SCAR ad hoc Working Group ANTOSTRAT Member of IASC Working Group on Arctic Glaciology Member of Steuergruppe Satellitenmission GRACE Member of Steuergruppe Satellitenmission CRYOSAT
H. Oerter:	Member of SCAR Standing Scientific Group (SSG) of Physics Member of EPICA Scientific Steering Committee Sekretär Deutscher Landesausschuss SCAR/IASC
R. Stein:	Co-chair of the IODP Science Steering and Evaluation Panel (SSEP)
F. Wilhelms:	Chair of Organizing committee of "11th International Conference on the Physics and Chemistry of Ice PCI 2006, Bremerhaven, Germany, July 23rd–28th, 2006" www.pcice2006.de Co-chair of SC for "6th International Workshop on Ice Drilling Technology" www.idt-workshop.unh.edu

Workpackage POL 7: From permafrost to deep sea in the Arctic

(Spokesman: Prof. Dr. Michael Schlüter)

Academic results

Within the period considered in this report we undertook several expeditions to permafrost regions and coastal areas as the Laptev Sea or Svalbard, to the continental margin of the Barents Sea, and to the deep-sea long-term observatory ("Hausgarten") in the Arctic. Furthermore, technical developments were started for improved data acquisition by e.g. *in situ* techniques and experiments. The data and samples we compiled provide information about coastal dynamics, distribution and stability of subseafloor permafrost layers, formation and fluxes of methane from soils and sediments to the atmosphere and hydrosphere, respectively, and about carbon fluxes to the deep sea and the role of small-scale biogeochemical and physical gradients at the sediment-water interface. As a step towards a joined information analysis, linking e.g. different regional compartments, data were integrated into Geo-Information-Systems (GIS).

A) The role of permafrost coasts in the Arctic system

Ice-rich permafrost deposits of Arctic coastal lowlands are sensible to climatic changes. Coastal erosion and degradation of permafrost play a significant role in the entire Arctic system concerning material fluxes. Remote sensing, GIS-methods and digital terrain models are efficient tools to classify the thermokarst affected costal plain of regions as the Laptev Sea area as well as to quantify the landscape dynamics. Despite the large number of indirect evidences for the existence of Arctic subsea permafrost, its evolution, characteristics and distribution in the nearshore zone are still poorly understood. An offshore permafrost drilling transect was performed in the Western Laptev Sea in April 2005 within the expedition COAST consisting of 5 boreholes from the coast to the offshore zone (12 km off the coast) down to approximately 80 m below sea-level.

The first results clearly show that relict subsea permafrost exists in the nearshore zone of the Laptev Sea. All boreholes encountered frozen terrestrial permafrost deposits. At 12 km distance from the coast, in a water depth of ca. 6 m, the subsea permafrost table is located at approximately 30 m below seabed. According to analyses of Landsat-7 and field data up to 78 % of the coastal plain near the COAST drill transect is affected by permafrost degradation. This thawing result in increasing matter fluxes of sediment, freshwater, and carbon to the hydrosphere and atmosphere, accelerates the coastal retreat, and finally changes of existing biocoenoses. The thermal and simultaneous mechanical destruction of permafrost, called thermo-erosion, results in a massive coastal retreat of several meters per year at Arctic ice-rich permafrost coasts. High-resolution aerial and satellite imagery from 1950-2005 were used for the assessment of coastal retreat rates and coastal dynamics. Based on GIS analyses, the future evolution of such coasts and resulting ecological and economical challenges can be forecasted. Investigations on the fractal characteristics associated with Arctic shoreline are used to correct estimations of circum-Arctic release of organic carbon by coastal erosion.

B) Methane Budgets in Terrestrial and Marine Polar Environments

Methane is produced by microbial activity in soils and sediments which are enriched in organic matter. Furthermore, methane and higher hydrocarbons are delivered from depth along e.g. faults and conduits. Although a significant part of the methane is re-oxidized on by aerobic or anerobic micro-organisms, at sites characterized by fluid flow or by break up of gas hydrates significant amounts of CH_4 might escape to the atmosphere and hydrosphere, respectively. As a step towards a contribution to a methane budget for polar environments we investigated terrestrial areas of the Lena Delta and marine environments off Svalbard and the Håkon Mosby Mud Volcano, located at the Barents Sea continental margin. The later is characterized by fluid and mud flows from depth as well as by the occurrence of gashydrates.

For the understanding and assessment of the recent and future terrestrial carbon dynamics of the Siberian Arctic two expeditions to the Lena Delta – LENA 04 and LENA 05 – were carried out to study the methane fluxes as well as the microbial processes and community structures in permafrost environments. The long-term studies on carbon turnover showed large differences in methane emission from the different permafrost landscapes varying between 1 to 362 mg CH_4 m^{-2} d^{-1}. These differences on the ecosystem-level could be attributed to the different activity of the involved microbial communities as well as of the plant-mediated CH_4 transport. The microbial community composition in the permafrost habitats was analyzed by fluorescence *in situ* hybridization (FISH) and RNA-based approaches, which indicated high cell numbers and a high

diversity for the different investigated microbial groups. For the first time the methane emission was balanced for the whole Lena Delta by using remote sensing and GIS methods. The investigations showed that the annual methane release of the Lena Delta (north of 70° N) amounts to about 80000 tons, which is comparable for instance to the Yukon Kuskokwim Delta located at lower latitudes (south of 65° N). It can be concluded from our results firstly that the Lena Delta represent an important source of atmospheric methane and secondly that the microbial communities in permafrost environments are composed of members of all three domains of life (Bacteria, Archaea, Eukarya), with a total biomass comparable to temperate soil ecosystems.

In the marine environment the Håkon Mosby Mud Volcano (HMMV), located at the continental slope of the western Barents Sea fan, is the only active Mud Volcano reported for high northern latitudes. During the "Polarstern" cruise ARK XIX3b, the HMMV was investigated by several dives with the Remotely Operated Vehicle "Victor6000" owned by the French institute IFREMER. The data obtained during this and former cruises were integrated for spatial analysis into GIS.

A high resolution microbathymetric map with a vertical resolution less than 10 cm was derived during these dives and video streams of the vertical camera were converted into georeferenced mosaics. This provides a detailed image about the spatial distribution of seafloor features as chemoautotrophic bacterial mats and pogonophorans or mud flows. The activity of chemoautotrophic communities regulates the release of methane from sediments into the bottom water. Based on spatial analysis of the georeferenced mosaics different biogeochemical habitats were identified and quantified on a m²-basis. Investigation of the flat area in the centre of HMMV revealed that approximately 16% (115,165 m²) is nearly void of any benthic communities. This area is considered as a region of high methane discharge into bottom water. An area of 5% (38,244 m²), located in the south-eastern part, is densely inhabited by *Beggiatoa* spp. bacteria. The hummocky outer part is colonised dominantly by pogonophoran tube worms (37.3%; 276,121 m²) and only occasional by *Beggiatoa*. Our geochemical and hydro-acoustic observations revealed the discharge of gas hydrate-coated methane bubbles and gas hydrate flakes forming huge methane plumes extending from the seabed in 1250 m depth up to 750 m high into the water column. This depth coincides with the upper limit of the temperature-pressure field of gas hydrate stability. This suggests that a significant portion of the methane discharged as bubbles at the seafloor can reach the upper water column and may be transported towards the surface of the ocean.

C) Benthic diversity and fluxes in the polar deep-sea

One of the hypotheses we follow is that small-scale biogeochemical and physical gradients at the sediment-water interface, to a yet unknown extent, are either influenced or generated by large motile organisms (*biogenic engineering*), leading to a persistent mosaic of micro-habitats at the deep-seafloor allowing the coexistence of numerous species, especially at small spatial scales. Recent results on the influence of deep-sea sponges (as an example of a biogenic structure) on the small-scale distribution patterns of benthic deep-sea nematodes support these theoretical considerations. A comparison of the nematode communities from sponge with those from control samples (without sponge) showed an influence of the biogenic structure "sponge" on both diversity patterns and habitat heterogeneity. The functional structure of the nematode communities from sponge and control cores differs mainly in feeding- and body shape-types. On average, there are a higher proportion of selective deposit feeders with an interstitial life style in sponge-core communities whereas non-selective deposit-feeders with a burrowing life style are more abundant in control-core communities. Overall, the nematode communities from the sponge samples show a higher functional divergence and thus a high degree of niche differentiation. To study the trophic relationships between benthic megafaunal organisms we conducted radio stable isotope analysis on tissue samples of organisms from six stations that constitute the shallower part of the "Hausgarten" depth transect (1200-3200m). Our results indicate that while scavengers such as starfish and lysianassid amphipods occupied the highest trophic level zoarcid fish had an intermediate trophic position, reflecting their preference for macrofaunal invertebrates. The benthic food web sampled ranged from four to six trophic levels. This large figure indicates a complex food web structure with many niches caused by intense recycling of nutrients, which is characteristic for food-limited deep-sea environments.

State of achievements of deliverables

1. The role of permafrost coasts in the Arctic system

A. *Quantitative assessments of recent and near future dynamics of arctic coasts and their role in the entire Arctic system concerning material fluxes*

A circum-Arctic coastal segmentation and classification has been developed in GIS (Geographical Information System) format to visualize and analyse the current status of the Arctic coastal region and its sensitivity to environmental changes. Incorporating layers of coastal erosion rates, ground ice and carbon content for over 1000 coastal segments, the classification permits calculations of total organic carbon and sediment fluxes from the coastal zone to the Arctic Ocean. The database, which includes the coastal classification and the relevant environmental and climate forcing data, was presented at the 2nd International Conference on Arctic Research Planning (ICARP II) in Copenhagen (November 2005). It has been translated into a geodatabase running in ARC-GIS. After the current final edits are completed, this geodatabase will be linked and released on its own ARC-Internet Map Server housed at the Alfred Wegener Institute.

B. *Models of the onshore/offshore permafrost distribution in the coastal region of the Siberian Arctic and projections of its development under future climate scenarios.*

Supporting this geo-database are efforts being made to understand recent dynamics of the Arctic coasts. An expedition to the Laptev Sea coastline in 2005 led to the recovery of permafrost cores along a transect from an onshore position to a point 12 km offshore. In all of the marine cores frozen sediments were found, whose cryological and isotope characteristics correspond to those of the terrestrial permafrost. Pore water geochemistry showed the influence of saline sea waters, which have diffused into bottom sediments to depths of over 5 m and maintain the sediments in an unfrozen state at subzero temperatures. These cores are currently being analysed for cryogenic, thermal and physical properties, and for microbiology and geochemistry. The results will determine the relative roles of alluvial processes, marine sedimentation or mid to late Pleistocene periglacial deposition in the creation of the current coastline.

2. Methane Budgets in Terrestrial and Marine Polar Environments

A *Quantification and spatial distribution of production, oxidation and release of CH_4 from soils to the atmosphere as well as from sediments to the water column/atmosphere; Identification of major pathways and microbial communities within the polar CH_4 cycle*

- Balance of methane emission for the Lena Delta (Siberia) on the basis of long-term data sets and remote sensing approaches.
- First characterization of methanogenic community by molecular methods.
- Spatial budget –on a m²-basis- about the distribution of chemoautotrophic communities linked to the CH_4-cycle at the seafloor of a mud volcano.
- Quantification of the release of methane bubbles from the seafloor at the Håkon Mosby Mud Volcano.
- Development of new in situ pore water sampling technique, able to preserve high CH_4 concentrations during depressurization of the sample along the ascent from the seafloor to the surface.

B. Modelling of climate-driven formation and degradation of gas hydrates in permafrost and sediments and numerical modelling of reactions, transport and thermodynamics considering microbial pathways and transfer across sediment-water or soil-atmosphere boundaries

- In the first phase of the work package data required for modelling were compiled. This includes data about the temperature field at the Håkon Mosby Mud Volcano. A 2D model were developed for the interpretation of the temperature data and to deduce the history of mud expulsions. These activities are part of our close cooperation with the IFREMER.

- Since reaction and transport processes in permafrost regions and mud volcanoes are variable at small scale, we started to developed a 2D reaction-transport-model, coupling fluid flow, heat conduction, and chemical reactions. For this purpose a finite volume approach is applied. After completing the OOP design, source code for flexible gridding procedures and diagenetic reactions were established.

C *Understanding the regulation of microbial activity relevant for the turnover of methane and linked element cycles*

- Recently it was shown that methane fluxes are mainly regulated by the activity of methane oxidizing bacteria, which are characterized by psychrotolerant eco-types
- High resolution mapping of biogeochemical habitats and chemoautotrophic communities at the Håkon Mosby Mud Volcano, which provides information about the "biofilter capacity" regulating the recycling and flux of CH_4 in surface sediments

3. Benthic diversity and fluxes in the polar deep-sea

A Quantification of the interactions between macro- and meiofauna, bottom current regime, sediment properties, food availability and water chemistry

- Analyses of biogenic sediment compounds between the summers of 2000 and 2005 revealed a general decreasing input of phytodetritial matter to the seafloor, and subsequently, a decreasing trend in sediment-bound organic matter and total microbial biomass (TMB) in the sediments.
- Significant impact of hexactenellid Arctic deep-sea sponges on meiofauna diversity patterns and habitat heterogeneity were described thus improving our basic undersanding of ecosystem functioning at high spatial resolution.
- A depth gradient of benthic standing stock at "Hausgarten" observatory was described in detail.

B Linking conceptual and numerical models of remineralisation and exchange processes across the sediment-water interface to species distribution

- Dense aggregations of calanoid copepods observed and quantified close to the seafloor may indicate a close pelago-benthic coupling at "Hausgarten"
- The benthic food web sampled at "Hausgarten" ranged from four to six trophic levels indicating a complex food web structure with many niches caused by intense recycling of nutrients.
- Considerable differences in organic carbon consumption along a depth transect were measured by *in situ* enrichment experiments sampled with a ROV.
- Bacterial activity in the upper centimetre of deep sea sediment becomes limited through oxygen depletion caused by rapid turnover of large amount of organic carbon. Implication on bacterial and meiofauna species distribution is still investigated.

