EXPEDITIONSPROGRAMM NR. 86

FS POLARSTERN

ANT-XXVII/1

ANT-XXVII/2

ANT-XXVII/3

ANT-XXVII/4

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ANT-XXVII/1

25 October 2010 - 25 November 2010

Bremerhaven - Las Palmas - Cape Town

Chief Scientist

Karl Bumke

Contents

1. ÜBERBLICK UND FAHRTVERLAUF

Karl Bumke, IfM-GEOMAR

Am 25. Oktober 2010 wird FS *Polarstern* den Fahrtabschnitt ANT-XXVII/1 von Bremerhaven nach Kapstadt antreten. Die Fahrt wird zur kontinuierlichen Messung atmosphärischer und ozeanischer Eigenschaften sowie der Energie- und Stoffflüsse zwischen Ozean und Atmosphäre Gerätetests genutzt.

Das weiterentwickelte Gerät Hydrosweep DS-3 soll im Einsatz auf See getestet werden. Diese Tests werden in der Biskaya, am afrikanischen Kontinentalhang und bei der Romanche-Bruchzone stattfinden, um sie mit den Ergebnissen früherer Expeditionen vergleichen zu können. Die Wassertiefen sollen bis zu 8000 m betragen. Das Unterwasser-Navigations-System POSIDONIA 6000 soll nach Modifikationen der Schutzscheibe getestet werden, um seine Einsatztauglichkeit zu zeigen.

Um die experimentelle Erfassung von Stoff- und Energieaustausch zwischen Ozean und Atmosphäre auf eine solide Basis zu stellen, ist im Rahmen von OCEANET geplant, mittels der Vernetzung der Expertisen des IFM-GEOMAR (CO_2-/O_2-Flüsse, photosynthetischer Status, Energiehaushalt, Fernerkundung), des IfT (Lidarmessungen), des GKSS Forschungszentrums („FerryBox“ und Fernerkundung der marinen Biologie mit ENVISAT/MERIS) und des AWI-Bremerhaven (CO_2-System, marine Infrastruktur von FS *Polarstern*) autonome Messsysteme zu entwickeln, die langfristig für den operationellen Betrieb an Bord von Fracht- und Forschungsschiffen vorgesehen sind.

Die kontinuierliche Messung kosmischer Teilchen erfolgt, um die Breitenabhängigkeit auf Grund sildes Erdmagnetfeldes und das „kosmische Wetter“ zu untersuchen. Unter Einbeziehung der Wolkenbeobachtungen kann der Einfluss der Rate kosmischer Teilchen auf die Bewölkung untersucht werden.

Die Bestimmung „neuer“ potentieller persistenter organischer Schadstoffe (Persistent organic pollutants = POPs) z.B. alternative Flammschutzmittel und verschiedener „traditioneller“ POPs erfolgt zur Untersuchung ihres Transport- und Verteilungsverhaltens in der Atmosphäre und im Ozean. So werden z.B. polychlorierte Biphynele (PCBs) und polybromierte Dephenylether (PBDEs) in der Atmosphäre in entlegene Regionen transportiert. Die Untersuchung von Halogenkohlenwasserstoffen soll die Frage beantworten, welche Rolle der Ozean im globalen Haushalt der Kohlenwasserstoffe spielt. Darauf basierend werden Vorhersagemodelle entwickelt, die beantworten sollen, wie kommende globale Änderungen sich auf die Transporte dieser Stoffe zwischen Ozean und Atmosphäre auswirken. Reaktive Halogene spielen eine wichtige Rolle in der Chemie der maritimen Atmosphäre, indem sie Einfluss auf das atmosphärische Ozon ausüben und darüber hinaus an der Bildung ultrafeiner Partikel beteiligt sind. Die Messungen von Jodmonoxid und Stickstoffdioxid mit DOAS sollen die Frage beantworten, welche Rolle der offene Ozean bei diesen Prozessen im Vergleich zu den Küstenregionen spielt.

Ein neu entwickeltes seegängiges Membran-Einlass-Massenspektrometer (MIMS) soll getestet werden. Die Messungen sollen die Auswirkung des atmosphärischen CO_2 auf Kieselalgen zeigen. Diese Messungen erlauben die Quantifizierung der zellularen Kohlenstoffflüsse und die Untersuchung von Photosynthese-Prozessen.

Im Südatlantik soll eine Tiefseeverankerung vor Namibia nahe des Walfischrückens ausgebracht werden. Die Verankerung trägt einen passiv-akustischen Rekorder, Sonovault, um die Anwesenheit der großen Bartenwale in ihren vermutlichen, bislang jedoch weitgehend unbestätigten Brutgebieten zu untersuchen.

Polarstern wird am 25. November 2010 in Kapstadt einlaufen.

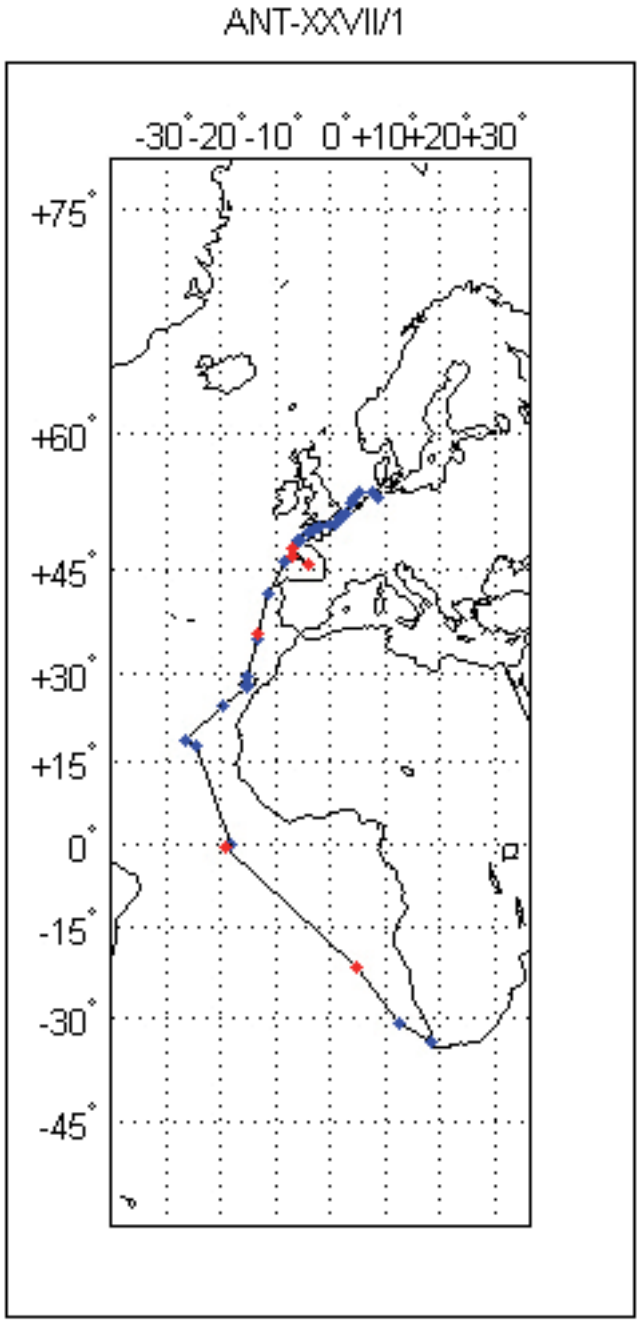

Abb.1.1: Fahrtroute während ANT-XXVII/1
Fig. 1.1: Route of ANT-XXVII/1

SUMMARY AND ITINERARY

On 25 October 2010 RV *Polarstern* will start the cruise ANT-XXVII/1 from Bremerhaven to Cape Town. The cruise will be utilized for continuous measurements of atmospheric and marine properties as well as for energy and material fluxes between ocean and atmosphere and instrument tests.

Sea acceptance tests of the upgraded version Hydrosweep DS-3 will take place in the Bay of Biscay, at the African continental slope, and in the area of the Romanche fracture zone at water depths up to 8,000 m to compare the gained data with those of former cruises. The modified protective window of the underwater navigation system will be tested intensively to ensure its usefulness for future cruises.

In order to provide a solid basis for the observational monitoring of energy and material exchange between ocean and atmosphere it is planned in the context of the OCEANET project to develop an autonomous observation system for operational use onboard cargo and research vessels. The project is based on a network of expertise from IFM-GEOMAR (CO_2-/O_2-fluxes, photosynthetic status, energy budget, remote sensing), IfT (lidar measurements), the GKSS research center (ferry box, remote sensing of marine biology with ENVISAT/MERIS) and AWI-Bremerhaven (CO_2-system, marine infrastructure of *Polarstern*).

The latitude dependence of the particle flux and possible of “cosmic weather” effects are investigated by continuous rate measurement of cosmic particles. With the simultaneous observations of clouds, the influence of the cosmic particle flux on cloud formation can be studied.

Persistent organic pollutants (POPs), such as polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs) will be measured to determine “new” possible POPs (e.g. alternative flame retardants) and several legacy POPs with respect to their transport and portioning between atmosphere and ocean. Measurements of halocarbon will be used to improve the understanding of the role of the ocean in the global halocarbon cycle. This allows the development of numerical models to predict, how the expected global change will affect the air sea interaction of halocarbons. A newly developed ship-going membrane-inlet mass spectrometer will be tested. Measurements will be performed to understand the relation between the atmospheric CO_2 and the diatom population. The measurements will allow cell processes to be addressed and therefore to quantify processes of photosynthesis. Measurements of Iodine monoxide and nitrogen dioxid will be performed with DOAS to improve our understanding how the open sea contributes to the global budget of reactive iodine. Reactive halogens play an important role in the chemistry of the marine atmosphere by influencing ozone concentration and by forming new ultrafine particles.

Steaming towards Cape Town, a deep-sea mooring shall be deployed off Namibia near Walvis Ridge. The mooring shall host a passive acoustic monitoring device, SonoVault, to verify the presence of large mysticetes species on their proposed, yet largely unconfirmed, breeding grounds.

Polarstern will arrive in Cape Town on 25 November 2010.

2. AUTONOMOUS MEASUREMENT PLATFORMS FOR ENERGY AND MATERIAL EXCHANGE BETWEEN OCEAN AND ATMOSPHERE (OCEANET): ATMOSPHERE

K. Bumke, J. Kalischi, Y. Zoll, (IFM-GEOMAR), A. Macke D. Althausen (not on board), T. Kanitz (IfT), H. Kleta (DWD), G. Horváth (MPI), A. Horvath (Environmental Optics Laboratory), A. Barta (Estrato); A. Egri and M. Blaho (not on board) (Environmental Optics Laboratory, Budapest)

Objectives

Radiation & microwave remote sensing

The net radiation budget at the surface is the driving force for most physical processes in the climate system. It is mainly determined by the complex spatial distribution of humidity, temperature and condensates in the atmosphere. The project aims at observing both the radiation budget and the state of the cloudy atmosphere as accurate as possible to provide realistic atmosphere-radiation relationships for use in climate models and in remote sensing. While similar experiments have been performed from land stations, only few data from measurements over ocean areas exist. The present project is part of the “Meridional Ocean Radiation Experiment” MORE which uses Atlantic transfers of various research vessels for the combined measurements of the atmospheric state since 2004. The main project behind this cruise is the WGL-PAKT Initiative OCEANET.

A multichannel microwave radiometer will be applied to continuously retrieve temperature and humidity profiles as well as cloud liquid water path over the ocean. Time series of these profiles will show small scale atmospheric structures as well as the effects of the mean state of the atmosphere and its variability on the co-located measurements of the downwelling shortwave and longwave radiation. The atmospheric profiles will also be used to validate the satellite based profiles from the IASI instrument onboard the new European polar orbiting satellite MetOp.

Atmospheric aerosol optical thickness will be measured by means of hand-held sun photometer and spectral solar radiometer. A spectral UV-radiometer will perform high resolution UV radiance observations from 200 to 400 nm wavelengths. Most instruments will be integrated in the new container-based atmosphere observatory.

Air-sea interaction and fluxes

Great emphasis has to be put on air-sea fluxes of momentum, sensible and latent heat to improve numerical models of weather forecast and climate simulations since oceans cover 71 % of the earth’s surface. The fluxes of sensible and latent heat are also of importance for the energy budget of the ocean and the atmosphere. Due to the steady increase of many trace gases in the atmosphere like CO_2, *in-situ* gas flux measurements are required to establish parameterizations that provide flux estimates in climate models.

To estimate the turbulent fluxes of momentum, sensible heat, latent heat, and CO_2 a sonic-anemometer and an open path LiCor will be mounted. Measurements are taken at a sampling

rate of 10 Hz (LiCor) respectively 30 Hz (sonic-anemometer) allowing to derive the fluxes by applying the inertial dissipation method. This method relies on measurements at high frequencies, less distorted by the motion and the superstructure of the ship than the covariance technique. With additional measurements of the sea surface temperature (SST) in combination with observations of the standard meteorological parameters and measurements of the CO_2 content in ocean and atmosphere which are at a lower data rate performed by marine chemists (see section 2) flux parameterizations can be derived.

To measure the SST a system of an upward and a downward looking radiometers is used. The measured brightness temperatures of the ocean and the atmosphere are also of interest for the estimates of the net radiation budget.

Autonomous observations of standard meteorological parameters

An autonomous meteorology observing system operated by the DWD will be tested in collaboration with the container based atmosphere observatory.

Lidar observations

The high temporal and spatial variability of atmospheric aerosol characteristics, i.e. in number concentration, size distribution, shape and chemical ingredients, complicates their exact specification and consideration in radiative transfer models.

The Raman lidar measurement technique is able to provide main information about the vertical profiles of aerosols. With this technique the particle backscatter and extinction coefficient can be determined, i.e. the aerosol optical properties can be described in a quantitative way. Furthermore the use of three backscatter coefficients and two extinction coefficients enable an inversion method to estimate the main microphysical properties at any measured height.

24-h measurements by the 3+2+1 Raman lidar system PollyXT aboard the *Polarstern* at its transit cruises imply the opportunity to characterize the optical and microphysical particle properties above the Atlantic Ocean. These particles in different layers of the atmosphere above the Atlantic are lifted up and are intercontinentally transported from distinct source regions like anthropogenic emissions from North America, dust from Saharan region or smoke from biomass burning in South America or Africa.

Enhance research is focused on the aerosol properties, due to the variable effects on down- and upwelling radiation, which are still uncertain. The determined optical and microphysical particle data will be used in the height resolved radiative model LibRadtran. This model allows an estimation of the radiative influence of different aerosols, even if they occur in separated layers.

The height resolved results will be compared by simultaneous column integrated ship and space borne measurements, also in the case of vertically separated aerosol layers.

Whole-sky cloud imaging

During the expedition a fully-automated polarimetric whole-sky cloud imaging instrument will be deployed as well as its portable semi-manual version for the OCEANET research project to detect and investigate clouds, especially thin cirrus. The current cloud detector of this project is solely photometric, that is, it only uses intensity measurements in three independent spectral channels. Our detector, however, provides more information of a given sky scene and, thus, can theoretically give more accurate and more reliable results. It is already experimentally

proven in a few case studies that additional sky polarization data can enhance the reliability and accuracy of cloud detection. It is even possible to derive other useful parameters, such as relative cloud-base height distribution from polarimetric measurements, which can further help to categorize cloud types. Our main goal is to quantitatively test in a large statistical dataset whether or not our polarimetric instrument can consistently give better cloud detection than the current photometric one. The evaluation of these results may also uncover additional areas of atmospheric research where our new measurement method can be successfully used.

In addition to clouds, we would also like to measure the polarization characteristics of other atmospheric optical phenomena, especially twilight skies after sunset and prior to sunrise, fogbows, and various halos around the sun and the moon. Although fogbows and halos have often been photographed, their polarization characteristics have only been investigated theoretically via mathematical calculations and computer simulations. The polarization pattern of the twilight sky after sunset and prior to sunrise is important for the navigation of certain dusk-, night- and dawn-active (crepuscular and nocturnal) animals, for example bees. It is also possible that beyond fogbows and halos, we can measure the polarization pattern of some unexpected phenomena (for example, dust storms), as happened frequently during our earlier expeditions, field trips and measurement campaigns.

Work at sea

Upon departure from Bremerhaven the container-based atmosphere observatory will be installed at the observation deck of *Polarstern*. The following individual instruments are combined:

- Multichannel microwave radiometer HATRPO. The instruments requires occasional calibrations with liquid nitrogen as well as tipp-calibrations under calm sea and homogeneous atmospheric conditions.
- Multichannel Raman-Lidar Polly for aerosol measurements. PollyXT is designed as standalone portable Raman lidar system. After measurements at Manaus, Brazil and New Delhi, India, it will be the first time that this system will be operated onboard a ship. Therefore, the system requires calibration and technical service all the time. It will operate whenever weather is appreciable and placed in the OCEANET container at the observation deck.
- Whole sky imager for cloud structure measurements
- Sonic anemometer USA-1 to measure the wind components and temperature
- LiCor to measure water vapour and CO_2
- M-100 absorption hygrometer to measure water vapour
- System of a KT-4 and a KT-19 radiometer to measure SST and the brightness temperature of the atmosphere
- Installation of the DWD autonomous meteorology observing system into the container-based atmosphere observatory.
- The automated imaging polarimetric cloud detector will be set up on the main deck to continuously measure the polarization pattern of the sky during daylight hours, and independently of weather. It is planned to start data processing aboard the ship.

When a unique atmospheric optical phenomenon (for example, fogbow, rainbow, sunhalo, moonhalo, noctilucent cloud, etc.) appears, a researcher will measure its polarization characteristics using the portable imaging polarimeter.

Occasional extra-radiosoundings will have to be performed close to the overpass times of the MetOp satellite. Synoptical observations will be done every hour, aerosol optical thickness measurements every 30 minutes (under direct sun conditions). Most instruments require little maintenance.

Turbulence measurements should take place on a mast or similar device close to the bow to minimize the flow distortion by the ship's superstructure.

Expected results

- Two-dimensional structure of the clear sky atmosphere and corresponding net radiation budget.
- Horizontal structure of the cloud water path and its effect on the downwelling shortwave and longwave radiation
- Vertical structure of temperature and humidity as well as its variability for validation of satellite products
- Vertical profiles of tropospheric aerosols and their effect on radiation
- Sea surface roughness (tilt angle distribution)
- Turbulent fluxes of momentum, sensible, and latent heat
- Flux of CO_2 between ocean and atmosphere
- Parameterizations for measured radiation fluxes (it is expected that this will require more data than those which will be gained during this planned cruise)
- The processed data will contain the degree and angle of polarization patterns of the full sky from which clouds can be detected and additional cloud properties (for example relative cloud base height, proportion of cloud cover, etc.) can be derived, with probably higher accuracy than with a simple photometric instrument (traditional whole-sky imager).

In addition, from data obtained with the portable imaging polarimeter, the polarization characteristics of atmospheric optical events of opportunity can be quantitatively determined and compared with theoretical and computational models.