Personnel

Personnel	Institutional funding	Third party funding
	Scientists / PhD / Technicians	Scientists / PhD / Technicians
AWI	11.5 / 3 / 6.3	6.6 / 5.5 / 0.7

Publication outcome numbers

Academic Publications Refereed only	2004-2006
ISI	27
Non ISI	9
PhD theses	2
Master & Diplom These	-
Books	-
Book chapters	1

Key publications

1. Rachold, V., Are, F.E., Atkinson, G. Cherkashov D.E., S.M. Solomon (eds), 2005. Arctic Coastal Dynamics - Geo-Marine Letters, 25(2/3): 63-203.
2. Seeberg-Elverfeldt, J., Schlüter, M., Feseker, T., Kölling, M., 2005. Rhizon sampling of porewaters near the sediment-water interface of aquatic systems. *Limnol. Oceanogr: Methods* 3, 2005, 361–371.
3. Sauter, E. J., Muyakshin, S. I., Charlou, J.-L., Schlüter, M., Boetius, A., Jerosch, K., Damm, E., Foucher, J.-P., Klages, M., 2006. Methane discharge from a deep-sea submarine mud volcano into the upper water column by gas hydrate-coated methane bubbles. Earth and Planetary Science Letter 243(3/4): 354-365.

4. Soltwedel, T., Bauerfeind, E., Bergmann, M., Budaeva, N., Hoste, E., Jaeckisch, N., Juterzenka, K. v., Matthiessen, J., Mokievsky, V., Nöthig, E.-M., Quéric, N., Sablotny, B., Sauter, E., Schewe, I., Urban-Malinga, B., Wegner, J., Wlodarska-Kowalczuk, M., Klages, M., 2005. HAUSGARTEN: multidisciplinary investigations at a deep-sea, long-term observatory in the Arctic Ocean. Oceanography 18(3): 46-61.
5. Wagner D, Lipski A, Embacher A, and Gattinger A., 2005. Methane fluxes in permafrost habitats of the Lena Delta: effects of microbial community structure and organic matter quality. Environ. Microbiol. 7, 1582-1592.

List of guest scientists

1. Rivkina, E. Institute of Soil Science Pushchino 03.05.04 - 14.05. 04,BMBF
2. Ogorodov, S.Moscow State University, 18.05.05. - 17.06. 05, INTAS
   18.12. 05 – 18.01. 06 INTAS
3. Fedorova, Irina, Petersburg State University, 03.10. 04 - 03.01. 05, DAAD
   03.10. 04 - 03.01. 05, DAAD Grant
   30.03.06 - 30.04. 06, Otto Schmidt Grant
4. Gordeev, V. PP Shirshov Institute of Oceanology, Moscow, 17.05. -16.06. 04, INTAS
   18.01. - 18.02. 05
5. Jürgens, G.,University of Helsinki, Finland, 10.04. - 30.04. 05
6. Couture, N., Mc Gill University Montreal, 15.05 - 15.07. 05
   14.03. - 20.04. 06
7. Grigoriev, M., Permafrost Institute Yakutsky, 13.09. -12.10. 04, BMBF
   30.05. - 27.06. 05, BMBF
   01.11- 30.11. 05, BMBF
8. Beuck, L., Universität Erlangen, 06. - 12.06.2005
9. Lansard, B., UMR CEA–CNRS, Gif sur Yvette, 10.-17.09.2005
10. Hall-Spencer, J. University of Plymouth, 25. - 29.07.2005
11. Mokievsky, V., P.P. Shirshov Institute Moscow, 15.11. - 24.12.2004
12. Feseker, T., Ifremer Centre Brest, France, 19.-26.02.2006

List of running/accepted third party funded projects

1. MarTech Virtual Institute "MarTech – Marine Technologies", HGF-Funding, M. Schlüter & M. Klages, 1.10.2003.30.09.2006, 720,000€
2. Prozessstudie zur Dynamik des Permafrostes in der Laptevsee, TP Geochemische Prozesse beim Versinken des Permafrostes BMBF FKZ 03G0589, H.-W. Hubberten; 710,000 €
3. METROL Methane fluxes in Ocean margin sediments: microbiological and geochemical control, EU –Funding, A. Boetius & M. Schlüter, 1.11.2002-31.10.2005 335.622 €
4. RCOM Research Center Ocean Margins, TP B1, C1 & E1, S. Kasten & M. Schlüter, 01.07.2005-30.06.2009, 285,000 €
5. Hotspot Ecosystem Research along the Margins of Euopean Seas (HERMES), EU, M. Klages, 01.04.2004 – 30.03.2009, EU-funding 299.927€
6. EXtreme ecosystem studies in the deep OCEan: Technological Developments (EXOCET/D), EU, E. Sauter, 01.01.2004 – 31.12.2006, EU-funding: 298.800€
7. Coastal Ocean Benthic Observatories (COBO), EU, T. Soltwedel, 01.03.2004 – 28.02.2007, EU-funding: 170.112€
8. INTAS Project 01-2329 “Arctic coasts of Eurasia: dynamics, sediment budget and carbon flux in connection with permafrost degradation” 150,000 €
9. INTAS Project 01-2332 “Arctic coastal dynamics of Eurasia: classification, modern state and prediction of its development based on GIS technology“ 120,000 €
10. Bipolar Benthic Flux Study: "Quantification of organic carbon fluxes onto surface sediments of the Southern Ocean and comparison to the high latitude North Atlantic", DFG, 2004-2007, Sauter / Schlüter, 65,000€
11. HGF-Network “Integrated Earth Observation Systems” (IEOS), Problems of land surfaces, CarbonB alance; 20,000 €
12. 5th ACD Workshop - Dept of Geography, McGill University, Montréal (Canada), 13-16 October 2004, Canadian Department of Foreign Affairs and International Trade (DFAIT) 5,000 €; International Arctic Science Council (IASC) 30,000 €; Canadian International Development Agency (CIDA) 6,000 €; 4,000 €

13. Award of a FPVI European-funded Integrated Infrastructure Initiative grant, called SYNTHESYS (Synthesis of Systematic Resources) for a study visit to the Zoological Museum University of Copenhagen, February - March 2005, EU-funding: 3000,00

List of expeditions

1.	ALASKA 2004/2	15.07. - 30.07.2004	Fairbanks, Toolik Lake. Prudhoe Bay	1/1
2.	LENA DELTA 2004	13.05. - 28.07.2004	Samoylov Island, Lena Delta	2/1
3.	LIVINGSTON 2005	21.01. - 10.03.2005	Livingston Island, South Shetland Islands	3/0
4.	COAST I	04. 2005	Western Laptev Sea	1/0
5.	ALASKA 2005	09.08. - 09.09.2005	Fairbanks, Toolik Lake	1/0
6.	LENA DELTA 2005/1	03.07. - 07.09.2005	Samoylov, Lena Delta	1/2
7.	PS ARK XX/1	16.06. - 16.07.2004,	Fram Strait,	4/1
8.	PS ARK XXI/1b	13.08. - 25.08.2005,	Fram Strait,	4/1
9.	"RV Atalante"	13.09. - 30.09.2005	Norwegian continental margin, Fram Strait,	5/3
10.	"RV Tethys II"	09.03. - 13.03.2006,	Mediterranean,	1/1

List of external co-operations

1. Department of Geography, Laval University, Quebec, Canada (M. Allard)
2. University Potsdam (H. Asche, I. Schneider)
3. University of Alaska, Fairbanks, USA (D. Atkinson, L. Hinzmann)
4. McGill University, Montreal, Canada (N. Couture)
5. University of New South Wales, School of Biotechnology and Biomolecular (R. Cavicchioli)
6. St. Petersburg State University (I. Federova)
7. DLR (K. Günther, D. Möhlemann, P. Rettberg, E. Hauber)
8. Arctic Centre at Groningen University, The Netherlands (L.Hacquebord)
9. University of Helsinki, Dept. of Applied Chemistry and Microbiology (G. Jurgens)
10. University Hamburg (E.-M. Pfeifer, E. Spiek)
11. ETH, Institute of Terrestrial Ecology (J. Zeyer)
12. Max-Planck Institute for Marine Microbiology, Bremen (A. Boetius, J. Harder)
13. University Tromsø, Norway (J. Mienert)
14. P.P. Shirshov Institute Moscow, Russia (A. Gebruk)
15. IFM-Geomar/IPÖ University Kiel (O. Pfannkuche / D. Piepenburg)
16. Ifremer Center Toulon, France (V. Rigaud)
17. International University Bremen (Dr. L. Thomsen)
18. National Oceanographic Center Southampton, UK (P. Weaver)
19. Zoological Museum University of Copenhagen, Denmark (P. R. Møller, O. S. Tendal, d. Eibye-Jacobsen)
20. University of Hawaii at Manoa Honolulu, U.S.A. (C. Smith)

List of co-operations in MARCOPOLI

Related to studies on coastal environments there is a close co-operation with CO4. This is related to GIS-work and studies on fluxes through the sediment-water-interface.

There is substantial co-operation with colleaques in POL 4 „Benthic organisms in polar marine food webs" namely in the workpackage „Response of polar marine life to recent change" considering intermediate disturbances and habitat complexity which are suggested as potential factors determining biodiversity.

Concerning methodological advice and support considerable exchange exists with colleaques working in POL4 and CO2 (for example stable radio isotope analysis, enzymatic analysis on the aerobic capacity and enzymatic level of tissue samples from Arctic deep-sea eelpouts, otoliths readings, etc).

The Arctic Coastal Dynamics project is a regional project within the Land-Ocean Interactions in the Coastal Zone program. Hartwig H. Kremer at the Institute for Coastal Research, GKSS Research Centre GmbH, Geesthacht is the Chief Executive Officer.

List of memberships in national and international committees

Dirk Wagner:	IPA Working Group “Permafrost Astrobiology”
Hugues Lantuit:	International Polar Year Youth Steering Committee, Steering committee member Permafrost Young Researchers Network, Chairman ESF network SEDIFLUX, Steering committee member Working Group on Sediment Budgets in Cold Environments (SEDIBUD), Core group members ESF pool of reviewers, member
Paul Overduin:	Co-Chair, Coastal and Offshore Permafrost Working Group, International Permafrost Association (IPA) Co-Leader, Arctic Coastal Dynamics Project, (IASC and IGBP-IHDP-LOICZ) IPA-International Polar Year Steering Committee Lead PI on International Polar Year Coastal Margins Cluster
M. Klages:	Member of the Cruise Planning Committee RV “Sonne” Member of the Scientific Advisory Board of the Gesellschaft für Maritime Technologie Member of the Programme Review Group of the Ocean Engineering Department of the National Oceanographic Center Southampton (NOCS) Member of the “Comité de Pilotage” in the *Module de Mesure en Route* (MMR) project at Ifremer Member of the Organizing Committee of the Japanese German Frontiers of Sciences Conferences (nomination by Alexander von Humboldt Foundation) Member of the Organizing Committee of the Young Scientist Conference 2007 (nominated by ICES) Member of the ICARP II working group „Deep Basins“

Additional funding theme NEW KEYS: New Keys on polar climate archives
(Spokesman: Dr. Hubertus Fischer)

Academic results

The overall objective of NEW KEYS is the development and application of new tools for the interpretation of paleoclimatic ice core records with special emphasis on questions regarding changes in global biogeochemical cycles. These tools comprise novel analytical developments for high precision and high-resolution measurements, biogeochemical models to aid a quantitative interpretation of new ice core data as well as process studies to constrain physicochemical effects affecting the information in the ice core archive.

Bubble enclosures in polar ice cores represent the only direct archive of the paleoatmospheric composition among others providing unique data on greenhouse forcing in the past. However, the sources and causes of changes in greenhouse gas emissions in the past are still not sufficiently understood. Accordingly, a major focus of NEW KEYS lies on the utilization of the isotopic information in greenhouse gases entrapped in bubble enclosures in polar ice cores allowing for a source attribution of atmospheric concentration changes in the past. To this end a new mass spectrometer lab solely designed for ice core applications has been established at AWI within the last 3 years and new extraction and high precision gas chromatography isotope ratio mass spectrometry (GCMS) techniques have been developed. E.g. a novel sublimation extraction method has been established which enables to quantitatively extract CO_2 from air trapped in bubble and clathrate ice, a prerequisite for isotopically unfractionated samples. This extraction technique is used in conjunction with a newly developed GCMS method and allows for $\delta^{13}CO2$ analysis with a reproducibility better than 0.05 ‰ for a single small (35 g) ice sample. This precision is 2 times better than previous techniques using 5-30 times more ice and is compulsory to unambiguously quantify changes in the global carbon cycle in the past. Furthermore, a fully automated melt water extraction for $\delta^{13}CH_4$ GCMS analysis on small ice samples has been developed, which allows determination of the carbon isotopic composition of methane to better than 0.2 ‰ for 200 g ice core samples. Application of these new analytical techniques and extension of the analytical capability for hydrogen isotopic analysis on CH_4 to constrain the carbon and methane budget in the past are envisaged for the second half of the MARCOPOLI program.

Quantitative interpretation of CO_2 and $\delta^{13}CO_2$ records in polar ice cores can only be achieved using carbon cycle models. To this end the new global carbon cycle model BICYCLE has been set up. BICYCLE is a detailed multibox model comprising atmosphere, biosphere and ocean reservoirs as well as sediment interaction with ocean circulation fitted to observational data. While a box model is limited in the physical processes resolved it has the advantage that it can be forced forward in time using paleoclimatic data. Accordingly, with this approach we were for the first time able to transiently model changes in CO_2 and $\delta^{13}CO_2$ and to quantitatively explain the observed 80-100 ppmv change in atmospheric CO_2 over the last glacial/interglacial transition. Hindcasting the CO_2 changes prior to the last glacial termination using this model reproduced the Vostok ice core data over the last 400,000 years very well and was also able to correctly predict the reduced glacial/interglacial amplitude in CO_2 changes revealed in the EPICA Dome C ice cores between 420,000-650,000 years before present. Furthermore this model has been recently used to quantify the contribution of a changing carbon cycle to the observed enrichment in glacial atmospheric $\Delta^{14}C$. For the interpretation of the millenial-scale variability of 10-20 ppmv measured in CO_2 during MIS3 the impact of a collapse of the Atlantic thermohaline circulation on terrestrial carbon storage was investigated with the state-of-the-art dynamic global vegetation model LPJ.

A second important constraint for the interpretation of gas records in polar ice cores represents the bubble enclosure process leading to an age offset between gas and ice at a certain depth, temporal smoothing of information stored in air bubbles and physical fractionation processes affecting the (isotopic) composition of the air enclosed. Although empirical firnification models are used to account for this, the physical processes of bubble enclosure, the driving environmental parameters and the natural variability of firnification in different climatological regimes on the ice sheets have to be understood precisely to unambiguously interpret ice core gas records. Within NEW NEYS a new high resolution 3D X-ray tomography method has been established which allows to reconstruct the gradual diagenesis of the pore space of the firn with depth and to observe the bubble enclosure process in time. Using the tomographic images together with latest techniques in image processing physical parameters of the pore space (porosity, tortuosity, connectivity etc.) and their anisotropy have been determined in subcentimeter resolution. Based on this, transport parameters such as diffusivity and permeability have been determined analytically using Lattice Boltzmann modeling for different climatological regimes on the ice sheets. The

extraordinary strong role of vertical stratification of the pore space, which is imprinted already in the top meters of the snow pack, has been identified and will be included in improved firnification models in the future. Recent extensive surface snow studies will complement this to improve our understanding of the role of surface temperature, occurrence of snow fall and summer insolation on the stratification, and thus bubble enclosure in polar ice.

The second focus within NEW KEYS is put on the quantification of changes in dust fluxes and its characterization with respect to transport (size distribution) and source (geochemical composition) properties. To this end a new high resolution melt water analysis has been established which allows to continuously determine dust concentration and size distribution down to sub-cm resolution. In addition these methods have been calibrated using classical size distribution techniques on discrete samples. Latest dust size distribution records from the EDML ice core for example reveal, that transport of mineral dust from Patagonia has been intensified during warm periods over the last 180,000 years. These bulk parameters are complemented by geochemical investigations on the trace element composition of mineral dust using inductively coupled plasma mass spectrometry (ICPMS) both on snow and aerosol samples. In addition to the measurement of elemental concentrations ((Fe, Al, Mn, Na, Mg, Ca, Pb, …) in the ppt range in melt water samples a novel laser ablation technique has been established in the last years, which allows to study trace element composition in sub-millimeter resolution directly in frozen ice. The potential further extension of these analyses on rare earth elements, which allow for an independent identification of different mineral dust source areas, is currently explored. In addition to the terrestrial dust studies the flux of interplanetary dust particles (IDPs) has been investigated in collaboration with the Lamont Doherty Earth Observatory (LDEO), New York using the unique He isotopic signature of IDPs archived in the EPICA ice cores. This led to the first ice core record of the interplanetary dust flux over the last 30,000 years supporting the use of ^{3}He as constant flux parameter in paleoclimatic applications. Among others, this can be also used as independent accumulation estimate in deep ice in the future. Further potential lies in the utilization of the He isotopic composition to constrain terrestrial dust sources.

State of achievements of deliverables

1. High-precision stable isotope measurements on greenhouse gases in bubble enclosures in polar ice cores

- A new mass spectrometer lab (consisting of 2 VG Isoprime and 1 Finnigan MAT 252) has been set up for high precision analysis of $\delta^{13}CO_2$ $\delta^{13}CH_4$ and δD (CH_4).
- A novel sublimation extraction and GCMS analysis for $\delta^{13}CO_2$ has been established. This allows for the first time $\delta^{13}C$ measurements on very small (35 g) ice core samples with a precision of < 0.05 ‰ both on bubble and deep clathrate ice.
- A quantitative melt extraction and GCMS preparation for $\delta^{13}C$ has been established allowing for $\delta^{13}C$ CH_4 measurements with a reproducibility of <0.2 ‰ for small ice core samples (200 g). A comparable GCMS line is currently established for δD (CH_4).

2. Modeling of the global carbon cycle:

- The global carbon cycle model BICYCLE has been set up and tested against current marine and atmospheric data. The model has been used in a transient forward modeling mode allowing for the first time to quantitatively account for the 80-100 ppmv change in atmospheric CO_2 over the last 800,000 years. The model has been also used for the assessment of $\delta^{13}C$ and $\Delta^{14}C$ in ice core and other paleoclimatic records.
- The application of the dynamic global vegation model LPJ to questions of fast climate fluctuations enabled us to draw conclusions on the impact of a reduced ocean circulation on terrestrial carbon storage and thus atmopsheric CO_2.

1. Gas entrapment process: 3D reconstructions of the firnification process using novel X-ray computer tomography

- Setup of high resolution 3D reconstructions of the firn space to quantify small scale changes in (closed and open) porosity, tortuosity etc.
- A Lattice Boltzmann model has been developed to derive diffusivity and permeability of gases in the pore space
- Based on a suite of firn cores from different glaciological regimes in the dry snow zone the dependence of the firn enclosure process on climatological parameters (temperature, accumulation, irradiation) has been derived.

2. Dust characterization: Size distribution and trace element analytics

- A new high-resolution melt water analysis has been set up for the determination of continuous dust concentration and size distribution which allow for the quantification of changes in long-range dust transport over time. This setup is used in routine operation for the continuous analysis of the EPICA ice cores.
- Bulk parameters of dust have been complemented by geochemical characterisation of the trace element composition using ICPMS in the ppt range. These can be performed both on meltwater samples as well as by our novel laser ablation technique in submillimeter resolution on frozen ice.
- novel He isotopic measurements have been performed on ice core samples in collaboration with Dr. Gisela Winckler, LDEO, which allow for a quantification of the extraterrestrial dust flux over time.

Personnel

Personnel	Institutional funding	Third party funding
	Scientists / PhD / Technicians	Scientists / PhD / Technicians
AWI	2/1/2	2/2/0

Publication outcome numbers

Academic Publications Refereed only	2004-2006
ISI	19
non ISI	12
PhD theses	0
Master & Diplom Theses	0
Books	1
Book chapters	1

Key publications

1. Freitag, J. Wilhelms, F. and Kipfstuhl, S., 2004, Microstructure dependent densification of polar firn derived from X-ray microtomography, *Journal of Glaciology*, 50, 169, 243-250
2. Köhler, P., Fischer, H., Munhoven, G. and Zeebe, R., 2005, Quantitative interpretation of atmospheric carbon records over the last glacial termination, *Global Biogeochemical Cycles*, 19, GB4020, doi: 10.1029/2004GB002345.
3. Schmitt, J. and Fischer, H., 2006, A sublimation technique for high-precision $\delta^{13}C$ on CO_2 and CO_2 mixing ratio from air trapped in deep ice cores, *Rapid Communication on Mass Spectrometry* (submitted).
4. Siegenthaler, U., Stocker, T. F., Monnin, E., Lüthi, D., Schwander, J., Stauffer, B., Raynaud, D., Barnola, J. -M., Fischer, H., Masson-Delmotte, V., Jouzel, J. 2005, Stable Carbon Cycle–Climate Relationship During the Late Pleistocene, *Science*, 310, 5752, 1313-1317
5. Winkler, G. and Fischer, H., 2006, 30,000 years of cosmic dust in Antarctic ice, *Science* (accepted).
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List of running/accepted third party funded projects

1. H. Fischer, DEKLIM young scientist research group RESPIC (Young scientist Research group on Earth climate System reconstructions on Polar Ice Cores) BMBF, 1.7.2001—30.06.06, 997.000,- €
2. H. Fischer, MEPHISTO (Differenzierung der Beitäge von MEthanquellen zur PaläoatmospHäre mithilfe der Methan-ISoTOpie von Lufteinschlüssen in polaren Eisbohrkernen), DFG Fi 717/3-1, 1.1.06-30.12.06, 30.750,- €.
3. H. Fischer, MEPHISTO (Differenzierung der Beitäge von MEthanquellen zur PaläoatmospHäre mithilfe der Methan-ISoTOpie von Lufteinschlüssen in polaren Eisbohrkernen), DFG (accepted), 1.1.07-30.12.07.
4. J. Freitag, INFITO (Untersuchung zum Einfluss klimatischer Randbedingungen auf den Aufbau oberflächennaher Firnschichten der polaren Eiskappen mittels 3D-Röntgen-Mikro-Computertomographie), DFG (accepted), 1.7.06-30.06.08

5. Wegner, Dissertation scholarship, Evangelische Studienwerk Villigst
6. S. Dietrich, Diploma Thesis scholarship, Hans Böckler Stiftung

Patents

Kriews, M., Reinhardt, H., Beninga, I., Dunker, E., Lüdke, C., Hoffmann, E.(2001). Element-Analyseverfahren zur Detektion von Spurenelementen und Anordnung zu seiner Durchführung, Patent DE0019934561A1, Deutsches Patent- und Markenamt, München.

List of expeditions (scientists/students)

1. EPICA-DML, Dec. 2003 - Feb. 2004, Dronning Maud Land (Antarctica), (0/1)
2. EPICA-DML, Nov. 2005 - Feb. 2006, Dronning Maud Land (Antarctica), (1/0)
3. VISA, Nov. 2004-Feb. 2005, Kottas Mountains (Antarctica) (0/1),

List of external co-operations

1. BAS, Cambridge, U.K., (M. Hutterli, E. Wolff)
2. CRREL, Hannover, NH, USA, (M. Albert)
3. Frauenhofer Institute, Kaiserslautern, (K. Schladitz)
4. GFZ Potsdam, (G. Haug)
5. INSTAAR, University of Boudler, USA, (J. White)
6. Institute for Analytical Sciences, Berlin (C. Lüdke, J. Skole, E. Hoffmann)
7. Institute for Environmental Physics, University of Heidelberg, Germany (D. Wagenbach)
8. LDEO, Columbia University, New York, USA, (B. Hönisch, G. Winckler)
9. LGGE Grenoble, France (J. Chappellaz, J.-M. Barnola, J.-R. Petit)
10. NASA, Goddard Space Flight Center, Greenbelt, MD, USA, (R. Muscheler)
11. NCAR, Boulder, USA, (R. Knutti)
12. Princeton University, USA, (S. Gerber)
13. RCOM, University of Bremen (M. Schulz, F. Abegg),
14. University Bern / PAGES, Switzerland, (T. Stocker, T Blunier, M. Leuenberger, F. Joos et al./T. Kiefer, C. Kull)
15. University of Copenhagen, , Denmark (D. Dahl-Jensen, K. Andersen, J.-P. Steffensen et al.)
16. University of Hawaii, USA, (R. Zeebe, A. Timmermann, O. Timm)
17. Universite de Liege, Belgium, (G. Munhoven)
18. University of Milan, Italy, (V. Maggi, B. Delmonte)
19. University of Utrecht, The Netherlands, (T. Röckmann)
20. University of Venice, Italy, (C. Barbante)

List of co-operations in MARCOPOLI

- Strong links exist between NEW KEYS and POL6. The major ice core projects are located within POL6 providing both the sample material essential for the novel analyses performed within NEW KEYS as well as the common paleoclimatic background and sharing many of the open questions addressed in NEW KEYS.
- Substantial synergies exist also with POL2, where process studies of the Southern Ocean ecosystem are performed providing the recent experimental background for changes in the global carbon cycle and paleoproducivity in the Southern Ocean. In return the modeling efforts in NEW KEYS provide quantitative estimates on the influence of various parameters on the global carbon cycle acting in the Southern Ocean.
- The carbon cycle modeling work in NEW KEYS also contributes to the goals of MAR 2, where the marine carbon cycle is investigated experimentally and where paleoclimate modeling studies are performed.
- Further links exist to the ice coring themes within NEW TECHNOLOGIES where the necessary methods for high quality deep ice coring are developed.

List of memberships in national and international committees

H. Fischer: member of the NGRIP steering committee
head of the EPICA lab consortium working on gases in ice cores
H. Fischer: member of the “International Partnerships in Ice Core Sciences (IPICS)” steering committee
initiator of the DFG SPP “INTERDYNAMICS” and member of the INTERDYNAMICS steering group

Topic I: Infrastructure

(Spokesman: Prof. Dr. Heinz Miller)

1. Introduction

AWI provides efficient “Large Scale Infrastructure” for marine and polar marine and terrestrial research matching the specific requirements. This infrastructure comprises the ice-breaking research vessel “Polarstern”, the research vessel “Heinke”, specially equipped aircraft for arctic and antarctic missions, research stations with associated observatories in the Arctic and Antarctic, and a vehicle fleet for deep field traverses in Antarctica. All “Large Scale Infrastructure” in accordance with the general Helmholtz mission is available not only for AWI’s research but also for external research institutions, and it is used within the frame of large international projects of polar and marine research.

Beside the permanent maintenance and advanced replacement of technical installations with respect to the scientific requirements the efficient operation of mobile and stationary platforms significantly depends on international coordination and support. This international collaboration is of mutual benefit to all partners because it leads to a significant cost reduction for everybody.

Since 2003 major effort was made by AWI to establish new international partnerships for running stationary research platforms in the Arctic and Antarctic as well as to organize international cooperation for establishing an intercontinental air-link as a gateway from Cape Town into Dronning Maud Land, Antarctica.

Likewise progress was made to cooperate with the national programs of Chile, Argentina and Uruguay to use the flight connections to the runway Teniente Marsh operated by the Chilean Air Force. This gateway is used by AWI for transportation of personnel to King George Island.

Currently the logistic cooperation in air transportation with various national operators and within international projects provides the possibility to reach all AWI research stations in the Arctic and Antarctic within 2 to 5 days. That is considered as a major success of international activities of AWI logistics to provide efficient access for research activities.