3. AUTONOMOUS MEASUREMENT PLATFORMS FOR SURFACE OCEAN BIOGEOCHEMISTRY (OCEANET): OCEAN

W. Mohr, L. Vielstädte, N.N. (IFM-GEOMAR)
Bremerhaven – Las Palmas: H. Bittig, T. Steinhoff (IFM-GEOMAR)
A. Körtzinger, J. La Roche (not on board) (IFM-GEOMAR)
M. Hoppema (not on board) (AWI), S. van Heuwen (not on board) (NIOZ)

Objectives

The aim of the WGL-PAKT-Initiative OCEANET is to develop new autonomous instruments for the investigation of energy and matter exchange at the air-sea interface. The multi-institutional participants from IFM-GEOMAR, GKSS and AWI intend to build up a sensor network that investigates atmospheric and surface ocean properties. In order to meet the growing demand for increased spatial and temporal data, autonomous sensor networks that can be deployed on

merchant vessels are needed. Tests of new instruments and measuring techniques as well as the installation of instrumentation aboard *Polarstern* are essential components of the project.

The oceanic component of this study focuses on the marine carbon cycle in the surface ocean which is of high climate relevance but at the same time susceptible to climate change. The surface ocean's CO_2 source/sink function is maintained by a complex interaction of physical and biological processes. Therefore its understanding requires measurement of various different parameters as it is pursued within OCEANET.

During the upcoming cruise the work carried out during the earlier transit expeditions (ANT-XXIV/4, ANT-XXV/1 and 5, ANT-XXVI/1 and 4) will be continued. During the first OCEANET cruise the feasibility of autonomous underway measurements was assessed for a wide range of instruments for measurement of physical (temperature, salinity, turbidity), chemical (CO_2 partial pressure (pCO_2), pH, oxygen, total gas tension, nutrients), and biological parameters (chlorophyll a, photosynthetic parameters) and first intercomparisons of measurements of pCO_2 and oxygen took place. During the second cruise the focus was on intercomparison measurements of CO_2 partial pressure with diverse autonomous underway flow-through as well as submersible systems. The work on the third transit dealt with the closer investigation of a commercial submersible pCO_2-sensor and included CTD casts with the instrument. Underway pCO_2-measurements were run as a reference. Nitrate and nutrient determinations were part of the work as well.

During ANT-XXVII/1 the "standard setup" of proved sensors will be installed. The standard sensors include pCO_2 measurements by the classical equilibrator system installed on board and measurements of dissolved oxygen, total gas tension and nitrate.

Furthermore biological measurements will be conducted. The main objective of this project is to assess the diversity and activity of diazotrophic microorganisms and to determine rates of carbon and dinitrogen (N_2) fixation rates along the meridional transect. Discrete seawater samples will be taken and filtered at regular time intervals from the ship's clean surface seawater supply, and frozen for later analysis with molecular biological methods (quantitative PCR etc.) and flow cytometry. Parallel seawater samples will be collected for on board incubation experiments for determination of carbon and N_2 fixation rates. For this purpose, the samples will be incubated in 4-L polycarbonate bottles for 24 h after an addition of stable nitrogen (^{15}N) and carbon (^{13}C) isotopes. The later analysis of the isotopic composition of the microorganisms will be carried out using mass spectrometry.

Work at sea

Measurements will be made continuously on pumped surface seawater using the following approaches:

- Autonomous continuous measurements of pCO_2 in surface waters with different instruments (AWI, NIOZ, IFM-GEOMAR)
- Autonomous continuous measurements of dissolved oxygen, nitrate and total gas tension in surface waters (IFM-GEOMAR)
- Discrete water samples for dissolved inorganic carbon and alkalinity will be taken every 8 hours (IFM-GEOMAR)
- Filtration of surface seawater for DNA/RNA and flow cytometry analysis will be carried out at intervals of 6 h throughout the transect (IFM-GEOMAR)

- Carbon and N_2 fixation rates will be measured in on-deck incubations every 24 h throughout the transect (IFM-GEOMAR)

Expected results

We will generate high-quality data in a high temporal resolution along the meridional surface transect through the Atlantic Ocean. The combined data set of autonomously recorded and discrete samples will provide a detailed insight in the carbon chemistry of the surface waters.

As during the previous OCEANET cruises (ANT-XXIV/4, ANT-XXVI/1 and ANTXXVI/4), we will obtain quantitative abundance estimates for seven phylotypes of diazotrophs using specific probes for the *nifH* gene which encodes a subunit of the nitrogenase enzyme. We will also determine where and when the *nif*H gene is actively transcribed in samples of the transect. By comparison with the results of the previous cruises, one of the goals is to observe whether or not trends observed in the North and South Atlantic will persist between the cruises.

4. RATE MEASUREMENT OF COSMIC PARTICLES IN DEPENDENCE ON LATITUDE AND WEATHER CONDITIONS

M. Walter (DESY, Zeuthen)

Objectives

The astroparticle physics group at DESY (Deutsches Elektronen-Synchrotron, member of the Helmholtz society) performs within international cooperation the experiments IceCube/IceTop at the Amundson-Scott South Pole Station and MAGIC at La Palma to search for galactical and extragalactical sources of high energy cosmic particles.

An outreach program was started in 2004 to allow students and scholar girls/boys (9^{th} to 13^{th} classes) to perform measurements with cosmic particles within project weeks and periods of practical training supported by scientists of the DESY astroparticle group. Goal of the project is to interest young people for modern physics and for experimental and analysis methods. See our web-site:

http://physik-begreifen-zeuthen.desy.de/angebote/kosmische_strahlung/index_ger.html

The cosmic particle detector installed on *Polarstern* consists of two scintillation counters working in coincidence mode. In addition there are three other devices to measure the GPS coordinates and time, the temperature and air pressure as well as the inclination of the detector correlated with the vessel movement. A python programme runs under Linux on a notebook to control data taking and storage on disk.

Work at sea

It is planned to run the detector during the whole expedition ANT-XXVII. The data will be made public via a web-interface so that they can be analyzed also by students within the outreach project.

Expected results

The scientific goals of the experiment are:

- The investigation of the cosmic particle rate in dependence on the latitude. The rate is smallest at the equator and increases to poles due to the influence of the Earth magnetic field. This geomagnetic cut-off will be measured.
- The possible measurement of sudden increase of the cosmic particle rate due to sun flares. Such flares of high particle intensities influence the “cosmic weather” and especially electronics systems installed on Earth or in satellites. It exists a net of detectors installed in different countries for an early warning system of such dangerous events. Our measurements can contribute to possible future extensions of this warning system.
- The investigation of the influence of cosmic particles on cloud formation. There are measurements which seem to show an influence on cloud formation with increasing rates of cosmic particles. But the existing data are not good enough to establish this hypothesis. Also here our measurements could contribute to clarify the situation.

5. SEA TRIAL AND TESTS OF THE UNDERWATER NAVIGATION SYSTEM POSIDONIA 6000 AFTER MODIFICATION OF THE PROTECTIVE WINDOW

S. El Naggar, P. Gerchow (AWI), J. Rogenhagen, W. Dimmler (Fielax)

Objectives

The underwater navigation system POSIDONIA was upgraded during *Polarstern’s* normal maintenance layover at the shipyard in Bremerhaven between 20 May and 12 June 2008.

Newly designed hard and software were installed and tested at harbour in Bremerhaven. A new acoustic array and window were fix-installed nearby the moon pool in addition to the mobile acoustic array and a complete new electronic cabinet was installed, modified and tested.

The first operational test under real conditions at sea was carried out during ARK-XXIII/1+2. The final sea trial and calibration were planned to be carried out during the ANT-XXV/1 on the way to Las Palmas from 03 November to 10 November 2008 at water depth of more than 3,000 m. The planned calibration and sea trials could not be carried out due to technical problems. The system was faulty and not operational.

The system was repaired by IXSEA in Bremerhaven during the shipyard stay of *Polarstern* from 24 May to 20 June 2009 when the damaged acoustic array and window were replaced by new components. Since then still a variety of problems had occurred which needed to be solved.

POSIDONIA was used during ARK-XXIV, but the new acoustic array was not useable, due to the diffraction occurred by the protection window. The system was not able to locate the target correctly and within the expected error bias. A new sea trial and calibration were done on both POSIDONIA systems during ANT- XXVI/1 on the way between Bremerhaven and Las Palmas (16 October – 27 October 2009). Again, the new fixed-installed acoustic array was not fully operational and it was not able to be calibrated. The protection window underwent a lot of disturbances by transponder positioning. Further investigations were necessary to improve the acoustical characteristic of the fixed array.

During ANT-XXVI/4 on the way from Las Palmas to Bremerhaven (08 May – 17 May 2010) new calibration tests were carried out on the new POSIDONIA system after removal the protective window in Punta Arenas on April 2010. The main objectives were to eliminate the effects of the protective window on the system, to check and to calibrate the system without the protective window. The fixed-installed acoustic array worked without window properly. Positioning data obtained were within the specifications and good enough to carry out the calibration. The housing of the acoustic array were modified during the ship yard stay of *Polarstern* in Bremerhaven (17 May – 10 June 2010) and the acoustic window was reinstalled again.

A new calibration and trials including the modified acoustic window will be done during ANT-XXVII/1 on the way from Bremerhaven to Las Palmas between 25 October 10 and 08 November 2010 at water depth of more than 3,000 m. The tests will provide new data set to evaluate the effects of the modified acoustic window and to compare the calibrations with and without window.

Work at sea

- System operational check including transponder test
- Preparing the transponder mooring
- Carrying out the sea trial and calibration (about 12 hours)
- Recovering of the Transponder
- Data analysis and validations
- Disembark the personal in Las Palmas

6. ATLANTIC BREEDING GROUNDS OF MYSTICETES OF THE SOUTHERN HEMISPHERE

M. Monsees (AWI), I. van Opzeeland, O. Boebel (not on board) (AWI)

Objectives

The large baleen whales of the Southern Hemisphere are migratory inhabitants of the open ocean and hence are not easily accessible for direct observation. They are thought to migrate between summer feeding grounds near Antarctica and winter breeding grounds in the subtropical ocean. However, knowledge on summer and particularly winter distribution of true (or Antarctic) blue (*Balaenoptera musculus intermedia)*, fin (*Balaenoptera physalus*), sei (*Balaenoptera borealis*) and Antarctic minke whales (*Balaenoptera bonaerensis*) is sparse and mainly based on historic catch data and the Discovery tagging program. The resulting uncertainty is clearly reflected even in contemporary distribution maps. Interestingly, in the southern Atlantic, the evidence at hand points to similar summer breeding grounds for all these species, namely the northern Angola Basin for Antarctic minke whales (7°S 3°W), the central Angola Basin for sei whales (15°S 5°W), and the southern Angola Basin for fin whales (21°S 1°E) and for true (or Antarctic) blue whales (22°S 7°E).

Given that many of the baleen whale species in the Southern Hemisphere have been severely depleted by commercial whaling, knowledge of the locations of their breeding grounds and an improved understanding of migratory routes and behaviour of these species is important for conservation measures to aid the recovery of these populations. All species are known to vocalize on the breeding grounds, rendering passive acoustic monitoring techniques therefore a valuable tool to study large baleen whale breeding ground distribution patterns. For blue and fin whales, geographic variation in vocalizations even allows identification of different (breeding) populations. Such information may provide insight into the extent to which each baleen whale species is grouped into separate localities on the breeding grounds.

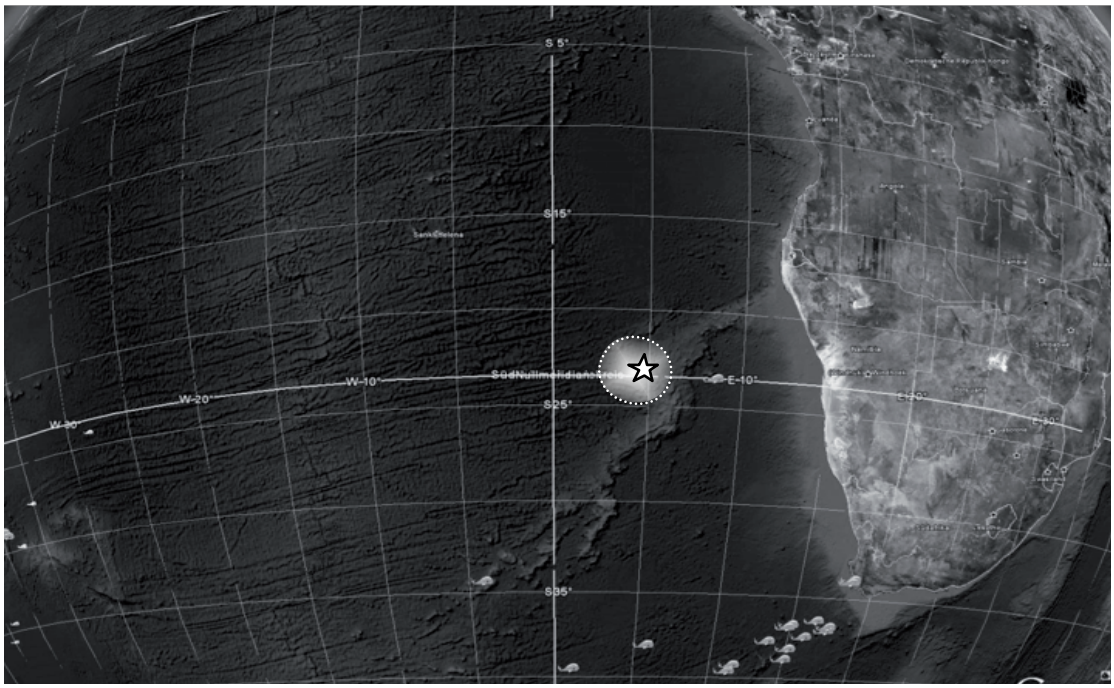

Fig. 6.1: Preferred mooring position at 22°S 5°E (white star) close to the northern edge of Walvis Ridge. The white circle indicates a (minimum) listening circle of 200 km.

Autonomous recording devices are battery-powered and record and store acoustic data internally. Dependent on data storage capacity of the device, recording bandwidth and sampling regime, recordings can be obtained over extended periods of time, in some cases up to several years. Best results are obtained when deployed in the so-called SOFAR channel, a sound-duct which is located at about 1,000 m depth in the subtropical ocean.

Work at sea

A single oceanographic mooring hosting a passive acoustic recorder (SonoVault) and a recording CTD shall be deployed in the southern Angola Basin for the duration of two years (Fig. 6.1: The deployment will be coincident with like recordings in the Antarctic summer feedinggrounds. The recorder shall be deployed at a depth of nominally 900 m, the core of the SOFAR channel, where detections ranges are expected to exceed the order of 200. This allows monitoring both the suspected fin and blue whale breeding grounds with only a single mooring. The mooring shall be recovered in 2012, preferably during another Polarstern transit cruise.

7. INVESTIGATION OF BROMINATED AND OOGANOPHOSPHORUS FLAME RETARDANTS AND MONITORING OF LEGACY POP'S IN THE ATLANTIC AND THE SOUTHERN OCEAN

Z. Xie, U. Bollmann (GKSS , J. Schuster (Lancaster University)
A. Möller, H. Wolschke (GKSS, not on board)

Objectives

Persistent organic pollutants (POPs) can enter the coast, marine and ocean environment by a number of processes, once introduced they are subject to biogeochemical cycling, sinks,

and bioaccumulation process. Apart from the discharge of the rivers and runoff, atmosphere is considered to be the primary and most rapid pathway for pollutant transport to the coast and marine environment as a result of their hydrophobic and semi-volatile nature, respectively.

Several leading groups of Environmental Chemistry are joining *Polarstern* during ANT-XXII to determine emerging and legacy persistent organic pollutants in moderate latitudes of the Northern and Southern hemisphere in proposal to further investigate their up-to-date levels and air-sea interactions in remote oceans. The research programme is focused on the determination of selected POPs in air and water, which is subdivided into several major groups.

Brominated flame retardants (BFRs). BFRs, primarily polybrominated diphenyl ethers (PBDEs), have been used to reduce the flammability of various commercial and industrial products the last decades. The global production volume of BFRs was 300.000 tonnes in 2004 with a continuous increase within the last decades. PBDEs are toxic, bioaccumulative and persistent compounds and have been regulated or banned by national and international regulations, which leads to increasing demand for non-regulated, non-PBDE flame retardants such as hexabromobenzene (HBB) and 1,2-bis(2,4,6-tribromophenoxy)ethane (BTBPE).

Phosphorus flame-retardants (OPFRs)

Organophosphorus compounds such as tris(2-chloroethyl) phosphate and triphenyl phosphate are widely used as flame retardants as well as plasticizer and in hydraulic fluids with a global production volume (as flame retardant) of ca. 210,000 tonnes in 2004. As a result of international regulations of PBDEs, the production volume of OPFRs is expected to increase, and thus leads to increasing emissions in the environment.

Current-use pesticides (CUPs)

Increased public and regulatory attention during and 1970s and 1980s resulted in bans for many legacy pesticides and has led to the development and licensing of new pesticides with less persistence. This group of newer compounds is called current-use pesticides. Because CUPs are extensively used worldwide, they are subjected to new concerns regarding the prevalence and effects of these compounds in the environment at low levels.

Among the legacy POPs of interest for this project are polychlorinated biphenyls (PCBs), polychlorinated dibenzodioxins/furans (PCDD/Fs) and polycyclic aromatic hydrocarbons (PAHs). The production of PCBs peaked in the 1960s. First restrictions and bans were established by individual countries in the 1970s and the following decades until it was globally banned in 2001. It was used in closed systems e.g. as a cooling agent in transformers as well as in open system like paints and glues. PCBs were produced as a mixture of different congeners with a varying grade of chlorination. Current sources for PCBs are dumps and old systems. PCDD/Fs and PAHs formed during combusition procedures. Also part of the monitored legacy POPs are organochlorinated pesticides (OCPs) like DDT and its degradation products DDE and DDD, as well as the chlordane, lindane and hexachlorobenzene (HCB). Even though the pesticides have been officially banned worldwide some are still in use in some countries.

Work at sea

High-volume air sampling

Two different high-volume air samplers will be deployed on the monkey deck of the *Polarstern*. GKSS high-volume air samplers are operated in 24 or 48 h, and Lancaster high-volume samplers are operated in 6 h period.

Air sampling with passive air samplers

Flying saucer devices (FSD) with PUF disks will be deployed at the start of the sampling campaign at areas where the high-volume air samplers are deployed (monkey deck) and sampling media is handled (laboratory, storage area). The samplers will remain until the active air sampling is concluded. The samples will be analyzed for the same compounds as the active air samples.

High-volume water sampling

High-volume water samples (1,000 L) will be taken from the ship's seawater system using an *in-situ* pump module with a glass fiber filter and a PAD-2 resin column.

Water sampling with passive water samplers

An accelerated solvent extraction (ASE) cell will be connected to a seawater tab. The ASE cell will be lined with polyethylene (PE) foil as sampling medium. A flow meter will be connected to the set up to monitor the flow rate of the system. The aim is a flow rate of 5 L/min and a deployment period of 3 days. The samples will be analyzed for PCBs, OCPs and PCDD/Fs.

Water sampling with solid-phase extraction

2-L water samplers will be collected from the ship sea water intake system, and from the CTD for different depth. The samples are extracted on board with SPE cartridge.

To investigate the occurrence and the environmental fate of legacy and emerging POPs, high-volume water and air samples will be simultaneously taken along ANT-XXVII/1. Concentrations of OPFRs and CUPs in ocean waters and the atmosphere from southern hemisphere will be investigated for the first time. Both the particulate and the gas or water phase will be analysed to identify the partitioning behaviour in the oceans and the atmosphere.

Expected results

Based on the data, the transport behaviour and long-range transport potential of emerging POPs on the southern Hemisphere and in Antarctica will be studied and finally the air-water exchange process will be examined. Short sampling periods should provide information about diurnal cycling of legacy POPs over open ocean areas.

8. HALOCARBON AIR SEA TRANSECT – ATLANTIC (HALOCAST-A) – FALL 2010

S. Yvon-Lewis, L. Hu (Texas A&M University)

Objectives

This project is an effort to study the spatial/temporal variability of methyl bromide (CH_3Br) and other halocarbons in the upper ocean in response to the implementation of the Montreal Protocol and its amendments [*UNEP*, 1995]. Assuming that rates of biological production in the ocean have not changed, our CH_3Br model predicts that CH_3Br should be less undersaturated than it was before the phaseout of non-quarantine and preshipment uses. The anthropogenic chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) should still be near equilibrium with regard to surface ocean saturation. However, the CFC surface ocean

concentrations should be lower and the HCFC surface ocean concentrations should be higher than before the implementation of the protocol. Spatial and temporal trends in the very short-lived species (VSLS) should not be impacted by the Montreal Protocol or its amendments as they are not currently regulated, and many VSLS are thought to be mostly biogenic. During this project, we will gain information on the temporal and spatial variability in these species through measurements made in regions and seasons where we made them a little over10 years ago.

This study is strongly related to Surface Ocean Lower Atmosphere Studies (SOLAS) goals. Advancing our understanding of ocean/atmospheric chemical coupling requires: 1) a comprehensive data base of the spatial/temporal variability of trace gases in the surface ocean, and 2) an understanding of the factors controlling the surface ocean distributions and air/sea fluxes of these gases. Understanding sources and sinks is the key to understanding their distributions, and to developing a predictive capability for how they will respond to the coming changes in climate such as changes in sea surface temperature (SST), ocean acidification, changes in salinity, etc.

Work at sea

Sampling and Analysis

We will collect and analyze samples from the underway flowing seawaters system and from buckets whenever possible.

- Halocarbon/C1-C3 hydrocarbon air and equilibrator headspace samples will be collected and analyzed continuously using a Weiss type equilibrator and a gas chromatograph with mass spectrometer (GCMS) and an FID. An air line is run to the bow for continuous air side measurements, and the equilibrator is used for the water-side measurements. The system is automated and alternates between air and equilibrator headspace samples.
- Degradation rate constants will be measured using water collected once per day with a bucket or from the underway system. Aliquots of water are filtered and others are not. All are spiked with ^{13}C labeled CH_3Br or CH_3Cl and the loss is measured over time with a purge and trap GCMS.
- Nutrient samples will be collected 2 times per day from the flow through system and frozen for analysis at TAMU
- Cyanobacteria samples will be collected 2 times per day from the flow through system and frozen for analysis at TAMU.
- Pigment samples will be collected 2 times per day from the flow through system and frozen for analysis at TAMU.

Expected results

Shipboard measurements will include underway saturation state measurements and degradation rate constants. Any differences from the predicted saturation state will be used to improve our understanding of the role of the ocean in the global cycling of halocarbons. The long-term goals of this work are to understand the origin and cycling of CH_3Br and other halocarbons in the oceans, and to develop a predictive capability for how the air/sea fluxes of oceanic trace gases will respond to the coming global changes in atmosphere/ocean chemistry and climate.

9. BATHYMETRY – HYDROSWEEP DS-3 UPGRADE SEA ACCEPTANCE TESTS AND DEEP SEA TRIALS

H.-W. Schenke, R. Krocker, F. Niederjasper, A. Gottschall, U. Gallbach, D. Ulrich, L. Schack, A. Prokoph (AWI)

Objectives

The HYDROSWEEP-System was installed on *Polarstern* in 1989, as follow-up system of SEABEAM, which was often damaged during ice-breaking. The SEABEAM- and HYDROSWEEP-Systems were routinely calibrated and tested in regions of different topographic structures, for example at continental shelf edges, abyssal plains and deep sea trenches or troughs. Calibrations, sea trials and data evaluation are indispensable and necessary to assure accuracy of the depth measurements and its derivative products, and the reliability of the physical observables (backscatter, side scan). A major software upgrade of HYDROSWEEP was realized in 1997 (HYDROSWEEP DS-2), followed by sea acceptance tests and detailed deep sea trials. A second software update was implemented in 2003, which included the extension of the opening angle to 120° (reaching up to 3,500 m water depth), the High Definition Beam Estimation Mode (HDBE) and the so-called Whale-Safe-Mode.

Since the first installation of HYDROSWEEP in 1989, neither the electronic sonar control systems nor the beam-forming firmware and software were upgraded or renewed. Since the electronic hardware was older than twenty years and thus overaged and outdated and upgrade was needed.

ATLAS-Hydrographic has now developed a substantial technical upgrade of HYDROSWEEP, the version DS-3, which includes beside a new survey planning software, a state-of-the-art data-acquisition software (HYPACK), and a new electronic control system. However, major improvements for scientific applications are the increase of the number of beams from 59 to 345 based on a newly patented reception beam-forming technology called High-Order-Beam-Forming (HOB). In addition, the opening angle can be increased to 140°, which enables in shallow waters a swath width of 5.5 times the depth.

Work at sea

Calibration and sea acceptance tests

The evaluation of the HYDROSWEEP capability and performance is conducted in two phases (Fig. 9.1). At first, the calibration of HYDROSWEEP is conducted at the edge of the French continental shelf and in the Biscay Abyssal Plain (Loc 1, Fig. 9.2) during which geometrical and electronic interaction and the functionality of all sensors (multibeam, positioning, attitude, time tagging, etc) are checked and analysed. The second part of tests involves the quality assessment, which is mainly based on the comparison to existing multibeam data and on the re-survey of specifically arranged profiles, for example at the Location 2 B (Fig. 9.3), which is used since 1986 (Meteor M4/1) as major test site. Data measured with DS-3 will be evaluated

and compared to multibeam data from past cruises. Geometric comparison and statistic evaluations will be conducted and utilized for the sea acceptance test.

If system performance and technical requirements are met as specified by the manufacturer, the sea acceptance test will be terminated before *Polarstern* reaches the Canary Islands. Along the transit from Bay of Biscay to Las Palmas multibeam data will be collected and compared to data recorded during earlier cruises. This comparison and data evaluation is also part of the acceptance test.

Deep sea trials

The operational area of *Polarstern* includes all depth ranges, from shallow waters of few hundred meters on continental shelves to deep sea troughs, reaching to more than 8.000 m water depth. Thus, it is important to check the maximum accessible depth and evaluate the accuracy of the measurements and, especially, verify the swath coverage achievable in the deep sea. In order to conduct these trials, several specific multibeam lines will be placed in the northern part of the Cape Verde Islands (Fig. 9.1) and at the Romanche Fracture Zone (RFZ).

The topographic structures of the RFZ are useful for performance tests of multibeam systems. The central and deepest part (depth > 8,000 m) is structured by an east-west trending trough with extreme steep slopes of more than 35° inclination. The relatively planar bottom of the trough is covered with sediments, but is also marked by small topographic undulations of less than 100 m.

Expected results

Deep sea trials and calibrations were earlier conducted at the RFZ during the expeditions Meteor M6/4 (1988) and *Polarstern* ANT-VIII/1 (1989). This data will be used for the deep sea trials during ANT-XVII/1. The track-lines across the RFZ must be precisely navigated along the existing profiles in order to conduct direct comparisons. At least two sound velocity profiles (SVP) must be measured at the beginning and at the end of the survey. During the transit from the RFZ test area to Cape Town *Polarstern* should follow existing multibeam track-lines.

Fig. 9.1: Locations for calibration and deep sea trials during ANT-XXVII/1

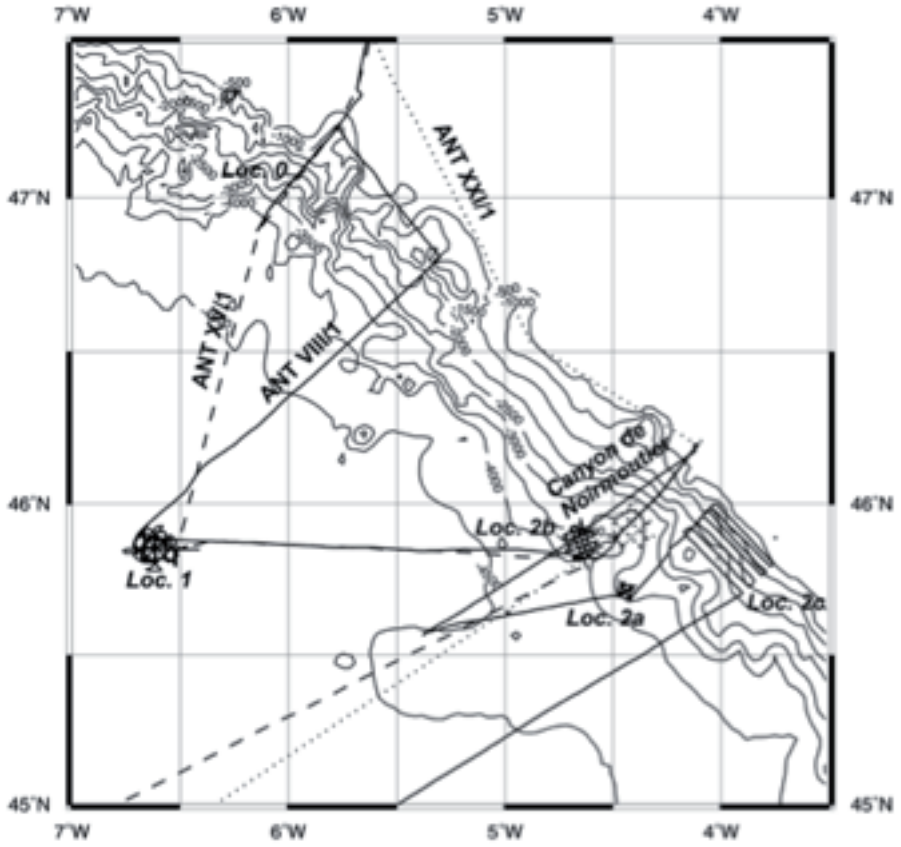

Fig. 9.2: Tracks of Polarstern multibeam calibrations at Loc. 1, 2a,b,c in the Bay of Biscay used during cruises (ANT-VIII/1, ANT-XV/1, ANT-XXI/1)

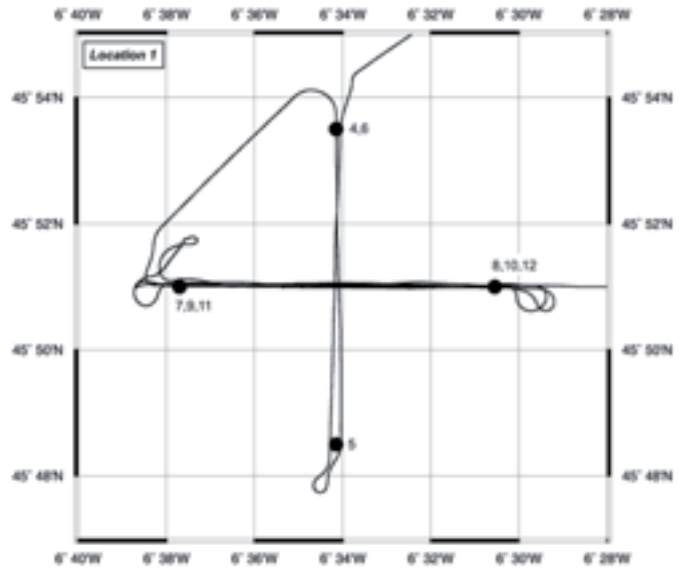

Fig. 9.3: Calibration profiles at Loc. 1 in the Biscay Abyssal Plain

10. ON-BOARD TESTING OF A NEWLY DEVELOPED SHIP GOING MEMBRANE-INLET MASS SPECTROMETER (MIMS) AND SETUP OF PCO_2/IRON EXPERIMENTS WITH NATURAL SOUTHERN OCEAN DIATOM POPULATIONS; SAMPLING OF POM FOR BIOMARKER ANALYSIS

K.-U. Richter, S. Kranz, U. Richter, M. Eichner (AWI), B. Rost (not on board) (AWI)

Objectives

The Southern Ocean exerts an exceptionally large influence on the marine carbon cycle and likely played a key role in glacial-interglacial atmospheric CO_2 transitions. CO_2-related changes in environmental conditions, both directly through ocean seawater acidification and indirectly via increasing thermal stratification, are expected to be particularly pronounced in high latitudes and hence provide the possibility for strong feedbacks on atmospheric CO_2. Despite these implications, little information is currently available on the potential CO_2 sensitivity and the underlying cellular processes of Southern Ocean phytoplankton.

Membrane-inlet mass spectrometry (MIMS) is the state-of-the-art technology to investigate *in vivo* responses of phytoplankton by monitoring cellular gas exchange processes. A seagoing MIMS with a novel cuvette/inlet system, developed at the AWI, will be tested and improved under ship conditions during ANT-XXVII/1. The MIMS system consists of a custom-made cuvette and inlet system combined with a quadrupol mass spectrometer. Dissolved gas molecules like CO_2 or O_2 permeate through the membrane and are ionized and detected only seconds later in the mass spectrometer. The advantage of this approach is that several processes can be observed and quantified simultaneously.

A suite of methods allows quantification of cellular C fluxes, a prerequisite to understand the effect of CO_2 on photosynthesis, growth and other down-stream processes. One method allows distinguishing between CO_2 and HCO_3^- as carbon sources and determines the uptake kinetics as a function of C availability or other environmental conditions. In another application, the use of stable isotopes allows to measure photosynthetic processes which are highly sensitive to iron limitation. Stable isotopes also allow the determination of carbon anhydrase activities, a key enzyme catalyzing the otherwise slow interconversion between CO_2 and HCO_3^-.

During this cruise, the MIMS will be configured and sensitivity tests for the hardware will be run. Calibrations and long term tests will ensure the function for further use during ANT-XXVII/2 where the machine is run by Dr. Scarlett Trimborn.

Next to the testing of the MIMS, the facilities used for a CO_2/Fe experiment with Southern Ocean diatoms during ANT-XXVII/2 will be build up. Additional, samples of pelagic foraminifera will be taken. Their elemental composition combined with ocean parameters like temperature and salinity will be implemented in a temperature/salinity proxy by Dr. Albert Benthien for Paleoclimatology.

Work at sea

The MIMS will be set up and hardware tests will be conducted. Calibrations of the machine will be performed and analysis of the data will be done instantly to monitor the stability of the system. To test biological samples with the MIMS system, seawater will be taken via the seawater supply line. The natural phytoplankton biomasses will be concentrated via filtration to gain cell densities appropriate for the machine.

During the cruise, the facilities for culture experiments of southern ocean diatoms used during ANT-XXVII/2 will be prepared. An iron free space will be built in a lab-container and the illumination as well as gas mixing systems for CO_2 perturbation experiments for phytoplankton assemblages will be set. All laboratory equipment will be prepared to ensure a smooth start of ANT-XXVII/2.

Surface water for biomarker analysis will be taken via the onboard seawater supply. The water will be filtered and the obtained biomass will be stored at -20°C for later analysis. Parameters like temperature, salinity as well as ship position will be taken from the board-computer system to assign the sample to the ocean parameters.

11. CAVITY-ENHANCED DOAS MEASUREMENTS OF IODINE MONOXIDE IN THE MARINE ATMOSPHERE

M. Horbanski (University Heidelberg)

Objectives

It is well known that reactive halogens play an important role in the chemistry of the marine atmosphere. Apart from bromine radicals, also iodine compounds emitted from biogenic sources might have the potential to destroy ozone and to form new ultrafine particles. Iodine monoxide at concentrations of around 20 ppt was detected in coastal regions (e.g., Mace Head, Ireland, and the coast of Brittany). While coastal regions – in comparison to their areas - are probably much stronger sources of reactive iodine than the open ocean, the latter covers a much larger fraction of the Earth's surface. Thus the contribution of coastal versus open ocean sources to the global budget of reactive iodine is unclear to date.

Most measurements of reactive iodine have been conducted using Long Path Differential Optical Absorption Spectroscopy (LP-DOAS) and Multi-Axis DOAS. LP-DOAS can quantify halogen monoxide radicals at ppt levels by recording their structured absorption using optical path lengths of several kilometres in the open atmosphere. Therefore, the obtained trace gas concentrations are an average along light paths of several kilometre length. However, such measurements are not possible on a ship since they require a distance of several kilometres between the telescope and a retro reflector. MAX-DOAS instruments, such as our system permanently operated on the *Polarstern*, observe scattered sunlight using a simple optical setup, but a precise quantification of trace gas concentrations is difficult because the light path is not well defined.

Well-defined optical path lengths of several kilometres can be achieved using Cavity Enhanced DOAS (CE-DOAS). CE-DOAS uses passive optical resonators to provide long light paths (> 1km), in a relatively compact setup with resonator lengths in the order of 1m.

Work at sea

We will perform measurements of iodine monoxide (IO) and nitrogen dioxide on the *Polarstern* cruise ANT-XXVII/1 from Bremerhaven to Cape Town using a newly developed CE-DOAS instrument. It will provide point-like measurements of IO with a detection limit of about 1 ppt, which will be compared to our MAX-DOAS measurements from the permanently installed instrument. The combination of both measurements will allow for a precise quantification of both IO surface concentration and layer height.

Expected results

These measurements will allow for a thorough test of our new CE-DOAS system, which will be shipped to Neumayer Station, where it will be used for measurements of iodine monoxide emitted by the snowpack during the summer campaign 2010/11.

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Yvon-Lewis	Shari	TEXAS A&M UNIV.	Oceanographer
Zoll	Yann	IFM-GEOMAR	Meteorologist

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Krohn, Günter	Ch. Eng.
Fallei, Holger	2. Offc.
Dugge, Heike	2.Offc.
Erich, Matthias	Doctor
Hecht, Andreas	R.Offc.
Minzlaff, Hans-Ulrich	2.Eng.
Sümnicht, Stefan	2.Eng.
Schaefer, Marc	3.Eng.
Scholz, Manfred	Elec.Tech.
Winter, Andreas	Electron.
Muhle, Helmut	Electron.
Fabrizius, Eduard	Electron.
Himmel,Frank	Electron
Loidl, Reiner	Boatsw.
Reise, Lutz	Carpenter
NN	A.B.
Brickmann, Peter	A.B.
Winkler, Michael	A.B.
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Bäcker, Andreas	A.B.
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Silinski, Frank	Cooksmate
Martens, Michael	Cooksmate
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Sun, Yong Shen	2.Steward
Chen, Quan Lun	2.Steward
Yu, Kwok Yuen	Laundrym.