Main AWI partners for logistic cooperation:

Arctic:	
France (IPEV)	AWIPEV-Base in Ny-Ålesund
Russia (AARI, LDR)	Samoylov Station in Siberia, air transportation
Norway (NPI) -	Ny-Ålesund
Antarctica:	
UK	positioning of Polar 2
Argentina	operation of Dallmann Laboratory
Chile	air transportation to and from Teniente Marsh (Chile)
Argentina	air transportation to and from Teniente Marsh (Chile)
Uruguay	air transportation to and from Teniente Marsh (Chile)
Russia	support for supply Dallmann Lab
South Africa	logistic cooperation in the Atka Bay, ship transportation
Japan	scientific flight missions in Eastern DML/S17
DROMLAN community	Gateway into Antarctic, logistic flights in DML

2. Dronning Maud Land Air Network (DROMLAN)

The aim of the Dronning Maud Land Air Network (DROMLAN) is to provide an intercontinental air-link from Cape Town to destinations within Dronning Maud Land (DML) to any member country of COMNAP and SCAR in science related activities, including logistics. A regular air-link will improve the accessibility and extend the time period for summer season activities.

National Antarctic programs (Belgium, Finland, Germany, India, Japan, Norway, Russia, South Africa, Sweden, The Netherlands and the United Kingdom) formally established DROMLAN as an international project at the XIV COMNAP-meeting in Shanghai in 2002.

The DROMLAN co-operation includes:

- To maintain, improve and run two airfields close to the stations Novolazarevskaya (Russia) and Troll (Norway) for intercontinental flights from Cape Town into Dronning Maud Land.
- To organize intercontinental air transport of personnel and cargo with appropriate aircraft between Cape Town and the airfields Novolazarevskaya and Troll.
- To organize connecting flights with small aircraft to all stations and field destinations in

Dronning Maud Land including further options such as Vostok, South Pole and stations of the East Antarctic shore region as well.

- To organize necessary services as weather forecast, fuel provision and accommodation.

Since the beginning AWI has taken leading initiatives to make this cooperation work and organize activities as a national contribution to all flight activities within DML the regular weather service at Neumayer Station.

First intercontinental flights were performed between Cape Town and the blue ice runway at Novolasarevskaya (Russia) during season 2002/2003. Since the blue ice runway at Troll station (Norway) became operational up to 5 intercontinental flights are performed with aircraft IL-76TD to Novo runway between November and February and one mid-season flight by C-130 to Troll runway in the beginning of January. Connecting flights to all stations and field destinations are performed with ski equipped aircraft BT-67. The Antarctic Logistic Center International (ALCI) as the commercial aircraft operator of the Russian Antarctic Expedition (RAE) coordinates all flight missions in cooperation with the DROMLAN members and operates IL-76TD and BT-67 aircraft. C-130 aircraft are mobilized by Norway or Sweden.

DROMLAN constitutes a new logistic concept for Neumayer and Kohnen stations. In each season since 2003/2004 almost all personnel as well as several tons of scientific equipment and spare parts have been taken to both stations. It became possible to start summer season already in November. In particular, at Kohnen the successful realization of EPICA in only three drilling seasons would not have been feasible without this network. On the other hand “Polarstern” has got more capacity to accommodate scientists when calling for Neumayer.

Within the frame of DROMLAN logistic support was also provided for the first NIPR – AWI scientific flight missions of Polar2 at S17.

DROMLAN transportation for AWI to Neumayer and Kohnen stations:

03/04:	personnel in:	63	personnel out:	51
	cargo in:	14706 kg	cargo out:	4050 kg
04/05:	personnel in:	30	personnel out:	41
	cargo in:	3186 kg	cargo out:	1925 kg
05/06:	personnel in:	61	personnel out:	66
	cargo in:	13533 kg	cargo out:	2495 kg

3. AWI stations operated within the frame of international partnership

AWIPEV-Base - Ny-Ålesund/ Spitsbergen

A new partnership was agreed between AWI and the Institute Polaire Francais Paul Emile Victore (IPEV) on merging the year round occupied Koldewey Station (AWI) and the summer only Robot and Corbel stations (IPEV) with the goal to establish a more efficient management and to jointly use scientific infrastructure. The agreement was signed in 2004 and practical matters on site were soon organized as well as a German-French scientific advisory board has been established. In March 2005 the first French-German workshop concerning research in Svalbard was conducted in Strasbourg at the headquarters of the ESF. The AWIPEV-Base is run by three wintering persons. They maintain facilities, perform continuous measurements and support the visiting scientists and their projects in the fields of marine and terrestrial biology, geosciences, glaciology, atmospheric physics and chemistry, and related fields. In the Arctic the AWIPEV-Base is the first research platform jointly operated by two European polar institutions.

A major recent addition is the participation of AWI in the International Marine Laboratory in Ny-Ålesund, which was commissioned in 2005 and is a state-of-the-art, large laboratory for marine sciences. AWI is a member of the international consortium, which finances its operation.

Activities at AWIPEV:

2003:

availability:	365 days
visiting scientists and technicians:	86 (50 AWI)
mandays:	1275 (additional 730 days over-wintering staff)

2004:

availability:	365 days
scientists and technicians::	75 (35 AWI)
mandays:	2176 (additional 730 days over-wintering staff)

2005:

availability:	365 days
scientists and technicians:	75 (42 AWI)
mandays:	2614 (additional 730 days over-wintering staff)

Russian-German Research Station Samoylov – Lena Delta (Siberia)

The Lena Delta – located at the coast of the Laptev Sea – is a key region to study the basic processes of the dynamic and development of permafrost in the Siberian Arctic. Within this context Samoylov Station has become an important logistic facilitiy in the frame of Russian-German cooperation.

The station is operated by the Lena Delts Reserve (LDR) in cooperation with AWI. The old building was reconstructed and completed by a new building in 2005. With the recent completion of the new building the Samoylov Station offers all necessary facilities to carry out research projects in the permafrost landscape. The station is easily reached by helicopter or boat from Tiksi and offers living space for eight scientists during winter time. Up to 16 people can be accommodated during summer period. Further improvements are one or two Zodiacs to carry out excursions to other sites of the Lena Delta.

Activities at Samoylov and Lena Delta:

2003:

availability:	122 days from July 03 until October 03
scientists and technicians:	9 (7 AWI, 1 Uni Hamburg, 1 Uni Potsdam)
mandays:	1098

2004:

availability:	79 days from May 04 until July 04
scientists and technicians:	6 (4 AWI, 1 GSF, 1 Uni Hamburg)
mandays:	308

2005:

availability:	64 days from July 05 until September 06
scientists and technicians:	17 (14 AWI, 2 Uni Hamburg, 1 Uni Leipzig)
mandays:	457

Dallmann Laboratory – King George Island

The Dallmann Laboratory at the Argentine Station Jubany on King George Island is used for about 5 months in each season. Research mainly focusses on marine-biological projects for which dry and wet laboratories has been reconstructed during the season 2004/05. Accommodation capacity was increased for up to 20 persons. Collaboration between AWI and DNA/IAA (Argentina) is arranged in a new cooperation agreement signed in 2006, which further improves logistic cooperation and scientific utilisation. For scientific coordination an advisory board has been convened with scientists from AWI, DNA and NWO.

Activities at Dallmann Laboratory:

03/04:

availability:	183 days from October 03 until April 04
scientists and technicians:	17 (5 AWI, 1 Uni Göteborg, 1 Uni Bonn, 2 Uni Jena, 8 IAA)
mandays:	1767

04/05:

availability:	158 days from October 04 until March 05
scientists and technicians:	24 (12 AWI, 1 Uni Göteborg, 1 Uni Kiel, 2 Uni Jena, 8 IAA)
mandays:	1894

05/06:

availability:	156 days from November 05 until April 06
scientists and technicians:	26 (11 AWI, 1 Uni Bonn, 1 Uni Innsbruck, 1 Fraunhofer Institute, 3 DLR, 8 IAA)
mandays:	1767

4 Status of Neumayer Station and Kohnen Station

Neumayer Station:

Neumayer Station is fully operational and accommodates the scientific observatories for geophysics, meteorology and air-chemistry and serves as a logistic base for airborne operations and surface traverses carrying supply to Kohnen station. The vehicle fleet was used for logistic support of Kohnen station. Since season 2000/2001 traverses have been performed from Neumayer to Kohnen every season.

New installations and activities since 2003/2004 season:

- Regular weather forecast service for DROMLAN flight operations and field activities every season since 2002/2003. This weather forecast is performed in cooperation between AWI and German Weather Service (DWD).
- The Infrasound Station IS27DE started work on March 1, 2003 and was certified on June 24, 2004 as part of a global network for monitoring the Comprehensive Nuclear Test-Ban Treaty (CTBT). Thus Germany fulfills a long-term commitment of this treaty.
- Installation of a new observatory – Perennial Acoustic Observatory of the Antarctic Ocean (PALAOA) - for marine acoustic studies at the Ekström ice shelf in 2005/2006, which performs automatic observations year round.
- A highlight of public outreach was the realization of the arts project “Library on Ice” during the season 2004/05.
- Concept and engineering design for the new Neumayer Station III has been a major work project since 2003.

Summer season activities:

03/04:

availability:	120 days from 6 November 03 until 06 March 04
scientists and technicians:	32 (19 wintering staff) (13 AWI logistics, 2 AWI science, 2 DWD, 2 Uni Hannover, 3 BGR, 2 Optimare, 6 DLR, 1 VIP-UBA, 1 GL)
mandays:	4500 estimated (1800 for science)

04/05:

availability:	98 days from 05 Novemeber 04 until 11 February 05
scientists and technicians:	56 (18 Wintering staff) (10 AWI logistics, 8 AWI science, 2 DWD, 3 TU Dresden, 2 Fielax, 1 GL, 1 artist, 2 Optimare, 6 DLR, 3 visitors (SCAR, SANAP))
mandays:	4500 estimated

05/06:

availability:	75 days from 26 November 05 until 09 February 06
scientists and technicians:	54 (18 Wintering staff) (9 AWI logistics, 10 AWI science, 2 Fielax, 1 BGR, 2 DWD, 2 TV team, 2 Optimare, 4 DLR, 4 AWI-VIP)
mandays:	4050 estimated

Vehicle fleet based at Neumayer Station

The Neumayer Station is the technical base to operate vehicles for logistic and scientific purposes. The vehicle fleet with tracking vehicles, cargo seldges, tank containers, skidoo and others is used for logistic work at the station, transport during ship unloading and loading as well as for logistic and scientific traverses up to the inland ice plateau. Surface traverses are extensive in terms of manpower, costs and time. AWI has developed a very efficient management and applied technology to efficiently meet all logistic and scientific needs. Efficiency of traverses means transporting large amount of cargo (mass and volume) over long distances in short time with few persons and low fuel consumption. As an example the average fuel consumption per vehicle for the round trip Neumayer - Kohnen - Neumayer is 3.5 l/km.

This state-of-the-art surface traverse tool is permanently maintained at a high standard and advanced replacements are performed accordingly in order to increase the efficiency as much as possible. In 2005 a new tracking vehicle (PB 300) was purchased in order to replace one of the old machinery. This new PB 300 is equipped with a special technical modification for deep field operations in the harsh conditions on the Antarctic inland ice plateau. This special modification is the result of a long-term technical cooperation and exchange of experience between AWI logistics and Kässbohrer company as the manufacturer of Pistenbully PB 300.
The current vehicle fleet for scientific and logistic surface traverses consists of:

6 tracking vehicles (5 PB 300, 1 PB 260)
16 cargo sledges for payloads (containers and bulk) up to 20 tons
6 tank containers
2 living containers
20 Skidoo Doo Alpine (Type II and III)
35 Nansen sledges

Surface traverse missions since 2003:

Season 03/04:
2 logistic traverses for supply of Kohnen Station – payload about 161 tons
5 Pistenbulli, 12.160 traverse-kilometres, 37.910 ltr. fuel consumption,

Season 04/05:
1 logisitic traverse for technical service at Kohnen Station and preparation for drilling – payload about 125 tons
4 Pistenbulli, 6080 traverse-kilometres, 18.892 ltr. fuel consumption

1 logistic traverse for field mission at Kottas
2 Pistenbulli, 1644 traverse-kilometers, 5.108 ltr. fuel consumption

Season 05/06:
1 supply traverse for Kohnen Station – payload about 105 tons
5 Pistenbulli, 7.600 traverse-kilometers, 23.000 ltr. fuel consumption

1 scientific traverse for snow sampling
2 Pistenbulli, 280 km eastbound Kohnen

Kohnen Station:
At Kohnen Station the deep ice core drilling within the European Project for Ice Coring in Antarctica (EPICA) was continued in the season 2003/04 and was successfully finished at a depth of 2774 m during the season 2005/06. Scientists and technicians as well as scientific equipment have been brought to the site via DROMLAN.

Summer activities:

03/04:

availability:	77 days from 01 December 03 until 15 February 04
scientists and technicians:	28 (10 AWI logistics, 11 AWI science, 1 UK, 1 Brazil, 1 Italy, 1 Denmark, 1 Sweden, 1 France, 1 Norway)
mandays:	2310 (1540 science)

04/05:

availability:	23 days from 23 December 04 until 15 January 05
technicians:	5 (4 AWI logisitics, 1 Kässbohrer company)
mandays:	115

05/06:

availability:	92 days from 06 November 05 until 06 February 06
	scientists and technicians: 26 (10 AWI logisitcs, 12 AWI science/drilling, 1 Uni Stockholm, 2 Uni Bern, 1 NPI)
mandays:	2015

5 Summary – operational, technical and scientific improvements since 2003
DROMLAN
Efficient access to Neumayer and Kohnen
In particular, a successful realization of the EPICA ice core deep drilling in only three drilling seasons would not have been feasible without the existence of this network.

AWIPEV-Koldewey:
Establishment of bilateral partnership to merge the German and French stations Koldewey (AWI), Robot and Corbel (IPEV) operation and coordination of scientific and logistic activities
French-German Scientific advisory board convened in 2004
Installation of Internet access and broadband high data transmission facilities in 2005

Samoylov Station
Reconstruction of the old building and construction of a new building in 2005
Agreement on logistic operation between AWI and Lena Delta Reserve (LDR)

Dallmann Laboratory
New contract on logistic and scientific cooperation with DNA (Argentina) in 2006
Scientific advisory board Germany, Argentina, The Netherlands in 2006
Reconstruction of laboratory facilities in 2005

Neumayer Station
Concept and engineering design of Neumayer Station III for the replacement of Neumayer Station II
Certification of IS27DE in 2004
Installation of a new observatory – Perennial Acoustic Observatory of the Antarctic Ocean (PALAOA) - for marine acoustic studies in 2004/2005

Kohnen Station
Finalization of EPICA
Installation of automatic observations for air chemistry and geophysics

Vehicle fleet
New Pistenbully PB 300 with special technical modification for deep field operations on the Antarctic inland ice plateau. This special vehicle modification is the result of a long-term cooperation and exchange of experience between AWI logistics and Kässbohrer company as the manufacturer of Pistenbully.