ANT-XXVII/2

28 November 2010 - 5 February 2011

Cape Town - Punta Arenas

Chief Scientist

Eberhard Fahrbach

CONTENTS

1. ÜBERBLICK UND FAHRTVERLAUF

Eberhard Fahrbach

Alfred-Wegener-Institut

Am 28. November 2010 wird das Forschungsschiff Polarstern von Kapstadt zur Antarktisreise ANT-XXVII/2 auslaufen. Zunächst wird der Kurs nach Südwesten führen und der Laufbahn des Jason-1-Satelliten folgen. Bei 51°S wird Polarstern den Meridian von Greenwich erreichen, von wo aus der Kurs direkt nach Süden führen wird.

Während der gesamten Reise werden Messungen von Temperatur, Salzgehalt und der Meeresströmung vom fahrenden Schiff aus erfolgen. Entlang der Kurslinie werden vertikal profilierende Driftkörper (Floats vom Typ NEMO - Navigating European Marine Observer und APEX) ausgelegt. Im Antarktischen Zirkumpolarstrom werden Bodendruckmesser mit nach oben schauenden Echoloten (PIES) ausgetauscht. Weiter südlich erfolgt die Aufnahme und Auslegung von Verankerungen, die Strömungs-, Temperatur- und Leitfähigkeitsmessgeräte, Schallquellen zur Ortung von Driftkörpern (Floats), akustische Registiergeräte und Eisecholote (upward looking sonar, ULS) zur Messung der Eisdicke tragen. An etwa 200 Stationen sind Messungen mit einem CTD-System (conductivity, temperature, depth) geplant, das mit Wasserschöpfern ausgestattet ist, um Proben zur Bestimmung der Konzentration von gelösten Nährstoffen, Sauerstoff, Spurenstoffen und CO_2-Parameter zu erhalten.

Da keine Reservezeit zur Verfügung steht, können Zeitverluste durch unvorhergesehene Ereignisse, schlechtes Wetter oder ausgedehntere Eisfahrt als entsprechend der mittleren Verhältnisse nur durch die Reduktion der Stationszeit aufgefangen werden.

Um den 20. Dezember sollen die Arbeiten auf dem Meridian von Greenwich abgeschlossen sein und Polarstern wird die Neumayer-Station zur Versorgung anlaufen. Anschließend wird die Reise in Richtung Kapp Norvegia im Weddellmeer fortgesetzt, wo die nächste Phase der Arbeiten bis zur Nordspitze der Antarktischen Halbinsel geplant ist. Auf einem Schnitt erfolgen CTD-Stationen mit Probennahmen für Spurenstoffe sowie die Aufnahme und Auslegung von Verankerungen sowie die Auslegung von Driftkörpern. Am 9. Januar 2011 wird die Jubany-Station mit dem Dallmann-Labor auf King George Island erreicht.

Der letzte Teil der Reise führt in die Gewässer westlich der Antarktischen Halbinsel, wo der Schwerpunkt bei biologischen Arbeiten liegt, für die auf einem Gitter Proben zur Untersuchung von Krill genommen werden. Nach Abschluss dieser Arbeiten wird etwa am 28. Januar 2011 die britische Station Rothera angelaufen, um Treibstoff für den Flugbetrieb abzuliefern.

Die Reise wird am 5. Februar 2011 in Punta Arenas enden. Die Fahrtroute ist in Abbildung 1.1 dargestellt.

Das Ziel der ozeanographischen Arbeiten besteht darin, die Bedeutung des atlantischen Sektors des Südlichen Ozeans für die großräumigen klimarelevante Vorgänge besser zu verstehen. Die Intensität und Struktur der thermohalinen Zirkulation, die Wirkung als Wärmepuffer, der Einfluss der Ozeanschichtung auf das Meereis und die Funktion als Quelle oder Senke für das Treibhausgas CO_2 bestimmen die Rolle des Ozeans für das Klima.

Im atlantischen Sektor des antarktischen zirkumpolaren Wassergürtels entsteht der größte Teil des Antarktischen Bodenwassers einer wesentlichen Komponente der globalen Umwälz-Zirkulation. Messungen im Tiefen- und Bodenwasser des Weddellmeers haben gezeigt, dass sich seine Eigenschaften im Zeitraum der letzten 20 Jahre merklich verändert haben. Gegen Ende der 80er Jahre fanden eine Erwärmung und die Salzgehaltszunahme des von Norden einströmenden Zirkumpolaren Tiefenwassers statt. Im weiteren Verlauf wurde die Temperaturzunahme in den tieferen Schichten des Boden- und Tiefenwassers sichtbar und breitete sich bis in das westliche Weddellmeer aus. Anschließend hat das Zirkumpolare Tiefenwasser eine Abkühlungsphase durchlaufen und erwärmt sich inzwischen wieder. Im Bodenwasser hält die Erwärmung am Meridian von Greenwich noch an, während im westlichen Weddellmeer Anzeichen der Abkühlung zu erkennen sind. Insgesamt haben sich die Wassermassen am Meridian von Greenwich über die gesamte Wassersäule erwärmt und der Salzgehalt hat zugenommen. Gleichzeitig mit der Erwärmung im Weddellmeer wurde eine Temperaturzunahme in der Tiefe des Einstroms von Zirkumpolaren Tiefenwasser auch weiter nördlich im zirkumpolaren Wassergürtel beobachtet. Im Südatlantik wurde ein Temperaturanstieg im Antarktischen Bodenwasser im Vemakanal gemessen, der darauf hindeutet, dass die Veränderungen in der Antarktis überregionale Auswirkungen haben. Die Erwärmung des Antarktischen Bodenwassers ist inzwischen beckenweit zu erkennen.

Das direkte Ziel der Untersuchungen ist es, einen Zusammenhang zwischen den Fluktuationen der atmosphärischen Bedingungen, der Eigenschaften der Wassermassen und den Meereisbedingungen nachzuweisen. Mit den Messungen sollen die in den vergangenen Jahren im atlantischen Sektor des Südlichen Ozeans beobachteten Veränderungen weiter verfolgt werden, um ihren zeitlichen Verlauf und ihre räumliche Verteilung zu quantifizieren. Um die Ursache der Veränderungen zu bestimmen, sollen die Fluktuationen des Antarktischen Zirkumpolarstroms südlich von Südafrika gemessen werden, wobei die Intensität und die Lage seiner südlichen Strombänder und der Übergang zum nördlichen Stromband des Weddellwirbels von Bedeutung sind.

Die physikalischen Untersuchungen werden durch ein Programm zur Messung von Spurenstoffen erweitert, die zur Wassermassencharakterisierung herangezogen werden. Damit wird die Abschätzung der Wassermassenbildungsraten ermöglicht.

Persistente organische Schadstoffe (Persistent organic pollutants = POPs), z.B. polychlorierte Biphenyle (PCBs) und Polybromierte Diphenylether (PBDEs) werden in der Atmosphäre in abgelegene Regionen der marinen Umwelt transportiert. Während der Reise ist die Bestimmung “neuer” potentieller POPs (z.B. alternative Flammschutzmittel) und verschiedener “traditioneller” POPs unter Berücksichtigung ihres Transport- und Verteilungsverhaltens zwischen der Atmosphäre und Seewasser geplant.

Im Rahmen des MAPS Projektes ist die kontinuierliche Erhebung von thermographischen Bilddaten geplant, um Mustererkennungsalgorithmen zur automatisch Detektion von Walen entwickeln zu können. Parallel zur automatischen Erfassung erfolgen visuelle Beobachtungen. Um die Effizienz der Algorithmen bei verschiedenen Umweltbedingungen (Wassertemperatur, Eisbedeckung, Sichtweite) bestimmen zu können, sollen die Autodetektionsdaten mit Walsichtungen des unabhängigen Beobachterteams verglichen werden.

Das Verständnis der wesentlichen biologischen Zusammenhänge und Umweltbedingungen, durch welche die erfolgreiche Fortpflanzung des Krills beeinflusst wird, ist Ziel biologischer Arbeiten. Sie sollen zeigen, wie sich die Brutsaison auf die erfolgreiche Eiablage und das Überleben der Larven auswirkt. Die Bedeutung natürlicher Variationen von Jahr zu Jahr bei der Reproduktion und dem Fortpflanzungserfolg und geographischer Variationen der Krill-

Verteilung, der Abundanz oder der Wachstums- und Sterblichkeitsraten in Beziehung zu den Verhältnissen innerhalb einer Saison oder von Saison zu Saison werden untersucht.

Die deutschen Krilldaten wurden über viele Jahre mit einer Standardausrüstung (RMT1+8) und Standardmethoden der Netzfang-Verfahren sowie der Probenbehandlung gewonnen. Dies erlaubt quantitative zwischenjährliche Vergleiche der Krill-Demographie und Populationdynamik. In der jüngsten Vergangenheit wurden Indizes für die Krilldichte, Eiablagezeit und Fortpflanzungserfolg entwickelt und durch die Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) standardisiert.

Probenahmen von benthischen Organismen in der Tiefsee sollen die Ergebnisse früherer Expeditionen zur Tiefsee-Biodiversität vervollständigen.

Es hat sich gezeigt, dass Umweltfaktoren wie die anhaltenden Ozean-Versauerung im Zusammenhang mit der sich verändernden atmosphärischen CO_2-Konzentration und saisonale CO_2-Variationen die Struktur und das Wachstum des Phytoplanktons beeinflussen. Um die Phytoplankton-Populationen entlang des Schiffskurses zu charakterisieren, werden An-Deck-CO_2/Eisen-Störungsexperimente mit natürlichen Phytoplankton-Gemeinschaften ausgeführt.

Das Ziel des Projektes ist es, mit hoher räumlicher Auflösung die klein-skalige Verteilung des pCO_2-Wertes im Oberflächenwasser, biologische Sauerstoffsättigung (O_2/Ar) und Dimethylsulfid (DMS) mit Massenspektrometrie zu bestimmen.

SUMMARY AND ITINERARY

Polarstern will leave on 28 November 2010 from Cape Town for the cruise ANT-XXVII/2 to Antarctica. First, she will steam to the southwest and follow up the ground track of the Jason-1 satellite. At 51°S Polarstern will reach the Meridian of Greenwich from whereon the course will be to the south.

Temperature, salinity and ocean currents will be measured en route. Along the track line floats will be deployed and moorings with bottom pressure sensors with inverted echosounders (PIES) will be exchanged. Measurements with a CTD probe (Conductivity, Temperature, Depth) will occur at approximately 200 hydrographic stations and water samples will be taken to determine the concentration of dissolved nutrients, oxygen, trace substances and CO_2 parameters. The final number of stations must be adapted to the progress of work. Since there is no spare time, time losses due to unexpected events, bad weather or more ice as expected have to be compensated by reduction of station time.

An essential part of the programme consists in the recovery and redeployment of moorings. They contain current meters, temperature and conductivity sensors, sound sources to locate floats, sound recorders and upward looking sonars (ULS) to measure the sea ice thickness. Additionally NEMO (Navigating European Marine Observer) and APEX floats will be deployed.

At about 20 December the work on the Meridian of Greenwich will be terminated and the Neumayer Station will be supplied.

The next phase of the cruise will take place on a transect across the Weddell Sea from Kapp Norvegia to the northern end of the Antarctic Peninsula. CTD stations, trace substance sampling and the deployment of moorings and floats will continue. On the 9 January 2011

Jubany Station and the Dallmann Laboratory on King George Island will be visited to calibrate a sonar system to be used in the krill programme.

The final part of the cruise will occur west of the Antarctic Peninsula where net samples will be carried out in the context of a krill programme as contribution to the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR). Finally, we will steam to the British Rothera Station to deliver by about 28 January 2011 fuel for air operations.

The cruise will end on 5 February 2011 in Punta Arenas. The cruise track is displayed in figure 1.1.

The physical oceanography programme intends to investigate the role of the Southern Ocean in the global climate system. Here we focus on the Atlantic sector including the Weddell Sea. The Antarctic ocean contributes through atmosphere-ice-ocean interaction processes to the variability of the climate system. A major contribution of the global deep and bottom water formation occurs in the Weddell Sea. It is controlled by the transport of source waters into the Weddell Sea, processes within the Weddell Sea, and the transport of modified water out of the Weddell Sea.

Recent observations indicate that the water mass properties of the Warm Deep Water are subject to significant variations. After an initial warming and salinity increase observed during the nineties cooling occurred which ended by about 2005 is now followed by warming again. The variations are most likely due to changes in the inflow from the circumpolar water belt in combination with changes in the ice-ocean-atmosphere interaction in the Weddell Sea induced by changes in the atmospheric forcing conditions.

To quantify the carbon budget of the Weddell Gyre repeat sections for TCO_2 and total alkalinity and ancillary variables will be used for estimating temporal changes in the carbon cycle, including ocean acidification. By comparison with earlier carbon data interannual variability will be estimated and the exchange of CO_2 between the ocean and the atmosphere in austral summer will be determined.

Persistent organic pollutants (POPs), such as polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs) are being transported in the atmosphere of the marine environment into remote areas. Measurements will be made to determine “new” possible POPs (e.g., alternative flame retardants) and several legacy POPs with respect to their transport and partitioning behaviour between the atmosphere and seawater.

Observation programmes of marine mammals include visual observations and automatic detection. An automatic whale blow detection system is developed on the basis of thermographic images from a 360° scanning IR sensor. To this end, visual observations and thermographic images shall be collected continuously throughout the cruise. To test the efficiency of detection algorithms for various species and under varying environmental conditions, autodetections shall be compared with sightings from an independent observer team.

The krill study in the context of CCAMLR will investigate the biological and environmental key factors which affect the successful reproduction and determine how the breeding season relates to successful spawning or larval survival. Natural variations in reproduction and recruitment success between years and geographical variations in krill distribution, abundance or growth and mortality rates in relation to within-season or between-season will be assessed.

The German krill data have been collected over the years with standard gear (RMT1+8) and standard methods for net sampling procedures as well as for sample handling and measuring and staging krill. These allow interannual comparison of quantitative aspects of krill demography and population dynamics.

Samples of macrobethic animals from the deep sea will complete the results from the previous expeditions about the deep-sea biodiversity.

Environmental factors like changing atmospheric CO_2 concentrations and the ongoing ocean acidification as well as to seasonal changes in CO_2 were found to also exert control on both phytoplankton structure and growth. To characterize phytoplankton populations along the cruise track on-deck CO_2/iron perturbation experiments with natural phytoplankton communities will be performed.

The goal of this project is to map, with high spatial resolution, the fine-scale distribution of surface water pCO_2, biological oxygen saturation (O_2/Ar) and dimethylsulfide (DMS) using ship-board mass spectrometry.

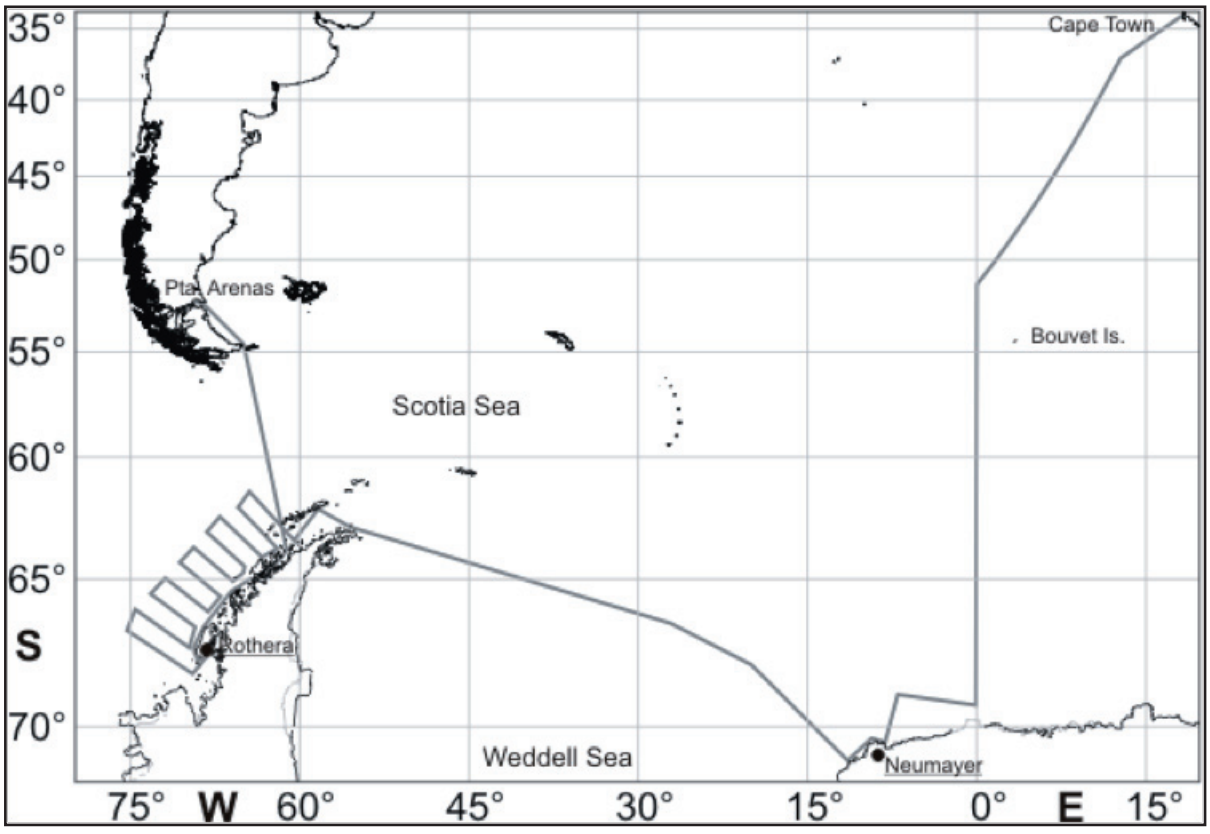

Abb.1.1: Fahrtroute während ANT-XXVII/2 von Kapstadt nach Punta Arenas mit Versorgungsaufenthalten bei der Neumayer und der Rothera Station.
Fig. 1.1: Route of ANT-XXVII/2 from Cape Town towards Punta Arenas with supply at Neumayer and Rothera stations.