Aircraft Polar 2
Certification and operation of new scientific instrumentation
- Airborne Mobile Aerosol Lidar (AMALi) – ASTAR campaign
- ASIRAS instrumentation

Polarstern:
Replacement and new installations of scientific equipment:
Replacement of advanced hydro-acoustic systems (Parasound, Hydrosweep)
New server and mass storage (3 Tera Bytes)
New satellite receiving system for HRPT images
Iridium communication including data transfer

Cruise leadership by French scientist Madame Provost

Geophysical instrumentation pool:
Within MARCOPOLI funding had been secured for the establishment of a marine geophysical instrumentation pool with initially 50 broadband ocean bottom seismometers. Through an additional grant it has been possible to enlarge the number of instruments to 80. This pool is starting to be operational and first successful trials have recently been carried out during the ongoing Polarstern cruise. The appropriate user advisory group has been established and has already formulated the deployment schedule for the next 2 years. Next in line is the acquisition of a digital marine streamer system to complete the marine equipment within the pool necessary for land-sea seismic investigations on continental margins.

6. Future activities

The scientific and logistic tasks in the Antarctic cannot be fulfilled with only one aircraft. Therefore, the substitution of Polar4 is of urgent necessity in order to re-establish the required performance of the polar aircraft operation. A new challenge will be the operation of UAVs (Unmanned Aerial Vehicle) in the future. Presently concepts are in preparation in order to use UAVs for new scientific questions.

The most ambitious project will be the construction of Neumayer Station III on the Ekström Ice Shelf, which will not be operational at latest in 2009. The planned construction of the base Neumayer III will not only be different from its two predecessor bases but also from all known base constructions in the Antarctic. The base itself will be mounted on a platform 6 m above the snow surface and covered by an aero-dynamical casing. The platform will be combined with a garage in the snow. The entire building with a weight of 2600 tons will be lifted once a year by means of hydraulic rams, which will be embedded in the pillars of the platform. This concept is conform to the regulations of the Environmental Protocol and will enable a longer life time of at least 25 years. In 2005 the draft Comprehensive Environmental Evaluation (CEE) was distributed among the Consultative Parties to the Antarctic Treaty. Manufacturing of station components is anticipated to start in 2006.

Finally we are expecting a positive recommendation by the “Wissenschaftsrat” to build AURORA BOREALIS. We have worked hard towards this goal by leading the work for the international science plan for this research icebreaker with drilling and year round operational capability in the Arctic as well as having a realistic design study available.

Personel

Personell	Institutional funding	Third party funding
	Scientists / PhD / Technicians	Scientists / PhD / Technicians
AWI	20 / 0 / 18	

Research Division Geosystem: Non Program Research

(Spokesman: Prof. Dr. Hans-W. Hubberten)

Report on the general development of the Research Division Geosystem

The research division Geosciences investigates the interaction between the geo-ecosystems and the climate system. This includes the past climate- and environment state as well as the recent response of the Earth systems to natural and anthropogenic-forced climate changes. The regional focus of efforts concentrates on the polar regions. The Artic and Antarctic regions are among the most sensitive to environmental change, and thus are key areas for understanding past and recent climate change. Different archives like ocean sediments, permafrost soils and continental ice are used to reconstruct variations in atmospheric and oceanic circulation as well as climate-induced impacts on the ecosystem. Moreover, the coastal and permafrost regions of the Arctic, the high-latitude continental shelfs and ocean margins as well as sea ice cover and continental ice sheets provide basic informations that are essential to assess future climate change, such as global warming and sea level rise. The cooperation of geophysical, geological, glaciological, and geochemical disciplines under one roof and the common use of central facilities provide an ideal research environment to investigate long-term and event-driven changes of the polar regions and to document qualitative and quantitative mass- and energy transfers in the complex system "continental ice – permafrost region – ocean – sediment".

The recovery of sediment and ice cores requires the integration into international programs (IODP, ICDP, EPICA, et al.) and the application of their technologies. The improvement and new development of drilling equipments, sensors, platforms (*Aurora Borealis*, underwater vehicles like ROV's and AUV's) as well as sensor-networks and autonomous observatories are necessary to decipher the distinctive interactions between the ecosystems and the climatic system, especially for those areas that are difficult to access.

These objectives supplement questions, which are investigated within the research divisions of Climate Sciences and Biosciences. This includes, for example, the numerical modelling of climatic and environmental changes in arctic coastal- and permafrost areas, the quantification of particle flux from the surface to the ocean floor, which is relevant for the benthic-pelagic linkages, as well as research of coastal dynamics and their effects on the coastal ecosystems.

The major part of the scientific research is embedded in the AWI-research program MarCoPoli This research is complemented by additional research themes (outside MarCoPoli) that are partly funded by soft money. Following is a short description of these themes:

Short description of additional research themes of the Geosystem

Integrated Ocean Drilling Program Leg 302 (Artic Coring Expedition, ACEX), (Prof. R. Stein)

The Arctic Coring Expedition set a new milestone in Arctic research during the late summer of 2004. The recovery of an about 420m thick sequence of late Cretaceous and Cenozoic sediment on Lomonosov Ridge/central Arctic Ocean during the IODP-ACEX Expedition 302 in 2004 allowed for the first time a detailed reconstruction of the early pre-glacial Arctic Ocean climate history. Studying these unique ACEX sediments, we concentrate on the Arctic Ocean organic carbon cycle and its relationship to the long- and short-term paleoenvironmental/paleoceanographic evolution during Paleocene-Eocene times. First detailed records from the entire approx. 200 m thick Paleogene organic-carbon-rich section of the ACEX drill site indicate that euxinic "Black Sea type" condtions favourable for the preservation of labile aquatic (marine algae-type) organic matter occurred throughout the upper early to middle Eocene, explained by salinity stratification due to freshwater discharge. The superimposed short-term (Milankovitch-type) variability in amount and composition of organic matter is related to changes in primary production and terrigenous input.

High resolution modelling of sediment erosion and particle transport across the NW African shelf ((Dr. A. Karakas, Prof. R. Schlitzer)

The region off Cape Blanc along the northwest African coast is dominated by persistent upwelling and strong activity of small scale eddies, filaments and jets. Vertical particle camera profiles obtained during recent cruises in this region show that two well-marked maxima of particle abundance in the water column exist, one at the surface and the other in subsurface layers between 200 and 400 m deep. Using a high resolution terrain-following coordinate ocean model with built-in ecosystem and sediment transport modules we show that the surface particle maximum can be explained by local productivity while the deeper, subsurface particle cloud most likely originates from particulate material eroded from the shallow shelf and transported offshore by

vigorous filament activity and dynamic features of the flow. Time-averaged effective transport patterns of particles reveal distinct maxima between 20.5°N and 23.5°N off Cape Blanc. South of Cape Bojador and off Cape Timiris, on the other hand, the effective transport distance patterns suggest energetic offshore activity. This work was conducted in cooperation with the DFG funded Research Center Ocean Margins (RCOM).

Eltanin Asteroid Impact Studies (Dr. R. Gersonde)

The late Pliocene (2.5 Ma) Eltanin impact into the Bellingshausen Sea (Pacific Southern Ocean) is the only known example of a km-sized asteroid impact into a deep-ocean (5 km) basin. We intensively investigated the impact area combining HYDROSWEEP bathymetric and PARASOUND sediment-echosounding surveys and the study of 20 sediment cores containing impact-related deposits. This survey revealed that the meteoritic ejecta is most concentrated on a topographic high, the Freeden Seamounts (57.3°S, 90.5°W), and in the deep basins to its north where the amount of meteoritic material deposited on the ocean floor is as much as 3 g/cm^2. We estimate that ground zero was in the region just north, or northwest, of the seamounts. Sediments as old as Eocene were eroded by the impact disturbance.

Deep-water renewal in the Skagerrak during the last 1200 years triggered by the NAO: evidence from benthic foraminiferal $\delta^{18}O$ (Prof. A. Mackensen)

Benthic foraminiferal tests of a sediment core from south-western Skagerrak (north-eastern North Sea, 420 m water depth) were investigated for their ratio of stable oxygen isotopes. During modern times sudden drops in temperature and salinity of Skagerrak deep-waters point to advection-induced cascades of colder and denser Central North Sea Waters entering the Skagerrak. These temperature drops, which are recorded in benthic foraminiferal tests via the stable oxygen isotopic composition, were used to reconstruct deep-water renewal in the Skagerrak. Our results suggest that at least during the last 1200 years Skagerrak deep-water renewal has been triggered by the negative phase of the North Atlantic Oscillation (NAO).

Development of an orbitally tuned Late Miocene time scale (5-12 Ma), (Prof. R. Tiedemann)

The astronomical tuning technique is presently the most accurate absolute dating method for sediment records spanning the time interval of the last 35 Ma, for which astronomers provide a valid and precise orbital solution for variations in Earth's orbital parameters (eccentricity, obliquity, precession). The orbitally tuned geological time scale has already become the standard chronology for the Pleistocene and Pliocene (0-5.3 Ma). Our goal is to expand and to astronomically calibrate the 'Magnetic Polarity Time Scale', the oxygen isotope stratigraphy and biostratigraphy to 12 Ma at South Pacific Site 1237 (Leg 202). So far, this is the only marine site that meets nearly all criteria of providing a complete Neogene reference section by integrating the excellent framework of both magnetostratigraphy and biostratigraphy into an orbitally tuned oxygen isotope stratigraphy. Our project is embedded into a joint effort with other national and international partners to develop a 'Magnetic Polarity Time Scale' and isotope stratigraphy for the entire Neogene.

Isotopes in benthic foraminifera from an upwelling system off Marocco (Prof. A. Mackensen)

The benthic foraminiferal species composition and the stable carbon isotopic composition of their tests were used to reconstruct paleoproductivity changes during the Holocene and Last Glacial Maximum (LGM) in the upwelling system off Morocco (NW-Africa). Recent benthic foraminiferal assemblages clearly indicate two distinct productivity regimes with eutrophic regions off Cape Ghir (31°N) as well as Cape Yubi (27°N), and an oligotrophic region between the capes. These trophic differences are reflected by more depleted $d^{13}C$ values of infaunal species in the eutrophic region than in the oligotrophic one. In the LGM, benthic foraminiferal faunas clearly indicate an increase in primary producticity compared to modern conditions. Benthic foraminiferal faunas reflect eutrophic conditions parallel along the African coast.

Development of technology within the scope of MarTech

The AWI, the MARUM (Univ. Bremen), the Hochschule Bremerhaven, the MPI for Marine Microbiology and the Transfer Centrum for Computer Science (Univ. Bremen) work together within the scope of the Virtual Institute of Marine Technology (MarTech, HGF Impulse and Integration Fond). Major objectives are the development of sensors, specimen equipment and software designed for the use with mobile underwater vehicles like AUV's, ROV's and crawlers, which are used in geochemical, biological and microbiological research.

Biogeochemical reactions and transport processes in marine sediments (Dr. S. Kasten)

The investigation, quantification and modelling of biogeochemical reactions and transport processes in marine sediments are the subjects of projects C1 „Sedimentary signatures and diagenetic processes of ocean margin deposits“ and E1 „ Structure and dynamics of cold seeps, associated communities and mineral precipitates“ in the frame of the DFG Research Center Ocean Margins RCOM as well as of three PhD projects of the European Graduate College EUROPROX (DFG). The focus of these studies has been, and will be, the early diagenetic formation of sedimentary signals under highly dynamic environmental and sedimentological conditions in different depositional environments and the use of secondary sediment attributes to reconstruct paleoceanographic conditions as well as accumulation environment and history.

Paleoclimate research on the Tibetan Plateau (Prof. U. Herzschuh)

The Tibetan Plateau is considered the “third pole” and is one of the major driving factor of global circulation systems. Therefore, past, present and future climate and environmental change on the Tibetan Plateau is of general interest within the “global warming” debate. The Late Quaternary climate development on the Tibetan Plateau is investigated at AWI Potsdam using a variety of proxies, which are preserved in lacustrine sediment archives (e.g. pollen, plant macrofossils, element concentrations). A recently granted DFG-Project focuses on the quantitative reconstruction of Late-Glacial climate oscillations on the Tibetan Plateau. For this purpose, a pollen-climate transfer function to infer quantitative July temperature and annual precipitation has been established.

Tolerance Limits of methanogenic archaea in terrestrial permafrost (Dr. D. Wagner)

Methane producing organisms (methanogenic archaea) isolated from Siberian permafrost were used in this project to study their physiological potential to survive under extreme environmental conditions in terrestrial, and probably in extraterrestrial permafrost like on Mars. Different stress conditions (low temperature, high salinity, radiation, desiccation and starvation) were tested with permafrost samples and pure cultures of methanogens. Finally the probability of methanogenic archaea to survive under present Martian thermo-physical conditions was studied by running a Mars simulation experiment. The results demonstrate for the first time that methanogenic archaea from permafrost are well adapted to permafrost conditions and even survived simulated Martian conditions in temperature and humidity.

Application of stable isotopes (Prof. H.-W. Hubberten)

Within the frame of teaching obligations at the University of Potsdam and in close collaboration with the FU Berlin (Prof. Pekdeger), the Isotope Laboratory is involved in three projects in regions around Berlin, Granada/Spain and Bursa/Turkey to tackle hydrological problems of the respective areas. These projects are partially funded by the DFG and other agencies (DAAD, Erasmus-program, WTZ).

The cooperation with the German Institute for Nutritional Research led to new conclusions in the application of stable isotopes in the area of Nutrional Physiology (especially concerning the conversion of energy in the human body).