2. OCEANOGRAPHY

2.1 Decadal variations of water mass properties in the Atlantic sector (WECCON-HAFOS)

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Objectives

The densest bottom waters of the global oceans originate in the Southern Ocean. Production and export of these dense waters constitute a vital component of the global climate system. The formation of dense water in polar areas is controlled by the delicate balance between supply of fresh water through precipitation and melt of continental and sea ice and the extraction of freshwater by sea ice formation and evaporation. The influence of Southern Ocean waters can be traced far into the northern hemisphere. As deep and bottom waters, they represent the deepest layer of the global overturning circulation. The Antarctic Circumpolar Current (ACC), the world´s most powerful current system, transports about 140 Sv (106 m3 s-1) of water at all depths. It connects the three ocean basins and forms an isolating water ring around the Antarctic continent. South of the ACC, in the subpolar region, warm and salty water masses are carried in the subpolar gyres to the continental margins of Antarctica. The most prominent are the Weddell and Ross Gyres. In the subpolar gyres, water mass modification occurs through ocean- ice-atmosphere interactions and mixing with adjacent water masses. The ACC is dynamically linked to meridional circulation cells, formed by southward ascending flow in intermediate depth feeding into northward flow above and below. In the deep cell water sinking near the continental water spreads to the adjacent ocean basins, in the shallow cell the northward flow occurs in the near surface layers. Dense waters are produced at several sites near the continental margins of Antarctica. Quantitatively the most important region for dense water formation may well be the Weddell Sea, however other areas provide significant contributions as well.

The basic mechanism of dense water generation involves upwelling of Circumpolar Deep Water which is relatively warm and salty into the surface layer where it comes into contact with the atmosphere and sea ice. The newly formed bottom water is significantly colder and slightly fresher as the initial Circumpolar Deep Water which indicates heat loss and the addition of freshwater. Since freshwater input in the upper oceanic layers is prohibitive to sinking through increasing stability of the water column, it has to be compensated by salt gain through fresh water extraction. The upwelled water is freshened by precipitation and melting of glacial and sea ice. Freshwater of glacial origin is supplied from the ice shelves or melting icebergs. Ice shelves melt at their fronts and undersides related to the oceanic circulation in the cavity. Iceberg melting depends highly on the iceberg drift and can supply freshwater to areas distant from the shelves as the Antarctic frontal system. Due to the spatial separation of major freezing and melting areas of sea ice cooling and salt release during sea-ice formation cause the compensation of the freshwater gain and subsequently the density increase which is needed for bottom water formation. Significant parts of the salt accumulation occur on the Antarctic shelves in coastal polynyas. Since extreme heat losses can only occur in ice free water areas,

the polynyas are areas of intense sea ice formation. Offshore winds compress the newly formed sea ice and keep an open sea surface in the polynyas.

The cold and saline water accumulated on the shelves can descend the continental slope and mix with water masses near the shelf edge or it can circulates under the vast ice shelves, where it is further cooled below the surface freezing point and freshened by melting of the ice shelf. The resulting Ice Shelf Water spills over the continental slope and mixes with ambient waters to form deep and bottom water. For both mechanisms relatively small scale processes at the shelf front, topographic features and the nonlinearity of the equation of state of sea water at low temperatures is of special importance to induce and maintain the sinking motion. The different processes, topographic settings and atmospheric forcing conditions lead to variable spatial characteristics of the resulting deep and bottom water masses which than spread along a variety of pathways to feed into the global oceanic circulation. Climate models suggest that dense water formation is sensitive to climate change. However, since the relatively small scale formation processes are poorly represented in the models further improvement is needed. The overturning affects as well the biogeochemical cycles and consequently its change can have a significant impact on ocean carbon uptake.

The properties and volume of the newly formed bottom water underlies significant variability on a wide range of time scales, which are only poorly explored due to the large efforts needed to obtain measurements in ice covered ocean areas. As for the atmospheric driving forces, the sea ice and upper ocean layers, seasonal variations are partly known and normally exceed in intensity the other scales of variability. However the spatial distribution pattern of the variability is only poorly resolved e.g. seasonal cycles of sea ice thickness are only available at a few sites. An estimate of the sea ice mass as a baseline to detect change is still not possible due to the missing measurements of sea ice thickness. Longer term variations of the atmosphere-ice-ocean system as the Southern Hemispheric Annular Mode and the Antarctic Dipole are only poorly observed and understood. Their influence on or interaction with oceanic conditions are only guessed on the basis of models which are only superficially validated due to lack of appropriate measurements.

The extreme regional and temporal variability represents a large source of uncertainty when data sets of different origin are combined. Therefore circumpolar data sets are needed of sufficient spatial and temporal coverage. At present such data sets can only be acquired satellite remote sensing. However, to penetrate into the ocean interior and to validate the remotely sensed data, an ocean observing system is needed, which combines remotely sensed data of sea ice and surface properties with in-situ measurements of atmospheric, sea ice and oceanic properties.

To achieve further progress significant steps occurred in the development of appropriate technology and logistics. Oceanic properties are measured under the sea ice which required the development of under-ice acoustic ranging and data transmitting systems. To construct from the achievable observations a comprehensive circumpolar view, model assimilations have to be done which require the development of appropriate models.

The WECCON project (Weddell Sea convection control) continues work which had occurred during the CASO project (Climate of Antarctica and the Southern Ocean) of the International Polar Year 2007/2008. It aims to investigate processes which occur in the Atlantic Sector of the Southern Ocean in cooperation with the Bjerknes Centre for Climate Research in Bergen, Norway and the British Antarctic Survey (BAS). In the framework of iAnZone, a programme associated to SCOR (Scientific Committee of Oceanographic Research) and its SASSI project (Synoptic Antarctic Shelf Slope Interactions Study) observation occurred in the area of Maud Rise and the Antarctic slope front area. The PIES deployments along the GoodHope/Greenwich

section further contribute to the DFG special research programme “Massentransporte”. The cruise occurs in the context of the PACES programme of the Hermann von Helmholtz Association of German Research Centres (HGF). It is a contribution to the Climate Variability and Predictability (CLIVAR) and the Climate and Cryosphere (CliC) projects of the World Climate Research Programme (WCRP) and Scientific Committee of Antarctic Research (SCAR). The ULSs are a contribution to the Antarctic Sea Ice Thickness Project (AnSITP). The deployment of floats occurs in the framework of the international Argo programme which contributes to the Global Ocean Observing System (GOOS). The work represents a further step towards a Southern Ocean Observing System (SOOS) by building further up the Hybrid Antarctic/Arctic Float Observing System (HAFOS).

Work at sea

The Polarstern cruise ANT-XXVII/2 will complement the efforts to obtain in-situ observations in the Atlantic sector of the Southern Ocean in order to allow a circumpolar view. Time series stations with moored instruments will provide measurements of water mass properties in the deep and the surface layers and of ice thickness. For this purpose moorings with current meters, temperature and salinity sensors as well as upward looking sonars will be recovered and redeployed. The physical oceanography measurements concentrate on two major areas: the Greenwich Meridian and the Weddell Sea.

CTD

Ship borne meridional transects are needed to determine water mass properties including tracer concentrations. They will occur along the Greenwich Meridian, across the Weddell Sea and on the CCAML grid west of the Antarctic Peninsula (Fig. 2.1).

A total number of about 200 CTD stations are planned. The CTD/water sampler consists of a SBE911plus CTD system in combination with a carousel water sampler SBE32 with 24 12-l bottles. To determine the distance to the bottom an altimeter from Benthos is mounted. A transmissiometer from Wetlabs, a SBE43 oxygen sensor from Seabird Electronics and a Fluorometer will be used.

SUbmersible Motion Observer (SUMO)

A fully functional prototype of the newly developed submersible motion observer (SUMO) will be tested. Without using any extra resources it will be mounted to the rosette and connected to the CTD via the auxiliary sensor channels not in use actually. At every CTD station different parameters can be measured and observed in real time, e.g. twist of the cable, angular velocity, heading of the rosette, combined tilt of the rosette, etc. while the comprehensive and more detailed data are stored and can be processed after each station. One to four channels can be used to transmit the desired information to the operator on board for improved knowledge of the state of rosette and CTD, avoidance of critical situations and saving of ship and station time. The final goals are the proof of functionality under real in-situ conditions, the determination of the best parameters to send to the operator for easiest and most efficient work and the measurement of the complete state of the rosette for validation of its model of the mechanical behaviour.

Moorings

The ship borne surveys are imbedded in the time series measurements with moorings, drifters and floats to quantify seasonal variability on transfer processes and to avoid the aliasing effect on longer term observations. Moorings will be recovered and redeployed (Fig. 2.1). The details

of the moored instruments are summarized in tables 2.1 to 2.4. The spreading of floats is able to extend the data from the sections over larger parts of the area.

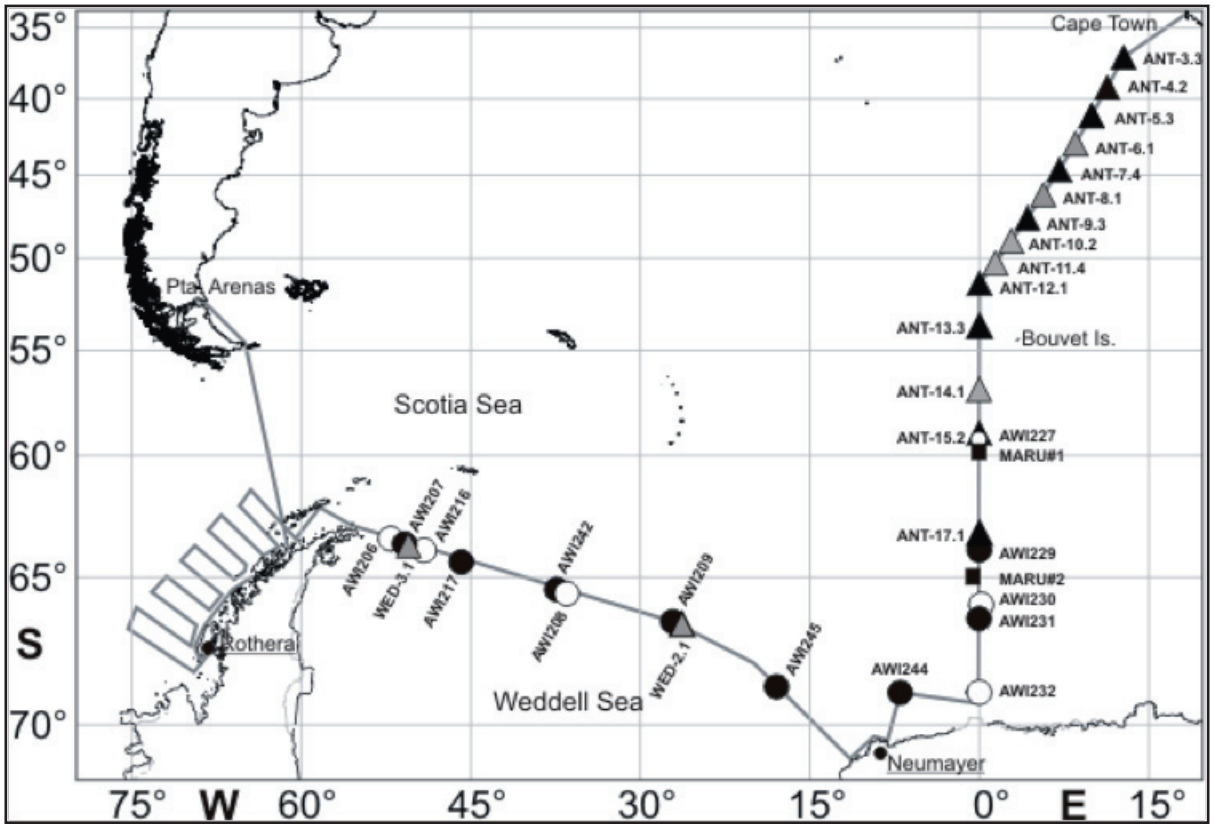

Fig. 2.1: Route of ANT-XXVII/2 with moorings. Black triangles indicated the locations of PIES re-deployments. Gray triangles are locations of additional deployed PIES. Squares indicated the locations of acoustic recorders to be recovered. These instruments were deployed during ANT-XXV/2. Circles indicated the locations of re-deployed mooring locations. Moorings containing a sound source are indicated as filled circles. Mooring AWI242 was deployed January 2007 for AWI by BAS and will be recovered only. Therefore the re-deployed mooring AWI208 will contain a sound source.

Table 2.1: Moorings to be recovered on the Greenwich meridian

Mooring	Latitude Longitude	Water Depth (m)	Date Time 1. Record	Instrument Type	Serial Number	Instrument Depth (m)
AWI232-9	68° 59.74' S	3419	11.03.2008	ULS	57	150
	00° 00.17' E		14:00	AURAL	085	216
				ADCP	6240	450
				AVT	9782	750
				RCM 11	144	1800
				SBE37	2086	3300
				RCM 11	486	3300
AWI231-8	66° 30.68' S	4546	07.03.2008	ULS	56	150
	00° 01.81' W		22:00	SBE37	1236	200
				SBE37	449	300
				SBE37	2088	400
				ADCP	825	450
				SBE37	2089	500
				SBE37	2090	600
				SBE37Pu	1237	700
				AVTP	10928	700
				SQ	30	850
				AVT	9180	1800
				SBE37	237	4500
				AVT	9186	4500
AWI230-6	66° 01.13' S	3577	08.03.2008	AURAL	086	200
	00° 04.77' E		14:00	AVTP	3517	200
				SBE37Pu	1229	200
				SBE37	2091	300
				SBE37	2092	400
				SBE37	2093	500
				SBE37	2094	600
				SBE37Pu	2237	700
				RCM 11	295	700
				AVTP	9188	1600
				SBE37	2099	3400
				RCM 11	504	3400
MARU#2	64° 05.07' S	5194	14.12.2008	PAM	2	5144
	00° 05.24' W		10:00			
AWI229-8	63° 58.03' S	5195	28.02.2008	ULS	64	150
	00° 003.10' W		18:00	SBE 37	2098	200
				SBE37	2096	300
				ADCP	5373	350

Mooring	Latitude Longitude	Water Depth (m)	Date Time 1. Record	Instrument Type	Serial Number	Instrument Depth (m)
				SBE16	2416	400
				SBE37	2099	500
				SBE37	2100	600
				SBE37Pu	2396	700
				AVTP	10925	704
				SQ	29	850
				AVT	9390	2000
				SBE37	2101	5150
				AVT	10499	5150
MARU#1	59° 10.28’ S	4838	12.12.2008	PAM	1	4798
	00° 00.39’ E		18:00			
AWI227-10	59° 04.10’S	4630	25.02.2008	SBE37P10	1565	4580
	00° 04.88’ W		14:00			

Table 2.2: Moorings to be recovered along transect from Kapp Norvegia towards Joinville Island

Mooring	Latitude Longitude	Water Depth (m)	Date Time 1. Record		Serial Number	Instrument Depth (m)
AWI244-1	68° 59.70' S	2927	13.03.2008	SQ	23	850
	06° 56.70' W		16:00			
AWI245-1	69° 03.68' S	4466	15.03.2008	SQ	24	850
	17° 25.89' W		16:00			
AWI209-5	66° 36.89' S	4864	18.03.2008	SBE 16	2415	300
	27° 07.08' W		20:00	SQ	34	800
				SBE37P	220	4800
				SBE37	230	4850
AWI208-5	65° 36.85' S	4770	21.03.2008	ULS	62	150
	36° 24.43' W		16:00	ADCP	3813	300
				SBE16	1979	300
				SBE37	435	4680
				SBE37	2234	4730
AWI242-1	65° 34.51' S	4715	30.01.2007	SQ	27	830
	37° 07.33' W		05:00	SBE37	221	4708
AWI217-3	64° 23.63' S	4456	24.03.2008	SQ	32	850
	45° 52.38' W		14:00	SBE37	250	4150
				SBE37	240	4350
				RCM 11	296	4351
AWI216-3	63° 54.03' S	3516	26.03.2008	SBE37	2392	3350
	49° 04.68' W		16:00	SBE37	2393	3400
				SBE37	439	3450
				RCM 11	298	3451
AWI207-7	63° 42.74' S	2500	27.03.2008	ULS	60	150
	50° 50.55' W		20:00	AVTP	10872	250
				SBE 16	2414	251
				AVT	10503	750
				SQ	36	850
				SBE37	2610	2100
				SBE37	2297	2200
				AVT	10530	2300
				SBE37	436	2490
				RCM 11	619	2490
AWI206-6	63° 28.77' S	950		ULS	61	150
	52° 05.77' W			AVTP	9206	250
				SBE37	1228	500
				AVT	9201	501
				SBE16	2422	700

Mooring	Latitude Longitude	Water Depth (m)	Date Time 1. Record		Serial Number	Instrument Depth (m)
				SBE37	438	900
				RCM 11	508	901

Table 2.3: Moorings to be deployed on the Greenwich meridian

Mooring	Latitude Longitude	Water Depth (m)		Instrument Type		Instrument Depth (m)
AWI232-10	68° 59.74’ S	3419		ULS		150
	00° 00.17’ E			AVTP		250
				AVT		750
				POD		950
				PAM		1000
				RCM 11		1800
				SBE37		3300
				RCM 11		3300
AWI231-9	66° 30.68’ S	4546		ULS		150
	00° 01.81’ W			AVTP		200
				SBE37		200
				SBE37		300
				SBE37		400
				SBE37		500
				SBE37		600
				SBE37Pu		700
				AVTP		700
				SQ		850
				PAM		1000
				AVT		1800
				SBE37		4500
				AVT		4500
AWI230-7	66° 01.13’ S	3577		AVTP		200
	00° 04.77’ E			SBE37Pu		200
				SBE37		300
				SBE37		400
				SBE37		500
				SBE37		600
				SBE37Pu		700
				RCM 11		700
				PAM		1000
				AVTP		1600
				SBE37		3400
				RCM 11		3400
AWI229-9	63° 58.03’ S	5195		ULS		150
	00° 003.10’ W			AVTP		200
				SBE37		200
				SBE37		300

Mooring	Latitude Longitude	Water Depth (m)		Instrument Type		Instrument Depth (m)
				SBE37		300
				SBE16		400
				SBE37		500
				SBE37		600
				SBE37Pu		700
				AVTP		704
				SQ		850
				PAM		1000
				AVT		2000
				SBE37		5150
				AVT		5150
AWI227-11	59° 04.10'S	4630		SBE37P10		4580
	00° 04.88' W					

Table 2.4: Moorings to be deployed along transect from Kapp Norvegia towards Joinville Island

Mooring	Latitude Longitude	Water Depth (m)		Instrument Type		Instrument Depth (m)
AWI244-2	68° 59.70' S	2927		SQ		850
	06° 56.70' W			PAM		1000
AWI245-2	69° 03.68' S	4466		SQ		850
	17° 25.89' W			PAM		1000
AWI209-6	66° 36.89' S	4864		SBE 16		300
	27° 07.08' W			SQ		800
				PAM		1000
				SBE37P		4800
				SBE37		4850
AWI208-6	65° 36.85' S	4770		ULS		150
	36° 24.43' W			SBE16		300
				SQ		800
				PAM		1000
				SBE37		4680
				SBE37		4730

Continuation

Mooring	Latitude Longitude	Water Depth (m)		Instrument Type		Instrument Depth (m)
AWI217-4	64° 23.63’ S	4456		SQ		850
	45° 52.38’ W			PAM		1000
				SBE37		4150
				SBE37		4350
				RCM 11		4351
AWI216-4	63° 54.03’ S	3516		SBE37		3350
	49° 04.68’ W			SBE37		3400
				SBE37		3450
				RCM 11		3451
AWI207-8	63° 42.74’ S	2500		ULS		150
	50° 50.55’ W			AVTP		250
				SBE 16		251
				AVT		750
				SQ		850
				POD		950
				PAM		1000
				SBE37		2100
				SBE37		2200
				AVT		2300
				SBE37		2490
				RCM 11		2490
AWI206-7	63° 28.77’ S	950		ULS		150
	52° 05.77’ W			AVTP		250
				SBE37		500
				AVT		501
				SBE16		700
				POD		750
				PAM		800
				SBE37		900
				RCM 11		901

Abbreviations:

ADCP RD-Instruments, Self Contained Acoustic Doppler Current Profiler

AURAL AURAL-Underwater Acoustic Recorder

AVTCP Aanderaa Current Meter with Temperature-, Conductivity- and Pressure Sensor

AVTP Aanderaa Current Meter with Temperature- and Pressure Sensor

AVT Aanderaa Current Meter with Temperature Sensor

PAM Passive Acoustic Monitor (Type: AURAL or SONOVAULT)

POD Porpoise Detector

RCM 11 Aanderaa Doppler Current Meter

SBE16 SeaBird Electronics Self Recording CTD to measure Temperature, Conductivity and Pressure

SBE37 SeaBird Electronics, Type: MicroCat, to measure Temperature and Conductivity

SQ Sound Source for SOFAR-Drifter

ULS Upward looking sonar from Christian Michelsen Research Inc. to measure the ice draft

Profiling floats

Profiling floats will be deployed. The float system complements Argo in ice-free and under-ice condition to reach a global coverage. Moorings with sound sources for under ice navigation will be recovered and redeployed. The Argo project set the goal of achieving at least the 3° x 3° sampling of the global array throughout the world ocean. Acoustically tracked floats will provide profiles and current velocities from key ice-covered seas. The floats will be programmed to continue to profile and store data beneath ice. Once the floats detect open water, the stored profiles will be transmitted. While the position of the sub-ice profiles is not known without acoustic navigation, the floats can survive the winter and the stored profiles provide a statistical description of winter stratification.