Personel

Personel	Institutional funding	Third party funding
	Scientists / PhD / Technicians	Scientists / PhD / Technicians
AWI	10 / 1 / 3	9 / 4 / 1

Publication outcome numbers

Academic Publications Refereed only	2004	2005	2006 (Jan till March)
ISI	5	5	3
non ISI	6	2	0
PhD theses	0	1	0
Master & Diplom Theses	0	0	0
Books	1	0	0
Book chapters	5	0	0

Key publications:

1. Brückner, S., Mackensen, A. (2006). Deep-water renewal in the Skagerrak during the last 1200 years triggered by the North Atlantic Oscillation: evidence from benthic foraminiferal $\delta^{18}O$. The Holocene, 16, 3, in press.
2. Licari, L., Mackensen, A. (2005). Benthic foraminifera off West Africa (1°N to 32°S): Do live assemblages from the topmost sediment reliably record environmental variability?, Marine micropaleontology, 55/3-4, 205-233.
3. Karakas, G., Nowald, N., Blaas, M., Marchesiello, P., Frickenhaus, S., Schlitzer, R.(2006). High resolution modelling of sediment erosion and particle transport across the NW African shelf, Journal of geophysical research-oceans, in press.
4. Herzschuh, U., 2006. Palaeo-moisture evolution at the margins of the Asian monsoon during the last 50 ka. Quaternary Science Reviews 25, 163-178.
5. Sluijs, A., Schouten, S., Pagani, M., Pedentchouk, N., Brinkhuis, H., Sinninghe Damsté, J. S., Dickens, G. R., Huber, M., Reichart, G. -J., Stein, R., Matthiessen, J., Lourens, L. J., Backman, J., Moran, K.(2006). Subtropical Arctic Ocean temperatures during the Palaeocene-Eocene thermal maximum, Nature.

Research Division Biosciences: Non Program Research

(Spokesman: Prof. Dr. Allan Cembella)

Report on the general development of the Research Division Biosciences

The research mandate of the AWI Biosciences Division is to explore and elucidate the role of marine biota within the Earth System. Marine organisms are an active component of that system, in that some organisms synthesize organic from inorganic material, and pass on and circulate such organic material within complex food webs. By actively performing this metabolic activity, they drive and couple the biogeochemical cycles, and in this way can influence the Earth's climate, with a consequent feedback effect to which they are subject. Marine organisms are organized in complex marine ecosystems that are the result of very long evolutionary processes. The functionality, stress-bearing capacity and usability of these systems can only be understood in the context of physical, chemical and geological factors, but it is important not to ignore the specific interactions between the different organisms and community structure.

Division Biosciences has been recently restructured by fusion of the former Pelagic and Benthic Ecosystems Divisions, thereby removing an artificial potential barrier to integrative process studies such as on benthic-pelagic coupling. This restructuring was accompanied by a redefinition of the research programme for the newly designated section Ecological Chemistry and the transformation of two former project groups, specifically on UV Radiation Effects and Carbon Cycling, into the sections designated Macroalgal Biology and Marine Biogeochemistry, respectively. The sections function as the centres of disciplinary expertise and are also responsible for the operation and maintenance of specialized equipment and facilities. A further structural change has been the enhanced incorporation and improved linkages of the biological research programmes on the island stations of Helgoland (BAH) and Sylt (Wattenmeerstation) with biological sciences conducted in Bremerhaven.

The fundamental challenge facing the marine biosciences is to understand the ways in which the multitude of different organisms known today coexist, as well as the resultant complexity of ecosystems and the underlying evolutionary processes. Due to their specific evolutionary history and climatic features in the present, polar ecosystems provide a unique 'laboratory' for the comparative study of functional interrelationships. In the coastal and shelf ecosystems of the North Atlantic, climate-related or anthropogenic changes (e.g. shifts in the geographical distribution and spread of marine fauna and flora) are being identified at an early stage, documented as they occur and analysed in detail.

The Biosciences Division has benefited from major recent investments in technology, specifically by acquisition of advanced equipment such as ICP-MS, high resolution NMR, quadrupole LC-MS/MS, and DNA sequencing facilities. This has enabled major advances in the disciplinary programmes on marine natural products chemistry, metabolomics, chemistry of trace organic components, including toxins and allelochemicals, isotopic analysis and biogeochemistry, functional genomics and gene expression. The AWI biosciences groups are moving rapidly towards integrative ecology and physiological aspects (as opposed to pure autecological studies). The incorporation of molecular technologies for phylogenetic reconstruction, taxonomy, rapid taxon-specific diagnostics, ecotoxicology, and gene expression has already contributed to our understanding of functional ecosystem dynamics. Collaboration between experimenters and modellers, for example, on process modelling over different geographical and time-scales, permits exploration of scenarios for links between 'target parameters' and 'proxies'. Ecosystem model development requires in-depth knowledge of how ecosystems are organised and function in order to determine the limits to the stress-bearing capacity and further use of these resources. Understanding can only be achieved by advancing interdisciplinary study of these processes and refining models of marine food webs and biogeochemical cycles. The biological component of Earth System modelling is therefore of great importance for predicting the future development of the biosphere.

In addition to their MARCOPOLI research, scientists within the AWI Biosciences Division are actively involved and play a crucial role in many major international science programmes. Within the **International Geosphere Biosphere Programme** (IGBP), AWI biologists participate in research on the structure and functioning of marine ecosystems and modelling based on their physical and biological components in **Global Ecosystem Dynamics** (GED), in identifying and developing a mechanistic understanding and mathematical description of biogeochemical fluxes in **Integrated Marine Biogeochemistry and Ecosystem Research** (IMBER), in explaining and predicting processes at the ocean-atmosphere boundary layer in **Surface Ocean Lower Atmosphere** (SOLAS) and in describing the processes at the land-ocean transition in **Land Ocean**

Interactions in the Coastal Zones (LOICZ). Subsumed under the Integrated Global Observing Strategy (IGOS), a number of coastal research programmes are of major importance, such as the **Global Ocean Observation System** (GOOS), and specifically the **Coastal Ocean Observing Panel** (COOP) and the **Ocean Observations Panel for Climate** (OOPC). AWI is represented on the Steering Committee of the international SCOR/IOC programme **Global Ecology and Oceanography of Harmful Algal Blooms** (GEOHAB). In a context of increasing extinction rates among marine organisms, AWI researchers are involved in the internationally coordinated **Census of Marine Life** programme aimed at protecting the marine environment and its organisms. Finally, the bioscience division is represented on six different ICES Working Groups on topics ranging from fisheries science to harmful algal blooms, ecotoxicology and benthic ecology.

Short description of additional research themes of Biosciences

Arctic Operational Platform (ARCOP) (EU project) (Dr. Gerd Dieckmann)

In this EU Project we developed a technique to remediate oil in sea-ice. We found that sea-ice bacteria can digest oil that penetrated into sea-ice. We determined the degradation rate in the field and in experiments in relation to temperature and nutrient supply over a period of several months. The addition of fishmeal increases oil degradation at near-zero temperatures but not much below freezing. We are currently characterizing the microbial community responsible for this oil degradation.

Microarrays for the detection of pathogenic protozoa, flagellated algae and diatoms (MICROPAD) (EU project) (Dr. Linda K. Medlin and Dr. Katja Metfies)

The goal of this EU project is to develop new molecular probes for investigating the biodiversity of the group of microscopic algae known as cryptophytes. These probes have been produced and adapted for the application of solid phase cytometry, which allows for the automated detection and enumeration of microalgae in cultures and field samples.

Integrative processes concerning formation, nanostructure, and lightweight structures of diatoms and other marine organisms (Nanolight, Ammolight) (BMBF-Project) (Dr. Christian Hamm)

In this continuing project, the objective is to investigate the interactive adjustments of nanostructures, material properties and lightweight geometries of marine shells on the basis of natural selection for stable lightweight constructions in marine ecosystems. The heavily silicified diatom *Fragilariopsis kerguelensis* comprises up to 90% of the opal belt in Antarctica, most likely as a result of an exceptional resilience to mechanical attack by zooplankton. Calculations using finite-element analyses predicted that the silica of *F. kerguelensis* frustules cannot be homogeneous, but must be a rather complex nanocomposite material. These predicted highly anisotropic properties of the frustules are reflected in the nanostructure of the diatom silica. Such materials have great potential for biotechnological applications in the emerging fields of nanotechnology and bionics. First results were transferred to technical applications and have resulted in a patent and several utility patents “Gebrauchsmusterschutzrechte”. The applied part of this project will be implemented within the framework of the new Institute of Marine Applied Research (IMARE).

Mariculture at wind parks: Fitness, parasites and substrates for *Mytilus* (Mytifit) and hydrodynamical forces and mechanical structures (Aqualast) (Senate Bremen, BMBF) (Dr. Bela Buck)

In a series of programmes the possibilities and limitations of sustainable offshore-aquaculture in the German Bight are being investigated. As an additional multifunctional use of wind parks, cultures of mussels and sea-kelp were grown on structures attached to windmill poles. Stable growth-rings are more suitable than long-lines to withstand the strong hydrodynamic stresses in the upper water column. Kelp have been shown to withstand such hydrodynamic tension extremely well even at exposed positions. Densities of mussel larvae decreased with increasing distance from the coast but no macro-parasites were found inside offshore mussels. Some technical and legal restrictions still exist, but successful offshore aquaculture seems to be feasible in the near future. This project will be implemented within the framework of the new Institute of Marine Applied Research (IMARE).

Mangroves, a major source of dissolved organic carbon to the oceans (partly funded by DAAD) (Prof. Dr. Gerd Kattner and Dr. Boris Koch)

Dissolved organic matter in the world oceans contains an amount of carbon similar to that of atmospheric carbon dioxide. In a study in northern Brazil, we have established that mangroves provide more than 10% of dissolved organic carbon supplied to the global ocean from land, although mangroves cover less than 0.1% of the global land area. Thus, mangroves play an important but unexpected role in the carbon cycle. This project highlights the importance of quantifying the sources of marine dissolved organic carbon for understanding global biogeochemical cycles.

Physiological acclimation of marine macrophytes along physico-chemical stress gradients (DFG Project) (University of Kiel/AWI, Nachwuchs Juniorprofessor Dr. Kai Bischoff)

This project is focussed on physiological acclimation of macroalgae in response to irradiance and temperature changes. Under natural conditions, marine macroalgae are exposed to large fluctuations in abiotic environmental variables, such as light and temperature; therefore, they require efficient acclimation mechanisms. Global environmental change, as well as anthropogenic influences, may further increase the amplitude of environmental variation (e.g. by stratospheric ozone depletion, greenhouse effect, etc.). Algal stress tolerance and acclimation potential are being assessed in laboratory and field experiments, representing stress gradients at different spatial scales: 1) latitudinal comparisons of related and morphologically similar species from different climatic regions reveal differences in acclimation mechanisms; 2) studies on the physiological basis of vertical zonation show habitat specific acclimation along the depth gradient; and 3) physiological and ecological acclimation of green algal mats show responses to small scale gradients in irradiance. During the first two years of the project these test systems were studied by measuring photosynthetic performance. However, as all kinds of abiotic stress do finally impair photosynthetic activity and frequently result in elevated production of reactive oxygen species (ROS), the studies during the third year will be focussed to the generation and scavenging of ROS in marine macroalgae. The results will reveal potential hazards to macrophyte-dominated ecosystems with respect to environmental change.

Electronic database for the reference collection ‚Macroalgae of the southern North Sea' (BMBF Project) (Dr. Inka Bartsch)

The 100-year-old, nationally and internationally renowned reference herbarium ‚*Macroalgae of the southern North Sea*' at Helgoland was digitised within the framework of the Global Biodiversity Information Facility (GBIF) initiative of Germany (www.gbif.de) The objective was to generate a virtual herbarium accessible via the Internet for easier use by scientists, students and coastal managers. To achieve this, the annotations of 7800 herbarium sheets in total were transferred into a database; important material was renovated and scanned. The annotations provide information about collector, determination, collection site and date, reproductive state and miscellaneous notes. The formerly hidden biodiversity information of this discontinuous time series was thereby made sustainable. Easy access is provided by the international GBIF Portal (www.gbif.org) where biodiversity databases from all over the world are linked and nomenclatural updates are provided by linkage with taxonomic databases. The herbarium provides evidence for approximately 80% of macroalgal species of the southern North Sea.

Development and practical evaluation of a macrophyto-benthos classification system for the EU-Water Framework Directive (WFD), water body Helgoland (LANU Schleswig Holstein) (Dr. Inka Bartsch)

Within the EU-Water Framework Directive every EU country is obliged to monitor and control the water quality of fresh water and marine habitats and to keep them in a good state. The precondition for this is the classification of the status of each given water body. This is achieved by the description of the historical, pristine conditions of the site and/or by expert judgement. This was done for Helgoland by reviewing all available historical data (literature, herbaria) and comparing them with the recent situation. A classification system based on macrophytes was developed, which suggests that the continuous observation of ephemeral green algae, perennial brown algae and the depth limit of macroalgae should be included as major components for the future detection of water quality change.

Effects of the variability of disturbance on the diversity and species composition of macro-epibenthic assemblages (GAME-project) (Dr. Markus Molis)

As part of the international research project GAME, we have shown that environmental effects on macro-epibenthic ecosystems are important determinants of the outcome of species

succession and competition processes. Many predictor variables fluctuate naturally; for example, fluctuating cloud cover yields variable UV-radiation regimes. Disturbances are one major driver of the diversity and species composition of communities. In our study, a disturbance event was artificially induced by random removal of biomass from field-grown macro-epibenthic assemblages. Our field-experiments indicated that the variability of disturbance events affects the structure of field-grown macro-epibenthic assemblages at Helgoland and reduces their diversity. Ecosystem functions may be influenced by the variability of equally intense disturbance events and therefore the design of future experiments on disturbance effects must include the variability of disturbance as a factor explaining variance in responses.

Climate variability and El Niño Southern Oscillation: Implications for natural coastal resources and management (CENSOR) (EU Project) (Prof. Dr. Wolf Arntz, Dr. Jürgen Laudien, Dr. Olaf Heilmayer)

The Humboldt Current Ecosystem (HCE) is significantly influenced by the El Niño-Southern Oscillation (ENSO). Both the warm (El Niño) and cold (La Niña) phases have severe ecological and socio-economic implications. The EU Project CENSOR aims to create a conceptual framework for the integrated interpretation of information on El Niño and La Niña effects based upon existing dispersed sets of data; 2) improve the understanding of coastal systems and thus support the income and livelihood of local communities by an interdisciplinary approach; 3) develop predictive tools to forecast ENSO-induced environmental change; and 4) propose innovative solutions appropriate for the social, economic, institutional and environmental contexts of the countries concerned.