The international Argo program aims at observing global ocean upper temperature and circulation by means of free floating Argo floats. Globally, approximately 3150 of such regularly undulating platforms are in operation. During the past years, the AWI pushed technological developments to extend the operational rage of Argo floats into seasonally ice-covered regions. To this end and with additional support by the EU project MERSEA and the BMBF Project German Argo the so-called NEMO float (Navigating European Marine Observer) was developed and tested, which are now fully operational. During ANT-XXVII/2, up to 20 NEMO floats will be deployed in the Weddell Sea. In addition, on request of Birgit Klein, Bundesamt für Seeschifffahrt und Hydrographie (BSH) and Andreas Sterl, Koninklijk Nederlands Meteorologisch Instituut (KNMI) we will deploy up to 5 additional NEMOs and 7 APEX floats (produced by Webb Research Corporation, USA) along the ships transect.

To obtain position for the CTD profiles collected by the floats during the winter season, the installation of a RAFOS sound source array is necessary. The travel time of sound signals of moored sound sources (1- 11) will be recorded by the free drifting floats. Using times of arrival of signals of two or more sources, the position of the receiver, i.e. the float, may be determined retrospectively.

The present state of planning for the installation of the RAFOS array is displayed in figure 2.3 and table 2.5. During ANT-XXVII/2 sound sources at positions 01, 02, 04, 05, 06, 09 and 11 shall be recovered and redeployed, while sound source 05 will be deployed in exchange for 08.

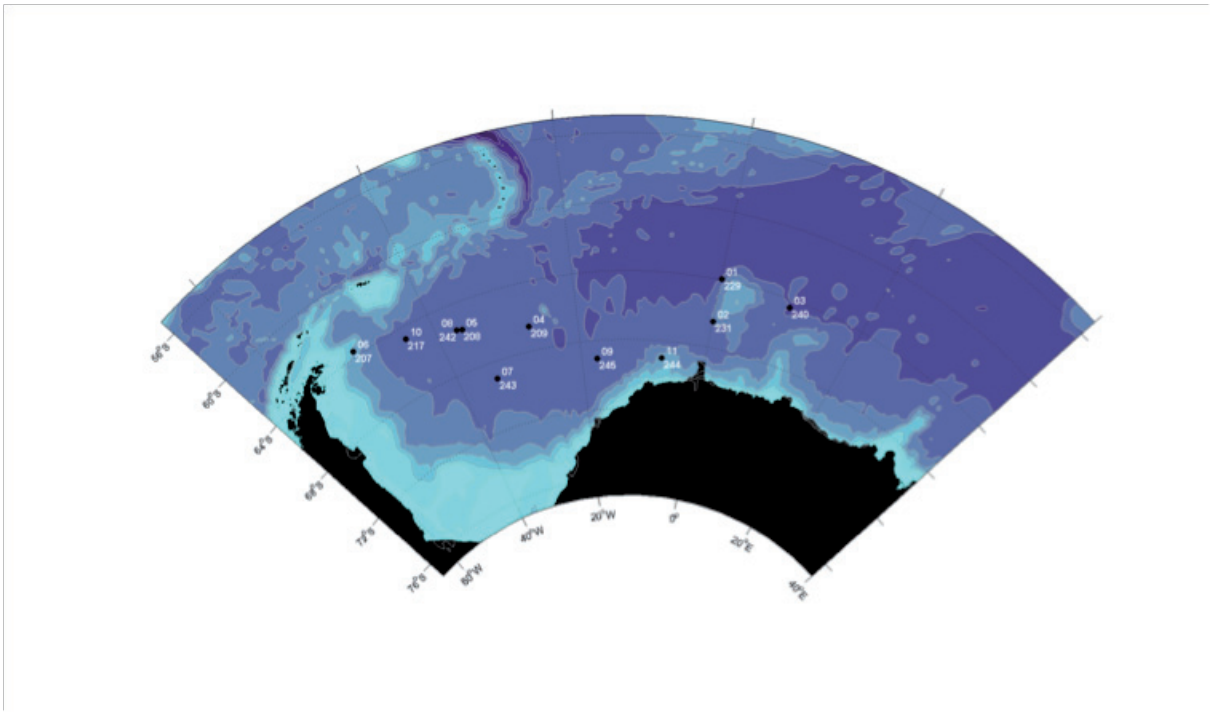

Fig. 2.3: Planned sound source array. Numbers next to the dots indicate sound source codes and corresponding mooring numbers

Tab. 2.5: State of the sound source array and planed activities during ANT-XXVII/2

	Mooring	action
W01	229	redeployment
W02	231	redeployment
W03	240	no action
W04	209	redeployment
W05	208	deployment in exchange for W08
W06	207	redeployment
W07	243	no action
W08	209	recovery no redeployment
W09	245	redeployment
W10	217	redeployment
W11	244	redeployment

PIES

Pressure sensor equipped Inverted Echo Sounders (PIES) are deployed by AWI on the GoodHope/Greenwich section across the Antarctic Circumpolar Current (ACC) and on a northwestern extension (Fig. 2.4). The aims of this PIES array operational since 2006 are (a)

observation of large-scale Ocean Bottom Pressure (OBP) variability and (b) observation of barotropic and baroclinic transport variability of the ACC.

The PIES are attached to a fixed steel frame at the bottom, measuring OBP (with a resolution of 0.001 dbar) and acoustic travel time of a sound signal from bottom to surface and back. With OBP measurements across the ACC, barotropic transport variability can be assessed. Also, the in-situ OBP time series are critical for validation of gravity measurements obtained from the GRACE satellite mission which assesses mass redistribution on a global scale. Acoustic travel times primarily depend on sound speed and hence temperature. By assigning OBP/travel time to the known range of temperature/salinity profiles across the ACC (Gravest Empirical Mode), the location of oceanic fronts, and baroclinic transport variability of the ACC are assessed.

During ANT-XXVII/2, up to 9 PIES will be recovered (for data retrieval and battery exchange) and re-deployed (Tab. 2.6). The planned deployment of a further 5 PIES along the GoodHope/ Greenwich section will improve the spatial resolution in the frontal zones of the ACC (Tab. 2.7). Most PIES deployment positions are located at crossover points of the Topex/Jason altimetry satellite, improving data analysis by the combination of OBP, travel time, and altimetric Sea Surface Height (SSH). Another 2 new deployments in the Weddell Sea are intended primarily to extend the data basis for validation of GRACE gravity measurements into Antarctic regions (Tab. 2.8).

3 PIES that have been operated since 2006 for GRACE validation on the northwestern extension of the array, far away from any regular cruise tracks, are scheduled for final recovery by the South African RV S.A. Agulhas (ANT 539, September 2010) and Polarstern (ANT-XXVII/3, PIES ANT 538, 537).

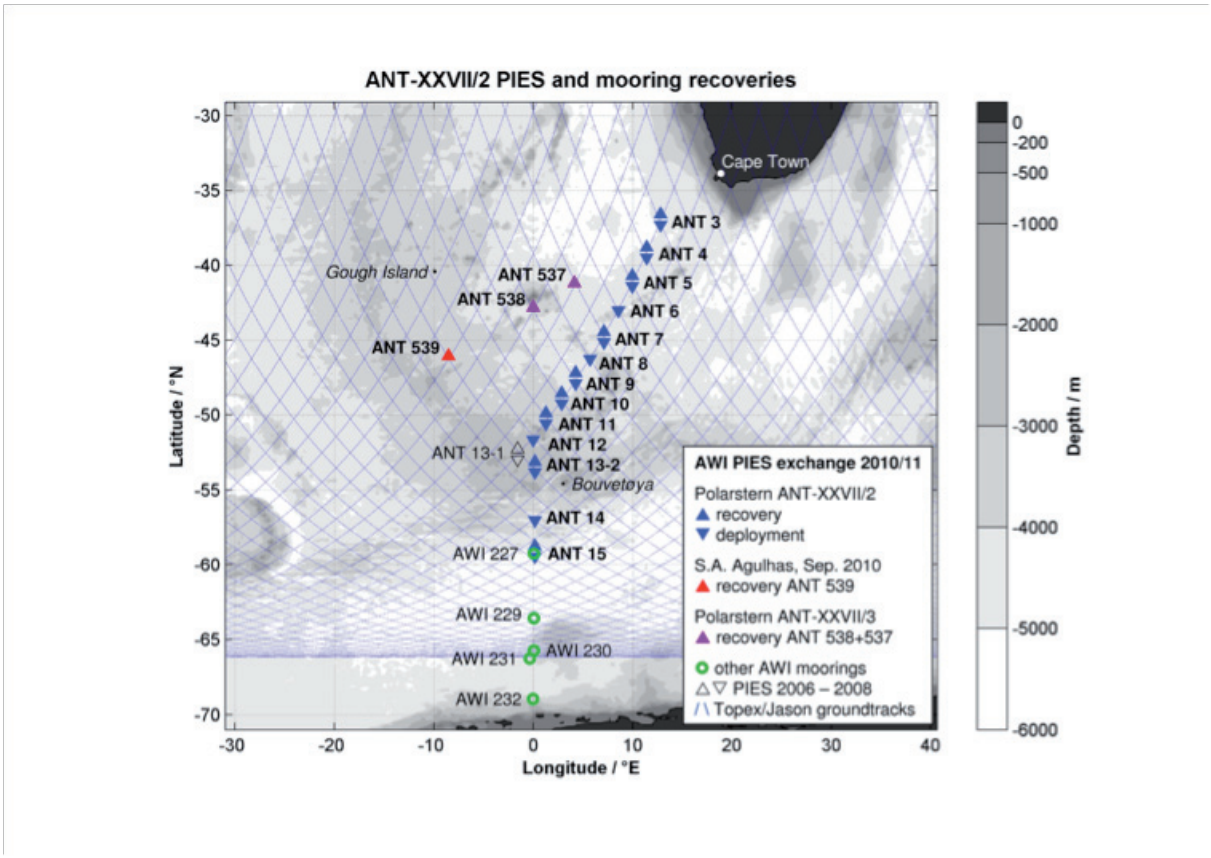

Fig. 2.4: Location of PIES to be served during ANT-XXVII/2

Table 2.6: Pressure Inverted Echo Sounders (PIES) to be recovered on the transect from South Africa to Antarctica

Mooring	Latitude Longitude	Depth (m)	Date Time deployed	Serial #	Xsea	Exp. (ANT..)
ANT-3.2	37° 05.88' S	4848	11.02.2008	192	-	SARS
	12° 45.21' E		17:26			
ANT-4.1	39° 12.78' S	4866-4709 !	08.12.2008	071	462	XXV-2
	11° 19.95' E		03:12			
ANT-5.2	41° 07.4 ' S	4675	13.02.2008	062	470	XXIV-3
	09° 57.7 ' E		01:50			
ANT-7.3	44° 39.65' S	4616	15.02.2008	184	387	XXIV-3
	07° 06.20' E		05:37			
ANT-9.2	47° 39.41' S	4538	17.02.2008	113	388	XXIV-3
	04° 15.69' E		09:42			
ANT-10.1	49° 00.65' S	4059-4059	10.12.2008	135	390	XXV-2
	02° 50.05' E		10:35			
ANT-11.3	50° 15.47' S	3844	18.02.2008	189	386	XXIV-3
	01° 26.33' E		19:20			
ANT-13.2	53° 31.19' S	2632	21.02.2008	125	471	XXIV-3
	00° 00.23' E		01:13			
ANT-15.1	59° 02.36' S	4647-4647	12.12.2008	074	467	XXV-2
	00° 05.28' E		15:56			

Table 2.7: Pressure Inverted Echo Sounders (PIES) to be deployed on the Greenwich meridian

Mooring	Latitude Longitude		Remark	Deployment
ANT-3.3	37° 05.88' S	5001	X-over	re-deployment
	12° 45.21' E			
ANT-4.2	39° 12.75' S	4709	X-over	re-deployment
	11° 20.07' E			
ANT-5.3	41° 09.80' S	4675	X-over	re-deployment
	09° 55.29' E			
ANT-6.1	42° 58.74' S	3653	X-over	new deployment
	08° 30.15' E			
ANT-7.4	44° 39.71' S	4616	X-over	re-deployment
	07° 05.01' E			
ANT-8.1	46° 12.97' S	4531	X-over	new deployment
	05° 40.23' E			
ANT-9.3	47° 39.92' S	4538	X-over	re-deployment

	04° 15.09’ E			
ANT-10.2	49° 00.68’ S	4059	X-over	re-deployment
	02° 49.95’ E			
ANT-11.4	50° 15.46’ S	3844	X-over	re-deployment
	01° 25.17’ E			
ANT-12.1	51° 25.10’ S	2639	X-over	new deployment
	00° 00.35’ E			
ANT-13.3	53° 31.20’ S	2632	X-over	re-deployment
	00° 00.08’ E			
ANT-14.1	56° 55.83’ S	4004	X-over	new deployment
	00° 00.04’ W			
ANT-15.2	59° 02.40’ S	4630	near AWI-227	re-deployment
	00° 05.30’ E		59°04.10’S 0°04.88’E	
ANT-17.1	63° 57.16’ S 00° 00.37’ W	5195	near AWI-229 63°58.03’S 0°03.10’W	new deployment

Table 2.8: Pressure Inverted Echo Sounders (PIES) to be deployed along transect from Kapp Norvegia towards Joinville Island

Mooring	Latitude Longitude	Depth (m)	Remark	Deployment
WED-2.1	66° 36.89’ S	4832	near AWI-209	new deployment
	27° 07.08’ W			
WED-3.1	63° 42.80’ S	2350	near AWI-207	new deployment
	50° 52.10’ W			

2.2 Measurement of trace gases (CFCs, SF6, Helium isotopes, Neon)

K. Bulsiewicz, P. Degenhardt, O. Huhn (IUP)

Objectives

The Weddell Sea is a key area for the formation of deep and bottom water. It is, hence, an important component of the Meridional Overturning Circulation and a significant sink for atmospheric gases. Climate relevant anthropogenic carbon (Cant) is taken up at the atmospheric interface and exported to depth and stored away from the atmosphere during formation of Weddell Sea Deep and Bottom Water (WSDW, WSBW). In turn, formation of these waters is influenced by climate change. Despite their importance, formation rates of WSDW and WSBW and the related Cant inventories in the Atlantic Sector of the Southern Ocean are not well known, and estimates of the temporal variability are quite uncertain.

The major aims of our CFC, SF6, helium isotopes, and neon measurements are:

1. to determine formation rates of WSDW and WSBW in the Weddell Basin and to quantify import and export rates of recently ventilated deep water across the Prime Meridian.

2. to calculate the Cant inventories in the Weddell Sea, especially in WSDW and WSBW

3. to distinguish and quantify source water masses involved in the formation of WSBW

4. to determine entrainment rates and upwelling velocities of mid-depth and subsurface water into the surface layer in the Weddell gyre.

The deep and bottom water formation in the Weddell Sea will be studied by using chlorofluorocarbon (CFC) inventories. Additionally we will be able for the first time to measure sulphur hexafluoride (SF6) in the Weddell Sea. From the continuation of the CFC time series since 1984 and our first SF6 measurements we expect further insight in the variability of the export of deep and bottom water out of the Weddell gyre across the Greenwich meridian as well as the import of deep water from easterly sources and a better constrain of the related Cant inventories. Combined hydrographic, CFC, SF6, helium, and neon data will allow to distinguish and quantify different source water masses that contribute to deep and bottom water formation. Entrainment rates and upwelling velocities of subsurface and mid-depth water into the surface layer will be studied by measuring helium isotope ratios on a sufficient spatial resolution.

Methods

Chlorofluorocarbons (CFCs) are gaseous, anthropogenic tracers that enter the ocean by gas exchange with the atmosphere. The evolution of these transient or age tracers in the ocean interior is determined by their temporal evolution in the atmospheric and subsequently by advection and mixing processes in deep and bottom water. Sulphur hexafluoride (SF6) is also a gaseous, anthropogenic transient tracer, acting on a shorter timescale than the CFCs and providing independent information, due to its steeper and still increasing atmospheric evolution. This enables us to identify very recently ventilated water masses and to determine their inner oceanic transit times with a much higher precision.

The total inventories of CFCs and SF6 and transient tracer based transit time distributions in deep and bottom water reflect the accumulation of CFCs and SF6 carried by its surface near source water masses. Together with the known atmospheric evolution, CFC and SF6 inventories and their changes allow estimating the renewal or formation rates of recently formed deep and bottom water. In turn, CFC and SF6 based transit time distributions can be used to calculate Cant concentrations in the inner ocean, employing the well known atmospheric pCO_2 history.

Our combined CFC and SF6 measurements as age tracers will improve the estimates of deep and bottom water formation rates and the related inventories of Cant significantly. Measurements of SF6 in the Weddell Sea will be carried out for the first time.

Using stable tracers like helium isotopes and neon, additional to temperature and salinity, allow one to carry out an Optimum Multiparameter analysis to estimate the contributions of the parent source water masses to the formation of deep and bottom water. Herein helium and neon are ideal tracers for glacial melt water, and the 3He/4He isotope ratio is a tracer for deep water from the Pacific entrained into the Weddell Sea as Warm Deep Water. Surface water 3He/4He disequilibria observed on previous expeditions in the Weddell Sea indicate upwelling or entrainment of subsurface or mid-depth water into the surface layer. Our measurements of helium isotopes (vertically and horizontally on a higher resolution than previously) will allow us to determine better constrained entrainment rates or even upwelling velocities.

Work at sea

The water samples for CFCs and SF6 will be collected into 200 ml glass ampoules from the CTD/rosette system preventing contact to atmospheric air and after flushing the ampoules

several minutes. The determination of CFC and SF6 concentrations is accomplished by purge and trap sample pre-treatment followed by gas chromatographic (GC) separation on a capillary column and electron capture detection (ECD).

The water samples for helium isotopes and neon are drawn from the CTD/rosette system as well and will be stored in gas tight copper tubes. The samples will be analysed later in the IUP Bremen mass spectrometry lab. After gas extraction, the samples will be analyzed with a special sector field and quadrupole mass spectrometer system.

2.3 Sampling for radiocarbon measurements

Not on board: R.M. Key (Princeton University) and A. McNichol (Woods Hole Oceanographic Institution)

Rationale

For almost 60 years radiocarbon has proven to be one of the most useful chemical tracers for large-scale ventilation and mixing. Naturally occurring radiocarbon is used to study mixing and ventilation processes in deep and abyssal waters. Radiocarbon produced by atmospheric bomb tests is used for similar studies in the upper water column. Because of its usefulness, radiocarbon was a prime tracer measured during the WOCE program in the 1990s. During the first decade of this century radiocarbon has been measured on most of the legs of the Repeat Hydrography or CLIVAR program. The change in bomb radiocarbon distribution over the past 10-20 years is proving to be an extremely useful diagnostic for global climate change models.

Objectives

A full oceanographic section of radiocarbon across the Weddell Sea was last collected on Meteor cruise 11/5, the first WOCE cruise A21/A12, in 1990 (Peter Schlosser, PI). Twenty years have passed and we expect to see dramatic changes in the distribution. Near surface concentrations will have decreased as the bomb transient moves deeper into the water column. Increased concentrations in Antarctic Bottom Water are expected. The WOCE results showed evidence of deep (not bottom) water formation at some locations. We will be particularly interested to see if these features still exist. Additionally, the data from this cruise will be matched up with that collected on the U.S. occupation of the A13.5 line earlier in 2010 to make a complete section across the southeastern Atlantic.

Work at sea / expected results

On this expedition radiocarbon will be collected at standard WOCE density. That is, full water column sampling will be done approximately every 5 degrees. One or two upper water column profiles will be collected between each full profile. Depending on the Rosette used, a maximum of 32 samples are collected for deep stations and 16 are normally collected for upper water column stations. Each sample requires one-half liter of water and approximately the same amount for rinsing prior to collection. Each sample is poisoned with saturated HgCl2, sealed, and returned to the National Ocean Sciences Accelerator Mass Spectrometry (NOSAMS) facility at Woods Hole Oceanographic Institution for analysis. All results will be completed within one year after the samples are returned and the final results will be made public immediately. It is mandatory that radiocarbon samples be collected from the same Rosette bottles sampled for alkalinity analysis. The alkalinity data are required to separate the bomb from the natural component.

2.4 Sea ice observations

M. Martin, R. Winkelmann (PIK), not on board: Dirk Notz (MPI für Meteorologie)

Objectives

Sea ice observations will be a contribution to the Antarctic Sea Ice Processes and Climate (ASPeCt) program, which aims at an improved understanding of the role of Antarctic sea ice in the global climate system. The sea ice thickness data collected in this framework form the only circumpolar ice thickness dataset available for the Southern Ocean and have been used for model validation studies.

Ice cores will be taken at suitable locations in order to measure profiles of sea-ice temperature and salinity as well as density and air content. In particular the latter parameters are largely unknown for Antarctic sea ice and would be of great importance for improved modelling of sea-ice thermodynamics. Knowledge of sea-ice density is crucial for reliable estimates of sea-ice thickness from space-borne freeboard measurements.

Work at sea

Sea ice observations will be conducted on an hourly basis from the bridge of Polarstern during daylight conditions (ca. from 05:00 to 21:00 UTC) when the ship will be steaming. According to the ASPeCt protocol, total ice concentration, and the thickness, concentration and morphology (ridge height, areal fraction of ridged ice, floe size; snow thickness) of the three dominant ice types within a 1 km radius from the ship will be recorded while the ship moved through the pack ice. The observations will be complemented by records of sea surface temperature, near-surface air temperature, wind speed and direction, and total cloud cover. All data collected will be sent to the ASPeCt database immediately after the cruise.

For the ice-core studies, at suitable intervals ice cores will be extracted from the ice. On site, temperature profiles of these cores will be measured. The cores will then be returned to the ship. Here, they will be cut into slices, which are then individually analyzed for density, air content and salinity. The density measurements will rely on a direct measurement of volume and mass, while the air-content measurements will be carried out by melting the samples under controlled conditions.

As the cruise will be conducted in austral summer, during the time of minimum ice extent, rather little sea ice will be encountered.

3. CHEMISTRY

3.1 Repeat sections of total carbon dioxide and total alkalinity across the southern Antarctic Circumpolar Current and Weddell Gyre

M. Hoppema (AWI), E. Jones (NIOZ)

Rationale

The level of atmospheric carbon dioxide (CO_2) has been continuously rising due to anthropogenic causes, and the CO_2 content of the oceans has subsequently increased. In the Southern Ocean, and particularly in the Weddell Sea, ventilation of the deep ocean takes place with concomitant uptake of anthropogenic CO_2. Deep water upwelling into the surface layer, which occurs before

the water masses participate in ventilation processes, leads to additional exchanges of heat, CO_2, and other gases with the atmosphere. Estimates of net oceanic CO_2 uptake south of 50°S for are as low as 0.1Pg C yr-1 (Takahashi et al., 2009), but it should be realized that the uptake of anthropogenic CO_2 must be much larger than this – natural CO_2 loss from the Southern Ocean is counteracting. While the rising atmospheric CO_2 level is well known, it is much harder to monitor the oceanic CO_2 increase due to the large background level of CO_2 in the oceans and the high natural variability. Our overall objective is to trace the anthropogenic CO_2 in the deep and surface waters of the Antarctic ocean and to investigate which factors exert influence on the CO_2 distribution. Substantial progress in these issues can only be made with data time series, e.g. as regular repeat sections. Data from this cruise will extend the longest combined oceanic time-series of CO_2 and transient tracers, hydrography, nutrients and oxygen on the Greenwich meridian. The region is also important from a biogeochemical point of view; our data will explore this further. The few available data on the partial pressure of CO_2 (pCO_2) suggest that the region is a significant CO_2 sink.

Objectives

- Quantification of the carbon budget of the Weddell gyre.
- Repeat sections for TCO_2 and total alkalinity and ancillary variables will be used for estimating temporal changes in the carbon cycle, including ocean acidification.
- Comparison with earlier carbon data and determination of interannual variability.
- Determine the exchange of CO_2 between the ocean and the atmosphere in austral summer.
- Investigate small-scale and meso-scale features of the CO_2 system in the surface ocean using the continuous pCO_2 measurements.

Work at sea

We will determine TCO_2 and total alkalinity on board ship in discrete water samples taken from the rosette sampler. Depending on the frequency with which new samples will be available, we will measure the samples immediately. In some cases, the samples will have to be stored in the dark for some hours or 2 days at most. Most stations will likely be sampled and CO_2 variables determined at all depths. TCO_2 is the sum of all dissolved inorganic carbon species and is analyzed by a precise coulometric method. The accuracy is set by internationally recognized and widely used certified reference material for TCO_2 (and alkalinity). The alkalinity measurements are made using potentiometric titration with strong acid (HCl) as a titrant. The acid consumption up to the second endpoint is equivalent to the titration alkalinity. The system uses a highly precise Metrohm Titrino for adding acid, a pH electrode and a reference electrode. Both TCO_2 and alkalinity are measured together with a VINDTA instrument (MARIANDA, Kiel), which combines the two measurements.

In addition, we will collect and use the surface water pCO_2 data of the permanently installed pCO_2 General Oceanics system on board Polarstern. This system uses an infra-red analyzer (Li-cor), both for seawater using a water-air equilibrator and for the atmosphere, the air being pumped from the crow's nest.

The TCO_2 and alkalinity data will be largely processed after the cruise. Data will be made public within due time after the cruise and will be submitted to the CO_2 data centre (CDIAC; Carbon Dioxide Information and Analysis Center, Boulder), and to Pangaea.

3.2 Investigation of brominated and organophosphorus flame retardants and monitoring of legacy POPs in Antarctica

A. Möller, H. Wolschke (GKSS), Z. Xie (GKSS, not on board), J. Schuster (University of Lancaster)

Objectives

Persistent organic pollutants (POPs) are known to be persistent, bioaccumulative, toxic and to undergo long-range atmospheric transport (LRAT) caused by their hydrophobic and semi-volatile properties. Once emitted into the environment, POPs are being discharged into the marine environment by freshwater discharge and surface runoff and, more important, transported and deposited via the atmosphere into remote areas such as the Antarctica and the Arctic. In the marine environment, they are subject to different processes like wet and dry deposition, (re)volatilization, sedimentation and bioaccumulation. Besides the legacy POPs, (e.g., polychlorinated biphenyls (PCBs), polychlorinated dibenzodioxins/furans (PCDD/Fs) and organochlorine pesticides (OCPs)) which are officially listed as POPs in the Stockholm Convention, there are several emerging pollutants whose occurrence and behaviour in the marine environment is not (well) studied such as brominated and organophosphorus flame retardants (BFRs and OPFRs) and current-use pesticides (CUPs).

BFRs, in particulate polybrominated diphenyl ethers (PBDEs), have been used for several decades in industrial and consumer products to reduce the inflammability. Since the technical Penta- and OctaBDEs were banned by the Stockholm Convention, there is increasing demand, production and, therefore, emission into the environment of non-regulated non-PBDE BFRs such as hexabromobenzene (HBB), 1,2-bis(2,4,6-tribromophenoxy)ethane (BTBPE) and the highly-chlorinated flame retardant Dechlorane Plus which have already been detected by environmental chemists from GKSS in air and water from the Greenland Sea during ARK-XXIV/3. Besides BFRs, halogenated and non-halogenated OPFRs such as tris(2-chloroethyl) phosphate (TCEP) and triphenyl phosphate (TPhP), are the second important group of organic flame retardants which are also widely used as plasticizers and hydraulic fluids. In the 1990s, they have been qualitatively found in air of Antarctica while concentration levels and distribution in the marine environment are lacking.

Among the legacy POPs of interest for this project are PCBs. Their production peaked in the 1960s. First restrictions and bans were established by individual countries in the 1970s and the following decades until PCBs were globally banned in 2001. It was used in closed systems e.g. as a cooling agent in transformers as well as in open systems like paints and glues. PCBs were produced as a mixture of different congeners with a varying grade of chlorination. Current sources for PCBs are dumps and old systems.

Also part of the monitored POPs are OCPs like DDT and its degradation products DDE and DDD, as well as the chlordane, lindane and hexachlorobenzene (HCB).

The objectives of this project are the determination of emerging and legacy POPs in air and seawater and to evaluate their spatial distribution, transport routes and air-water exchange processes along the cruise leg ANT-XXVII/2.

Work at sea

High-volume air sampling

Two different high-volume air samplers will be deployed on the monkey deck of Polarstern. GKSS high-volume air samplers equipped with a glass fiber filter (GFF) and a polyurethane plug (PUF)/PAD-1 or PAD-2 resin column are continuously operated in 72 h intervals, and Lancaster high-volume samplers equipped with a GFF and a PUF plug are operated in 24 h periods every three days.

High-volume water sampling

High-volume water samples (1,000 L) will be taken from the ship's seawater system using an in-situ pump module with a GFF and a PAD-2 or PAD-3 resin column.

Water sampling with solid-phase extraction

2-L water samplers will be collected from the ship sea water intake system, and from the CTD for different depth. The samples are extracted on board with SPE cartridges.

Snow sampling

10-50 L snow samples will be taken and melted in a stainless steel can and extracted using the same set-up as used for the high-volume water samples.

Extraction and analysis

All samples will be stored on board and extracted and analyzed in the labs of GKSS or Lancaster University.

Expected results

Caused by their high persistence and semi-volatile properties, several legacy and emerging POPs are expected to be found in Antarctica. Previous studies have shown to LRAT potential of PBDEs, while several non-PBDE flame retardants are expected to be found in similar concentration ranges. Data in air and water are expected to be confirmed by findings in snow. Besides BFRs, OPFRs and CUPs will be investigated for the first time in a remote area. Even though PCBs and OCPs are banned worldwide some are still in use in some countries and are still expected to be transported to Antarctica. Both the gaseous/dissolved phase and particulate phase will be analysed to identify the partitioning behaviour in the atmosphere and the ocean. Together with data from ANT-XXVII/1, the air-water exchange of several legacy and emerging POPs will be studied and compared among each other in order to investigate and evaluate their LRAT behaviour. Thereby, PBDEs and its alternatives are expected to show similar behaviour caused by their structural similarities.

4. BIOLOGY

4.1 Marine Mammal Survey

L. S. Lehnert, H. Verdaat, D Risch, C. Rocholl (FTZ - Westküste) not on board: U. Siebert, H. Herr

Objectives

Knowledge on distribution, density and abundance of cetaceans in the Southern Ocean is rather limited. Especially in pack-ice regions, little research has been conducted, as only

few vessels can penetrate into the ice. By means of a dedicated cetacean sighting survey following standard line-transect distance sampling methodology, our project aims to contribute to solid base line data on cetacean occurrence and abundance, needed by decision makers for management and protection. In addition behavioural observations shall investigate response behaviour of cetaceans towards vessels in Antarctic waters.

Work at sea

We will conduct shipboard and aerial cetacean sighting surveys whenever sighting and weather conditions permit (e.g. we need relatively calm seas in order to spot cetaceans). For the shipboard survey our observation platform will be the crow's nest and we will survey along the cruise track of Polarstern. During any shift 2 observers will collect sighting data according to distance sampling methodology and a third person will enter these data directly into a computer connected to a GPS. The same method will be followed during the aerial surveys which will be conducted by helicopter, in order to survey areas away from the ship. In addition to the distance sampling survey we will conduct some tracking from the crow's nest, i.e. following detected (groups of) animals with powerful binoculars („Big Eyes"), noting down their track as long as possible. This is a means to evaluate cetacean behaviour, for example in response to the ship.

Expected results

Our data will be used for population assessment of cetaceans in Antarctic waters. Along with distributional analyses of species occurrence, distance sampling evaluation will contribute to abundance estimation of species, e.g. the Antarctic minke whale (Balaenoptera bonarensis), which is still being hunted. Our tracking data will not only be used for behavioural studies, but also for a comparison with infrared cetacean detection data collected by the MAPS project during this cruise.

4.2 MAPS: Marine Mammal Perimeter Surveillance

O. Boebel, L. Kindermann, D. Zitterbart, A. Bombosch (AWI), not on board: E. Burkhardt (AWI)

Objectives

Both, non-governmental organizations and governmental agencies increasingly criticize the use of air-guns for marine geophysical research due to the enhanced noise levels these instruments introduce to the aquatic environment. To remedy possible detrimental effects to the marine fauna, mitigation measures are commonly requested, which in most cases imply visual observation of the ship's perimeter and shut down of seismic operations when whales are sighted within a predefined exclusion zone around the airguns. To facilitate such observations, the MAPS project aims at developing an automatic whale blow detection system on the basis of a 360° thermal imaging sensor, FIRST Navy.

Data collected with this system during two recent Polarstern cruises resulted in numerous detections during retrospective human visual screening, even in relatively warm waters of 6°C. These encouraging results however only represent a first step, as now a robust computer based image recognition algorithm needs to be developed and tested, which automatically processes the video stream for the occurrence of whale blows, resulting in issuing a real-time alert to the marine mammal observers and ship's crew. This project's goal is to test the efficiency of a first automated detection algorithm as developed on the basis of data to be collected during the expedition ANT-XXVI/3. This requires considering two questions:

1.) What is the number of missed events (i.e. whales present which are not detected by the automated algorithm).

2.) What is the number of false positives (i.e. events such as breaking waves that the auto-mated algorithm mistakenly identifies as whale blows).

Work at sea

During the cruise, two data sets will to be collected independently: a) video snippets of automatic IR based detections and b) protocols of visual sightings by independent observers. While a) is the subject of this project, visual surveys will be conducted independently under the auspices of the FTZ-Büsum, but also by the ship's nautical officers. Due to the IR system's immense requirements for data storage (3.5 TBytes per day), it is not possible to continuously save IR data for the entire cruise. Rather, IR video snippets will be saved on the basis of automated IR detections and on the basis of the abovementioned visual sightings. The resulting data set shall be used for retrospective testing of the auto-detector for its efficiency. To this end, the exact time (to the second) and direction of any visual sighting need to be recorded along with information on the species sighted.

Expected results

This effort is expect to result in the collection of a comprehensive data set for further system development and validation, behavioural analysis and a marine mammal sighting database. Sighting data will be merged with environmental proxies such as sea-ice conditions, water depth and sea surface temperature to be used in environmental suitability models. Behavioural analysis will provide high resolution tracks of marine mammals in the vicinity of the ship, including the distribution of concurrent ice-floes. System validation will lead to improved algorithms, with the aim to minimize the amount of false alerts.

4.3 Antarctic krill population dynamics

V. Siegel (vTI)

Objectives

Since 1978 krill data have been collected by German surveys or by international cooperation which contribute to the long-term monitoring of the stocks in the Antarctic Peninsula. Data have been collected on an annual basis but they also cover most of the seasonal cycle. This allows the study of seasonal as well as interannual aspects in krill demography and population dynamics. The planned Polarstern cruise is a continuation of this activity and therefore studies will focus on Antarctic krill as the primary target species. However, other heterospecific krill species as well as salps will also be recorded quantitatively.

Recent evidence indicates that annual surveys are necessary to fully understand the linkages between the environment, krill, and top predators. Concerning the krill part of the ecosystem we have to study the following questions:

What biological and environmental key factors affect the successful reproduction of krill?

How does breeding season relate to successful spawning or larval survival?

Which physical key factors influence krill larval survival and subsequently recruitment?

Can we detect natural variation in reproduction and recruitment success between years?

Are there geographical variations in krill distribution, abundance or growth and mortality rates in relation to within-season or between-season?

How does breeding and recruitment success relate to krill stock size?

Are there long-term trends in krill distribution patterns as well as abundance/biomass and if so, are they related to long-term trends in the environment?

These questions are of complex nature and require a large amount of data collected in a standardized way to allow direct comparisons between data sets. The German krill data have been collected over the years with standard gear (RMT1+8) and standard methods for net sampling procedures as well as for sample handling and measuring and staging krill. These allow interannual comparison of quantitative aspects of krill demography and population dynamics.