An enormous amount of ENSO literature has been cumulated and made available to the public at www.censor.name. Since July 2005 we have archived 1.500 ENSO data sets in data base PANGAEA. We standardised methods and conduct interdisciplinary process studies for understanding better the HCE: genetic markers are identified to describe genetic drift; macrofaunal communities and their dynamics are monitored to identify ENSO-indicators; *in situ* experiments to enhance recruitment of commercial species showed the importance of ecosystem engineering and habitat structure; tagging-recapture experiments and cohort analysis revealed growth parameters of selected commercial invertebrates; time series data showed that the strong 1997-98 EN forced drastic changes in zooplankton composition reversed during LN 1998, supporting the idea of decadal changes in the pelagic ecosystem.

After just 18 months, CENSOR has received great attention by stakeholders and decision makers. Beside the continuation of our interdisciplinary process studies, to feed into an ECOPATH model, we will focus on incorporating the scientific knowledge gained into an adjustment of traditional resource exploitation methods.

Expressed Sequence Tags of Toxic Algae (ESTTAL) (EU Project) (Prof. Dr. Allan Cembella – coordinator, Dr. Linda Medlin, Dr. Uwe John et al.)

Harmful algal blooms (HABs) are a phenomenon caused by the local proliferation of algae, with deleterious consequences, particularly in coastal waters throughout the world. In the EU ESTTAL project, we are conducting a limited genomic study of expressed sequence tags (ESTs) for a variety of toxigenic taxa representing major eukaryotic microalgal groups and cyanobacteria contributing to HABs in European waters. Recent technological advances in genomics and bioinformatics, and the acquisition of extensive sequence databases, now permit the analysis of genome-wide expression profiles from a diversity of species. Toxigenic strains of each taxonomic group are being grown under optimal conditions for toxin expression. After cloning of cDNA into plasmid vectors, approximately 10,000 clones from each species are being randomly sequenced for ESTs. The sequencing of these cDNA libraries as ESTs is underway and has been essentially completed for some of the designated taxa. Our approach is to annotate the ESTs and attempt to identify genes associated with toxin production. The sequence data will be analysed to identify genes that may be involved in cell regulation and growth, cell cycle events, stress response and the induction of sexuality. Successful completion of the ESTTAL project will yield new information on microalgal and cyanobacterial genomic sequences for a diversity of taxa and will assist in the diagnosis of genes related to toxin biosynthesis, growth and the formation of toxic blooms. Such knowledge can also contribute to the formulation of EU policy regarding the potential effects on HAB dynamics of the input of anthropogenic nutrients into coastal waters.

Impacts of offshore wind farms and bottom trawling on benthic ecology in the North Sea / Response of benthic communities and sediment to different regiments of fishing disturbance in European coastal waters (BeoFINO/RESPONSE) (BMU/EU) (Dr. Alexander Schroeder)

The aim of the BeoFINO/RESPONSE project is to investigate anthropogenic impacts of offshore wind farms and bottom trawling on the demersal system of the North Sea, specifically with respect to macrozoobenthic communities and demersal fish fauna.

BeoFINO studies have shown that the installation of offshore wind energy plants (WEP) will present an interference in the natural system. The artificial hard substrates of the FINO 1 platform underwater construction are inhabited by a high biomass community, which is quite different in species composition and diversity from communities on natural hard substrates. The additional food supply for the surrounding soft bottom fauna favours predatory species and scavengers. Furthermore, the current alterations in the vicinity of the underwater construction lead to erosion of the sea bottom and a remarkable alteration of the sediment structure. These processes in conjunction change the benthic community composition and function in the surrounding of the research platform.

At the same time, the 500m safety-zone around the platform may serve as a sanctuary for more sensitive species. Present results from the EU-project RESPONSE on the effects of bottom trawling show clear shifts in the community structure of the bottom fauna within the protected area. During the first two years, mainly opportunistic species profited from the exclusion of bottom trawling. Development of the present opportunistic fauna of the German Bight, which is shaped by continuous heavy trawling, towards a community characterised by longer lived species will require longer time spans.

The analysis of changes is expanded to include effects on the trophic system, including the spatio-temporal distribution of the fish fauna Results will feed into a mathematical model of the ecological processes in the vicinity of the platform to asses the cumulative effects of the planned large offshore wind farms in the North Sea.

Census of Marine Zooplankton (Sloan Foundation) (Prof. Dr. S. Schiel)

The Census of Marine Zooplankton (CMarZ) aims toward a taxonomically comprehensive assessment of biodiversity of animal plankton throughout the world ocean. The project goal is to produce and complete information on zooplankton species diversity, biomass, biogepgraphic distribution, genetic diversity, and community structure by 2010. CMarZ makes use of existing data and archived zooplankton collections and involves dedicated cruises. Sampling systems includes traditional nets, remote detection, optical sensors, remotely-operated or autonomous vehicles and submersibles. Close coordination between molecular and morphological systematic studies is essential. Important outcomes for CMarZ will be more complete knowledge of biodiversity, new understanding of the functional role of biodiversity in ocean ecosystems, and better characterization of global-scale patterns of zooplankton diversity in the world ocean. Three project offices have been established: in N. America (USA), Asia and Europe. The European office is located at the AWI.

Cooperative projects in the NMR laboratory (partly funded by external partners) (Prof. Dr. Hans-Otto Pörtner, Dr. Christian Bock)

The cellular background of the drastic drop in metabolic rate and in body temperature observed in mammalian hibernation is poorly understood. We therefore used magnetic resonance imaging (MRI) and ^{31}P NMR techniques to investigate brain metabolism in European ground squirrels during hibernation and arousal. We applied flow-, T_2*-weighted MRI and ^{31}P-MRS to hibernating European ground squirrels in torpor and during arousal to euthermy. Blood flow was low in arteries supplying the torpid brain, however, T_2*-weighted images revealed high tissue oxygenation. The results indicate that brain metabolism during torpor is reduced without limitations in oxygen supply, despite low blood flow.

Freshwater turtles frequently experience anoxia in frozen lakes during winter. Therefore, we investigated myocardial energy status and functioning as well as blood flows through the left aorta, pulmonary artery, and carotid artery *in vivo* by MRI and ^{31}P-MRS in anoxic turtles (*Trachemys scripta*) acclimated to cold and warm temperatures. Anoxia in the warm resulted in heart rate and blood flow being reduced, and in reduced cardiac pH_i. ATP levels were defended at 80% of control though the creatine-kinase reaction continuously increased and decreased. These continuous changes suggested that cardiac cellular energetic state was finally compromised during anoxia, despite a constant heart rate. In contrast, anoxia in the cold led to a stabilization of ATP, P_i and PCr levels. Despite these plateaus, bradycardia (a slowing of heart rate) and a reduction in pH_i

continued. Thus, a simple correlation does not seem to exist between cellular energy state and cardiac performance during anoxia.

Science for the Protection of Indonesian Coastal Ecosystems (SPICE) (BMBF Project): Role of fishery and algal farming for material flow and trophic transfer in tropical seagrass systems - Coral Reef-Based Ecosystems (Dr. H. Asmus) and Role of water column processes in material fluxes and trophic transfer in reef ecosystems (Prof. Dr. S. Schiel)

The overall goal of SPICE is to strengthen the scientific basis for protection of coral reefs in southwest Sulawesi, harbouring some of the richest but also most endangered coral reefs in the world. Deteriorating water quality due to increased terrigenous inputs of sediments, nutrients and pollutants are believed to be among the major causes of the demise of Indonesian coral reefs over the last decades. The aim of the pelagic studies is to assess the significance of suspended matter for the reef organisms and to demonstrate that environmental changes are an important factor for changes of phyto- and zooplankton and hence, for their consumers.

Tropical seagrass beds are substantial and integrated parts of coral reef systems and are threatened in the same way. However, they have a unique ecological structure and character and require therefore separate investigations and focus.

The project set new milestones in research of tropical seagrass systems by elucidating the role of holothuroid grazers for the system as well as by describing a separate “underground” community living in the burrows of thalassinid shrimps which play an active role in decomposition of leaf material of seagrasses and in nutrient cycling within the community. The biomass and growth of seagrass communities at the shelf edges are enhanced by local upwelling of nutrient rich deep water leading to strong fluctuations of oxygen saturation between night and day, which seem to inhibit development of a rich faunal association. Some fish species play an important role as grazers on epiphyte and as detritus feeders, depending directly on the seagrass. Direct human impact is barely visible in seagrass beds of the Spermonde archipelago, although over-fishing of the total shelf area may have altered the food web structure of all shelf ecosystems. Algal farming was found to be of minor influence on the system at the present state. However intensification of farming could lead to structural alterations caused especially by shading the seagrass plants.

The results of this project fill gaps in the current knowledge, contribute to a deeper understanding of ecological processes in coral reefs and tropical seagrass beds and helps to evaluate human impacts on these ecosystems. They will help to construct a detailed model of trophodynamic functioning of coral reefs and tropical seagrass beds in the near future.

Diversity and interactions of organisms associated with marine biotic habitats (BMBF Project) (Dr. Christian Buschbaum)

In the marine environment many organisms provide structural habitat for a multitude of associated species. The biogenic habitats formed by these ecosystem engineers are colonized by a rich and characteristic community of organisms and present biodiversity hotspots in comparison to the surrounding environment. Mytilid bivalves are a major group of ecosystem engineers, which are abundant on coasts worldwide. In this project, organisms associated with mussel (*Mytilus edulis*) beds in the northern Wadden Sea were compared with those of *Perumytilus purpuratus* along the rocky shore of central Chile. Studies were conducted on mussel beds from hard and soft bottoms to determine if some associated organisms contribute to the high diversity in these biogenic habitats. The study revealed that mussel beds provide a suitable habitat for many associated organisms on both sedimentary and rocky shores. Additionally, the investigations showed that soft bottom mussel beds are mainly overgrown by sessile organisms, which themselves contribute to the structural complexity and, therefore, high diversity. In beds of *P. purpuratus* in Chile, by contrast, many soft bottom organisms were predominantly found. They live between the mussels in sediment which was trapped by the mussel aggregation. Thus, along both sedimentary and rocky shores, mussel beds provide suitable living conditions for organisms that would not occur without these biogenic habitats.

Personnel

Personnel	Institutional funding	Third party funding
	Scientists / PhD / Technicians	Scientists / PhD / Technicians
AWI	16/4/10	4/11/2

Publication outcome numbers

Academic Publications Refereed only	2004 - 2006
ISI	52
non ISI	18
PhD theses	7
Master & Diplom Theses	5
Books	0
Book chapters	5

Key publications

1. Buck, B. H., Krause, G., Rosenthal, H. (2004). Extensive open ocean aquaculture development within wind farms in Germany: the prospect of offshore co-management and legal constraints, Ocean and Coastal Management, 47(3-4), 95-122.
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Research Division Climate Sciences: Non Program research

(Spokesman: Prof. Dr. Dirk Olbers)

Report on the general development of the Research Division Climate Sciences

The scientists in the research division Climate Sciences explore the physical and biochemical processes in the atmosphere, the cryosphere and the hydrosphere of our planet which shape the earth's climate. The aim of our research is to throw light on the physical and chemical processes in the named spheres, their interactions and their impact on changes in climate and environment. Extensive field measurements are effected, using research vessels, planes and observatories, primarily in polar areas in the ocean, in the sea ice and in the atmosphere in order to observe the state and the development of the spheres and the earth's climate and create preconditions for modelling and prediction. To obtain a basis for judging decadal and long-term processes, our measurements contain process studies which temporally concentrate on special questions as well as long-term programmes to register the condition of different components of the polar system. Corresponding measuring systems and observatories must be installed, optimised and maintained on a long-term basis. In parallel, we develop physical-mathematical models for single processes in the different spheres and for coupled models for the global climate system, and we assess the results.

The scientists in the research division Climate Sciences work in many areas of the research programme MARCOPOLI. There are also activities in non-MCPI research which are described below, sorted as per sections and major projects.

Short description of additional research themes of the Geosystem

Polar Meteorology (PD. Dr. Ulrike Wacker)

The non-MarCoPoll research in Polar Meteorology was concentrated on fundamental studies. They comprise investigations of cloud physical interactions and of turbulence and its parameterised treatment for strong convective conditions.

In the context of cloud physical research, dynamical features of a mixed-phase cloud were analysed with the help of a conceptual model; the newly developed version of this model is one-dimensional to account for interactions between cloud layers. Condensate mass is transported into and out of the cloud by precipitation and by vertical advection, and internal interactions are due to cloud microphysical transformations and vertical transports within the cloud. Thus, the model describes an open nonlinear system. A qualitative analysis revealed that this system shows multi-stability and bifurcations. Self-excited oscillations are possible. The time scales depend on, among others, the strength of the internal coupling. They are of the order of an hour, which is typical for real clouds. Moreover, three regimes could be identified depending on the 'parameter' vertical velocity.

A challenging problem in atmospheric research is the improvement of the parameterisation of transport of heat, momentum, and humidity under strong convective conditions. It is well known that under these conditions the application of higher-order turbulence closures (HOC) is superior to lower order models, since e.g., counter gradient transports of scalars can be modelled. However, HOC models require assumptions on the parameterisation of the fourth order moments. For a long time the so-called Millionshchikov hypothesis, that the fourth order moments can be approximated as quasi-normal (Gaussian), was accepted without discussion. We have now developed a refinement of this hypothesis. This led to a new parameterisation which is non-Gaussian due to the effect of coherent structures. The comparison between results of the new parameterisation with aircraft measurements and with large eddy simulation data shows a very good agreement for all moments. The new parameterisation has also been very successfully applied in astrophysics and ocean modelling.

Observational Oceanography (Dr. Eberhard Fahrbach)

The fieldwork in physical oceanography is aimed at investigations of water mass properties and transports in the Weddell Sea and Fram Strait by application of new technologies. The activities occurred in cooperation with the technology group Marine Observing Systems, complemented the MARCOPOLI programme and were supported by EU and BMBF projects. Whereas the focus in the MARCOPOLI projects is on the interpretation of the obtained data, the additional research activities aim at the design and implementation of observation systems which are able to maintain measurements over time scales which are beyond the MARCOPOLI period and pave the way towards operational systems. This requires the development of instruments (e.g.

floats in sea-ice covered areas), the realisation of measurements (e.g. deployment of arrays of sound sources which last at least 5 years) and the evaluation of measurements and model results on the optimisation of the deployment pattern (e.g. reduction of moorings to key areas or selection of more appropriate sensors). An important aspect is the reduction of the need of ship time by prolongation of the deployment periods. However, the need to obtain data in near real time as a step towards operational products or at least in time steps which allow analysis of the ongoing processes requires the implementation of either satellite or acoustic or combined transmission systems. The activities are concentrated to the Atlantic sector of the Southern Ocean and Fram Strait. The envisioned observation systems can only be maintained in international cooperation.

In the Weddell Sea water mass properties and transports were measured to detect decadal variations which might affect the large-scale oceanic overturning circulation. In the Atlantic sector of the Southern Ocean 92 profiling floats have been deployed since 1999 in the context of the international Argo project. Since December 2001, they have been equipped with an ice-sensing system developed in the technology group Marine Observing Systems to avoid surfacing and potential damage when sea ice is present. From January 2005 on, NEMO floats provided by Optimare Sensorsysteme were able to store profiles recorded under the sea ice. From the obtained data temperature and velocities fields in 750 m depth were derived. Both fields show large similarities, emphasizing the advective component of the heat transport in the Weddell gyre. At about 30°E, both temperature and flow field show clearly the southward spreading of waters influenced by the Antarctic Circumpolar Current. South of about 60°S, these waters spread to the west as part of the southern branch of the Weddell Gyre.

In Fram Strait data from the moored array maintained in the MARCOPOLI programme to measure the exchanges between the North Atlantic and the Arctic Ocean were supplemented by records from bottom pressure recorders equipped with inverted echosounders (PIES). The data were used to investigate the potential to detect changes in the heat content of the West Spitsbergen Current by variations of the propagation time of sound signals from the instruments to the sea surface and back. The variations of the volume transports should be revealed by variations of the horizontal pressure differences at the sea bottom. The obtained ranges of variability are large enough to be detected by PIES, and a direct transformation into heat transport will occur on the basis of the data from the current meter moorings. The potential to obtain data in shorter periods than the mooring replacement by autonomous data transmission systems (pop-up buoys) is investigated.

Paleo-climate Dynamics (Prof. Gerrit Lohmann)

Besides the themes covered by the MARCOPOLI programme, the section Paleo-climate Dynamics develops new methodical and textual special fields. There were extreme climate conditions in the earth's history in the Neoproterozoic 750 - 545 million years ago. In the frame of cooperations with the Universities of Würzburg and Bremen we are evaluating under which environmental conditions, earth orbital configurations and palaeogeography a glaciation of the earth's surface may have happened. For this purpose we use numerical climate models, explicitly depicting the surface characteristics and climate dynamics. It is shown that, like in the case of the simple energy balance models, there may be multiple steady states. The parameters to be varied are the atmosphere's CO2 content, the land-sea distribution, the albedo as well as the initial condition.

Outside the MARCOPOLI topics, we still work on prediction schemes for climate indices. The method of stable teleconnections used for reconstruction of indices of dominant patterns of modern climate variability from proxy data is used to derive statistical schemes for seasonal predictions of climate anomalies. The application of this methodology for the particular case of European jetstream, leads to a significant increase in the skill of the forecast of winter and spring river runoff anomalies using sea surface temperature, temperature and precipitation from stable regions as predictors.

Furthermore, the section has developed and uses a web-based analysis tool, with which instrumental model data can be compared with observational and proxy data. We also apply methods to reduce the data of time-spatial structures. This analysis tool was deployed for research purposes as well as for teaching at the University of Bremen and the European Graduate Lecture Courses.

Atmospheric Circulation (Prof. Klaus Dethloff)

In our non-MARCOPOLI research we prepare the IPY 2007/08 with modelling and measuring activities and their international coordination. For this purpose we refined the coupled regional model of the Arctic climate system HIRHAM-NAOSIM in the frame of the EU Project GLIMPSE. Simulations over 10 years with ERA 40 data forcing at the outer edges of 1990-2000

were effected in order to improve our understanding of the atmosphere-ocean-sea ice couplings. Although the simulations already show good results, the model develops too high winter temperatures, related with too thin ice in some Arctic regions.

Complementarily, we initiated an international CARMIP (Coupled Arctic Regional Climate Model Intercomparison Project) project as a part of the THORPEX IPY. On the measuring side we prepare to participate in radio- and ozone soundings at a Russian drifting station in the frame of the IPY.

In the frame of a DFG project, the regional atmosphere model HIRHAM was applied to simulate the circulation over the Antarctic. The aim was an improved understanding of the processes determining the regional circulation patterns of atmospheric and climate conditions in the Antarctic. Here, we mainly concentrated on the improved description of catabatic wind systems and their coupling with synoptic cyclones.

Ocean Dynamics (Prof. Dr. Dirk Olbers)

In our non-MARCOPOLI research we examined climate variations in the North Atlantic, and here especially the connection between vertical overturning and atmospheric forcing. In cooperation with the Institut für Meereskunde Kiel (IFM-GEOMAR) we combined data assimilation in the form of reduced rank Kalman filtering and inverse methods with forward modelling. We found a clear relation between circulation patterns and the North Atlantic Oscillation index (NAO) of the previous years.

In support of satellite missions (Geotechnology Programme) we participate in the calibration of altimeter data as well as gravity field analyses, mainly by modelling and data assimilation. We also evaluate measurement data of the pressure at the ocean bottom.

In the project MERSEA (Marine EnviRonment and Security for the European Area), supported by the EU, AWI works on two aspects. On the one hand we deal with the optimal ascertainment of parameters which are difficult to measure in nature, such as growth rates in biological-numeric models. On the other hand we work on the optimizing method itself, further developing and successfully using the ‚Sequential Importance Resampling' filter. A method has been designed that estimates the influence of processes not explicitly described by the model. An improved version of the SIR Filter has allowed us to calibrate the ecosystem model with the Bermuda Atlantic Time-series Study data set. Results show a better reproduction of the upper mixed layer ecosystem dynamics observed at the location.

A generalisation of the Transformed Eulerian and Temporal Residual Means for representing and parameterising meso-scale ocean eddy fluxes has been developed. The new formulation uses rotational fluxes of buoyancy, and the full hierarchy of statistical density moments, to reduce the cross-isopycnal eddy flux to the physically relevant component associated with the averaged water mass properties. The resulting eddy-induced-diapycnal diffusivity vanishes for adiabatic, statistically steady flow, and is related to either growth or decay of mesoscale density variance and/or the covariance between small-scale forcing (mixing) and density fluctuations.

Marine Observing Systems (Dr. Olaf Boebel)

The technology group „Marine Observing Systems" undertakes research to study the potential impact of anthropogenic sound on marine mammals in the Antarctic Ocean. The research focuses in particular on the effects of scientific sonars and air-guns used onboard RV Polarstern with regard to marine mammal physiology and behaviour. To this end, sound emission characteristics of various systems were analysed by means of models and *in-situ* measurements. Behavioural and physiological studies focus on measurements of the basic hearing abilities of Antarctic seals. Auditory evoked potentials (AEP), especially the auditory brainstem responses (ABR) of immobilised seals are measured by electro-encephalogram (EEG) electrodes leading to the detection of audible frequency ranges and corresponding hearing thresholds. Further efforts concentrate on the detection of marine mammals in the vicinity of RV Polarstern. MAPS (Marine Mammal Automated Perimeter Surveillance) uses infrared images and passive acoustic data to feed automated pattern recognition software. A third project, PALAOA (PerenniAL Acoustic Observatory in the Antarctic Ocean) seeks to improve our extremely patchy knowledge about abundance and distribution of marine mammals in the Weddell Sea, and Neumayer Base in particular. PALAOA uses four hydrophones deployed through the Ekström ice shelf to continuously collect broadband acoustic underwater recordings which are transferred in quasi real-time to AWI for further analysis. The data stream is made accessible to the public – particularly for use by schools - via the AWI web server at
http://www.awi.de/acoustics/livestream/.

Oceanographic technologies are developed within three projects, jointly funded by AWI and third parties (BMBF an EU) and in collaboration with a local SME, Optimare. The development of ice-compatible ARGO floats aims at the extension of the ARGO array of profiling floats into the Weddell Sea. Technical modifications helped to improve the float survival rate during austral winter – i.e. a period when the presence of sea-ice is likely to destroy the floats when at the surface – from less than 50% to 80%. The introduction of interim storage of wintertime data provided the first under-ice profiles from floats which will now be analysed to study water formation processes. To quality control the significant amount of data that is generated by these floats, efforts are carried out to implement an operational, automated data stream from raw- to quality-controlled data. A second oceanographic project aims to provide bottom pressure sensor data to validate geoid estimates from the GRACE satellite mission. As it is desirable to leave the bottom pressure sensors at the seafloor for as long as possible, infra-red coupled pop-up capsules are being developed to provide an early data transfer from the seafloor to the sea surface, from where the data will be transmitted to AWI via satellite link. Last not least, bottom pressure sensor packages are currently being modified and equipped with an acoustic modem to develop an inexpensive bottom pressure sensor package for the German-Indonesian Tsunami Early Warning System. The system is designed to be compatible with the US DART-II system to facilitate interchangeability.

Tsunami (Dr. Jens Schröter)

Lately, AWI has been cooperating with the German Consortium for the development of a tsunami early warning system in the Indian Ocean (GI-TEWS), doing modelling work with the finite elements ocean model developed in MARCOPOLI for the exact description of tsunami propagation. Furthermore, the model results support the development of an oceanic measuring net capable of discerning increased water levels connected with a tsunami and notifying onshore stations. Fast solution algorithms are necessary for modelling in order to obtain short forewarning times.

Earth observation systems (Helmholtz-EOS) (Prof. Peter Lemke)

Helmholtz-EOS is a research network in which selected processes in the earth system shall be understood and simulated by observing and modelling. Apart from AWI, also DLR, GFZ and GKSS participate in the network. Four themes are presently prosecuted with priority: ice and ocean, catastrophy management, processes of the land surface and the water cycle. A considerable part is the doctorate programme in two themes of which AWI participates:

Development of the global sea level The prevailing majority of human beings lives near the shore and is affected by changes in sea level. It is therefore of special interest to provide reliable statements on the extent of this change. Not only the mean global increase plays a role, but especially the regional differences are important. Our examinations focus on a more exact evaluation of the contribution of the different factors leading to a change in sea level.

Carbon dynamics in Arctic permafrost landscapes For realistically balancing greenhouse gas emissions from Arctic permafrost areas with the aid of remote sensing methods detailed field observations („ground truth“) are necessary as well as knowledge on the interactions between permafrost bottom, defrosting layer and surface-near air layers. We aim at developing a facility for balancing and predicting carbon fluxes in Arctic permafrost regions and their spatial extrapolation („upscaling“).

Aircraft- and land technique (Dr. Andreas Herber)

The Alfred Wegener Institute operates presently one ski-equipped aircraft (Dornier 228/101) for scientific and logistic purposes in polar regions. Aero-geophysical instrumentation, different atmospheric systems and also remote sensing systems for coastal research are available and will be used in future projects. The overall aim of our past and future aircraft-based research activities is to improve our understanding of interactions between Lithosphere, Ice, Ocean, and Atmosphere.

The airborne geophysical survey activities have been focused on mapping regional lithospheric structure above the Antarctic continent and Greenland. Glaciological measurements have been performed with the aim to study the internal structure of the Antarctic and Greenland ice sheets, especially between deep ice core drill sites. The atmospheric activities were focussed on the study of optical, physical, and chemical properties of aerosols and clouds to quantify aerosol and water vapour variability in polar regions. A second topic was here the investigation of radiative and turbulent processes in the planetary boundary layer and their interaction with surface in homogeneity due to melt ponds, ridges and leads in sea ice covered regions. During the Antarctic operations the polar aircraft were used also for logistic activities, especially for the transport of ice core from Kohnen station to Neumayer Station.

The scientific objectives of future campaigns need different mobile flexible platforms with operations in different climates for regular survey and case studies. Additional platforms could be

long-range fixed wing aircraft and unmanned air vehicles (UAVs). AWI is taking a holding on the operation costs for HALO (High Altitude and Long Range Aircraft), enabling a geophysical survey in the interior of Antarctica and atmospheric research flight crossing the Arctic Ocean. An additional programme is starting soon, using a specially designed UAV, the so-called POLARIS S16, for coastal and polar activities.

Collaborative Climate Community Data and Processing Grid (C3-Grid) (Prof. W. Hiller)
For the last decades the amount of data has increased enormously in this field of earth system sciences. Monitoring the earth with satellites results in a huge data stream.
On the other hand, due to rapid rise in computing power scientists are now able to use coupled models with higher resolution and complexity and to perform long term simulations producing petabytes of output. The data are stored in distributed archives. Up to now, no uniform access to these data is available what creates a bottleneck for the scientific work. Our project „Collaborative Climate Community Data and Processing Grid – C3-Grid“ proposes to link distributed data archives in several German institutions for earth system sciences. With the help of grid technologies we will build up an infrastructure for the scientists in climate research which provides tools for effective data discovery, data transfer and processing. This can increase the productivity in scientific work for the German climate scientists and can help to enforce the international collaboration.

Personnel

Personnel	Institutional funding	Third party funding
	Scientists / PhD / Technicians	Scientists / PhD / Technicians
AWI	9 / 6 / 0	8 / 10 / 2

Publication outcome numbers

Academic Publications Refereed only	2004-2006 publ./in press
ISI	134/27
non ISI	46/9
PhD theses	9/0
Master & Diplom Theses	2/0
Books	4/0
Book chapters	9/3

Key publications

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