In the recent past indices for krill density, spawning timing and recruitment success have been developed and standardized by CCAMLR. As a second step these quantitative indices will be determined and recorded, not only qualitatively like good or bad year, poor or high recruitment, early or late spawning. Available data also include standardized length frequency distributions, which are essential for calculation of growth rates and mortality rates.

From this basic parameters and indices the above listed questions can be addressed subsequently. After the seasonal variability of distribution and abundance and succession of maturity stages has been described, it will be necessary to estimate the range of within-season variability of population parameters like age structure, growth, and mortality. From the knowledge of seasonal variability of krill parameters the next step will be the identification of possible relationships between the biological and environmental parameters like temperature, sea surface temperature, sea ice, etc.

Work at sea

The planned investigations will be carried out in the area west of the Antarctic Peninsula during austral summer 2010, the main spawning season for the Antarctic krill. About 80 established standard stations will be covered along regularly spaced transects (Fig. 4.3.1) during a survey period of approximately 21 days. The plankton net RMT1+8 will be used as standard gear to collect krill samples from the upper 200 m surface layer. Biological parameters such as sex ratio, age composition and maturity stage development will be determined from each sample. These data will be analysed as part of the CCAMLR (Convention for the Conservation of Antarctic Marine Living Resources) related research activities of the Seafisheries Research Institute. Results will be submitted to the CCAMLR working group meetings to support the monitoring of the krill stocks in the Atlantic sector and the management of the krill fishery. Studies on the spawning success, survival rates and recruitment success are essential to develop prediction models for the development of the krill stocks.

The estimation of the actual standing stock biomass will be based on the data collected with the SIMRAD EK 60 hydroacoustic equipment, which was agreed upon by CCAMLR as the standard multifrequency echosounder. The biomass estimate resulting from this operation will help the CCAMLR working group to estimate the potential yield of the krill stock and set catch limits for the commercial fishing operations. A close international cooperation is envisaged with the US AMLR programme. A standardized synoptic survey will be conducted in January in the area of the South Shetland and Elephant Islands. Data will be exchanged and analyzed jointly, and will be submitted to CCAMLR.

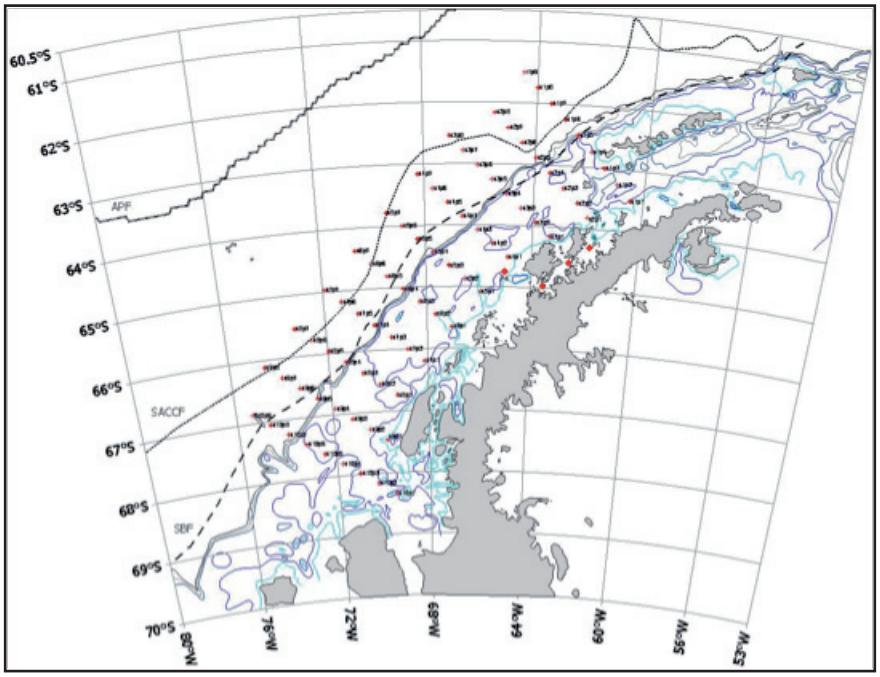

Fig. 4.3.1 Station chart of the RMT1+8 net sampling and CTD casts west of the Antarctic Peninsula in January 2011. Solid and dotted lines indicate the location of the frontal zones.

4.3.1 Krill larvae and Themisto amphipod, distribution and ecology

M. Haraldsson (vTi), K. Uryupova (MSU), D. Sologub (SIO)

Objectives

The focus of studies in krill larvae distribution and ecology will be at regional patterns associated with particular water masses and their modifications.

Work at sea

Krill larvae from RMT 1 catches will be subsampled. One portion of the catch will be fixed for further investigation. Preserved samples then will be sorted into species, stages and developmental forms and counted. These data will be used for quantitative assessment of euphausiid larvae distribution and composition and assessment of spawning timing of euphausiid species in relation to waters of various origin and other environmental and biological characteristics.

Material to study length/ weight relationships of particular stages of dominant krill species associated with different water masses will be collected from the rest of samples. The larvae will be identified, staged, assigned to particular development form a stage and measured. Then they will be deep frozen individually to obtain dry weight. Relationships between length, weight and development stage/ form of euphausiid larvae will be used to interpret the effect of environmental conditions in particular waters on krill larval development.

Simultaneous measurements will be carried out for environmental data: Sea ice distribution maps in the period preceeding survey (August – December) and chlorophyll a satellite data (September – January) will provide history of seasonal processes in particular areas.

Population differentiation in Euphausia superba

About 100 specimens from abundant sample associated with particular waters will be preserved in 96 % alcohol and analysed for mitochondrial genome microsatellites (using the DNA sequence of the mitochondrial genome of Euphausia superba). Larval samples for population genetics studies will be also complemented by tissue samples of juvenile krill associated with particular waters.

Species differentiation and evolution of Thysanoessa. Larvae of Thysanoessa spp. and adult specimens of Thysanoessa macrura will be preserved for molecular bar-coding analysis (using gene of the subunit of mytochondtal cytochrome oxidase, COI). This material will be further used for the analysis of phylogenetic relationships within Thysanoessa and its evolutionary history.

Amphipod Themisto: distribution, ecology and evolutionary history

The amphipod Themisto gaudichaudi will be studied as an important mesozooplankton predator. RMT 1 catches will be examined for Themisto spp. and other hyperiid species. The specimens of Themisto will be identified, counted and measured. Where possible sex will be indentified and the presence of female with marsupia recorded. Representative samples of Themisto gaidichaudi associated with waters of different origin will be prepared for length/ weight relationships.

Intact material of Themisto gaudichaidi from Bongo net samples will be used for feeding experiments in order to clarify if there is any preference to feeding on krill larvae and what predation rate of Themisto gaudichaudi can attained at dense concentrations of krill larvae.

Specimens of Themisto gaudichaudi and other species of hyperiids will be preserved in 96 % alcohol for bar-coding studies and subsequent reconstruction of evolutionary history of the Antarctic Hyperioidea with particular emphasis on relationships between the South and the North Hemisphere species of Themisto.

En route krill predators census as a proxy of abundant krill limits in the Weddell Sea

Crossing the Weddell Sea from the Georg from Neumayer Station to the tip of the Antarctic Peninsula is a good chance to provide insight into the role of the Weddell gyre for distribution of krill and its predators. Observations on marine mammals, sea birds and krill on the overturned ice floes will be conducted from the bridge using the methods adopted in the Arctic and Antarctic Research Institute (AARI). Increased density of crabeater seals and some other predators will be used as a proxy of abundant krill presence or absence. Sea ice concentration will be assessed using visual observations and satellite data processed in the AARI. Oceanographic information will be obtained from the continuous recording of sea surface temperature and salinity.

4.3.2 Environmental transcriptomics of the Southern Ocean Salpa thompsoni

P. Batta Lona (UC)

Objectives

The Southern Ocean Salpa thompsoni is subject to severe environmental (temperature) and biological conditions (food availability, energetic constraints, timing of reproduction), as well as the marked seasonal variability and long-term climate change. There is an urgent need to understand the potential for salps to adapt to climate change, yet few molecular resources are available for this species or its close relatives.

The goal of this effort is to collect and freeze Salpa thompsoni from different Southern Ocean locations and carry out transcriptome analysis by whole-genome RNA sequencing to characterize gene expression profiles in relation to life history processes and environmental conditions. If possible, selected other zooplankton species, including the krill Euphausia superba, will be collected and similarly preserved for genomic and transcriptomic analysis. The scientific experiments and analyses to be carried out using the specimens collected during this cruise will be a critical component of a dissertation research, aiding in a qualification for a Ph.D. degree at the University of Connecticut.

Work at sea

During ANT-XXVII/2, Salpa thompsoni will be collected by net tow (Rectangular Midwater Trawl or RMT). Analysis of DNA and RNA requires careful collection and preservation of specimens and tissue. Samples collected from the plankton net tows will be separated by taxon immediately after collection. All salps will be removed for identification of species while still living. Species other than Salpa thompsoni will be recorded and preserved either in ethanol or frozen. Quantification of species of salps will be done by counting colonies and zooids. Salpa thomsponi will be identified under the dissecting microscope, and the stomachs will be removed by dissection to avoid contamination of DNA from prey. The remaining tissue will be flash frozen in liquid nitrogen and stored at -80°C.

4.3.3 Hyperbenthos of deep-sea basins west of the Antarctic Peninsula

U. Mühlenhardt-Siegel (vTi)

Objectives

The assessment of Antarctic biodiversity and biogeography is of particular importance in the context of global environmental changes. Biogeography is closely linked to biodiversity and it is concerned with the geographic distribution of species and taxa in our biosphere. Knowledge of biodiversity and biogeography is central to any attempt to conserve species and their habitats. Moreover, this information can help to identify the origin of species in certain areas and their phylogenetic relationship. Which consists of coastal or shelf areas and more than 90 % is deep sea. The fauna living in the vast areas of the deep-sea, which represent 90 % of the ocean floor, are very poorly known, especially in the Antarctic where there has been a notable lack of biological sampling effort. Without doubt, the Antarctic deep sea still harbours many unknown taxa, despite the fact that many nations have intensified their Antarctic research activities during the last 20 years.

Main focus of the present analysis will be the peracarid order Cumacea (Crustacea).

The shelf areas of the Antarctic regions are relatively well sampled. Deep-sea samples from the Weddell Sea and some parts of the Ross Sea are available, however, results indicate a high degree of endemisms for each ocean basin. Samples from the deep sea (deeper than 2,000 m depth) from the Bellingshausen Sea west of the Antarctic Peninsula are still missing.

Work at sea

The most successful sampling gear for small macrobenthic animals is the epibenthic sledge; the box- and multi corers, and Agassiz trawl are much less efficient because of the limited sampling area and large mesh size, respectively. The epibenthic sledge, equipped with epi- and supranet of 500 µm mesh size, will be towed on the bottom at 0.5 m s-1 for approximately

10 - 15 minutes. The most time consuming part of the sampling will be the lowering and heaving phases.

The information about the cumaceans from the deep sea of the Bellingshausen Sea will complete the results from the ANDEEP expeditions about the biodiversity, faunal overlap and biogeography of this peracaridean group from the western and eastern Weddell Sea, South Sandwich Trench and Cape Basin. As the rate of endemism is expected to be about 20 - 25 % in Antarctic deep-sea basins, a number of new species will have to be identified and described. Information will be obtained on the occurrence of new and known species as well as their spatial overlap in distribution patterns. This will allow a more detailed description of biological provinces or bioregionalisation in general. The data will be submitted to the SCAR-MARBIN data base.

4.4 Effect of CO_2 and iron on phytoplankton growth

C. Hoppe, U. Richter , S. Trimborn (AWI), C. Couture, C. Payne (UBC), not on board: B. Rost (AWI), P. Tortell (UBC)

Objectives

The Southern Ocean accounts for ~20 % of the global annual phytoplankton production and is considered to exert a large influence on the marine carbon cycle and to have the greatest potential to affect atmospheric CO_2 concentrations. In-situ fertilization experiments have revealed that iron availability is the key factor controlling phytoplankton growth in the Southern Ocean. Aside from this crucial factor, other environmental factors like the ongoing ocean acidification due to changing atmospheric CO_2 concentrations as well as to seasonal changes in CO_2 were found to also exert control on both phytoplankton structure and growth. Unfortunately, its effects on the physiological ecology of the phytoplankton community have thus far received very little attention, even though large seasonal changes in CO_2 can be observed over the course of the growing season. Until now, research so far has focussed on the investigation of one of these two factors, while attention has not yet been paid to the assessment of iron availability in conjunction with CO_2, even though the combination of both factors may be crucial in controlling the phytoplankton species composition in the Southern Ocean.

Work at Sea

It is planned to characterize phytoplankton populations along the cruise track using membrane inlet mass spectrometry (MIMS), fluorescence induction relaxation fluorometry (FIRe) and 14C-based assays. As the planned cruise takes place during the early and late summer period when bloom events are quite common large variations in CO_2 concentrations can be expected imposing different physiological traits on the phytoplankton communities.

In addition to this, on-deck CO_2/iron pertubation experiments with natural phytoplankton communities south of the Polar Frontal Zone will be performed to address the important question of how CO_2-related changes in carbonate chemistry e.g. ocean acidification in combination with different iron availability will directly affect primary productivity and phytoplankton species composition. Therefore, incubations of natural assemblages will be exposed to CO_2 levels representing values of the last glacial maximum (~180 µatm), present-day (~380 µatm), and those projected for the year 2100 (~1,000 µatm).

Expected results

The physiological characterization of phytoplankton populations that are naturally exposed to changing CO_2 concentrations along the cruise track will help to provide a better ecophysiological explanation for the spatial distribution of Southern Ocean phytoplankton. Especially, the performance of shipboard iron-/CO_2 manipulation experiments will enable us to gain a process-based understanding of how the two environmental factors iron and CO_2 shape the Southern Ocean phytoplankton community structure, alter productivity and phytoplankton growth.

4.5 Biogenic gas distributions along frontal zones in the Southern Ocean

C. Couture C. D. Payne, P.D. Tortell[1], (UBC), [1] not on board

Objectives

The broad-scale patterns of biological productivity and biogenic gas distributions in the Southern Ocean are reasonably well understood. However, satellite imagery reveals significant meso-scale and sub mesoscale variability in biological and physical fields that is likely associated with frontal zones, continental shelf interactions and sea ice dynamics. This small-scale heterogeneity is very difficult to capture using conventional hydrographic surveys with discrete sampling stations separated by distances of hundreds of kilometers. The goal of this project is to map, with high spatial resolution, the fine-scale distribution of surface water pCO_2, biological oxygen saturation (DO2/Ar) and dimethylsulfide (DMS) using ship-board mass spectrometry.

Work at sea

Underway gas measurements will be conducted using ship-board membrane inlet mass spectrometry. Seawater from the ship's underway supply will be continuously pumped to flow-through sampling cuvette attached to a quadropole mass spectrometer. Gases are extracted across a membrane interface and analyzed selectively on the basis of charge to mass ratios ever ~ 30 seconds. Gas concentrations will be calibrated using temperature controlled seawater samples continuously bubbled with standard gas mixtures. Measurements will be made along the entire ship track.

Expected results

The proposed research will provide new information on the distribution of climate-active biogenic gases in the S. Ocean, with unprecedented spatial resolution. pCO_2 and DMS measurements will be used, in conjunction with sea ice and wind-speed data to compute sea-air fluxes. DO_2/Ar data will be used to derive estimates of net community production (i.e. water column photosynthesis minus community respiration). These parameters will be examined across a range of physical and biological conditions, enabling us to understand the influence of frontal zones, continental shelf inputs and sea ice dynamics in driving Southern Ocean biogeochemical processes.

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ANT-XXVII/3

08 February 2011 - 18 April 2011

Punta Arenas - Cape Town

Chief Scientist

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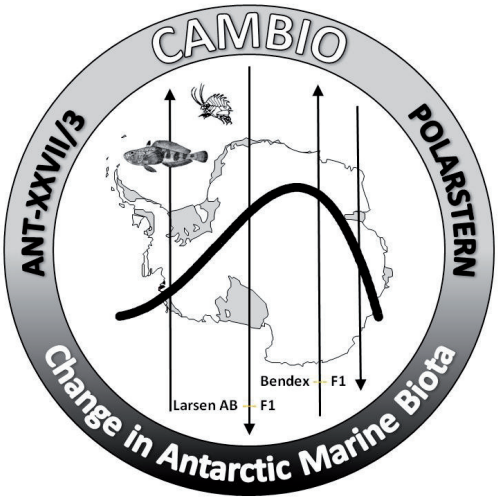

Contents

1. ÜBERBLICK UND FAHRTVERLAUF

R. Knust, C. Bock, D. Gerdes, K. Mintenbeck (AWI)

Laut Bericht des IPCC (Intergovernmental Panel on Climate Change) aus dem Jahr 2007 sind Anzeichen für Klimaveränderungen in der Gesamtantarktis zwar weniger offensichtlich als in der Arktis, in einigen Teilen der Antarktis gibt es aber bereits erhebliche Veränderungen im Temperaturregime. Die mittleren Lufttemperaturen an der Antarktischen Halbinsel und in der Bellingshausen-See sind seit 1950 um ca. 1,5° C gestiegen; in den letzten 100 Jahren sogar um ca. 3° C. Die Wassertemperatur bei Südgeorgien ist im Winter um 3,3° C und im Sommer um 0,9° C wärmer als zu Beginn des 20. Jahrhunderts. Als Folge der Erwärmung lässt sich insbesondere im Bereich der Antarktischen Halbinsel ein deutlicher Rückgang diverser Eisschelfe beobachten, so sind zum Beispiel in den vergangenen 10 Jahren an der Ostküste der Antarktischen Halbinsel die beiden Larsen-Schelfeise A und B mit einer Gesamtfläche von insgesamt ca. 80 x 80 km komplett weggebrochen. Die Veränderungen im Temperaturregime sowie die Veränderungen in der Eisschelfdynamik werden signifikante Einflüsse auf die Lebensgemeinschaften der betroffenen Schelfgebiete haben.

Mögliche langfristige Folgen einer fortschreitenden Erwärmung wird eine Verschiebung in der Artenzusammensetzung durch die Auslöschung (Extinktion) ansässiger (endemischer) Arten und Invasion von Arten aus nördlicheren Meeresgebieten sein. Dies wird potentiell mit signifikanten Veränderungen der Nahrungsnetzstruktur einhergehen. Ob eine Art unter veränderten abiotischen Bedingungen in ihrem Lebensraum erfolgreich bestehen kann, ist ebenso abhängig von der individuellen genetischen und physiologischen Ausstattung und Plastizität, wie das Neubesiedlungspotential invasiver Arten.

Untersuchungen während früherer Expeditionen zur Biogeographie und Biodiversität im Bereich der Scotia-See und der Bouvet-Insel haben gezeigt, dass diese Inseln im Südatlantik wichtige Trittsteine für eine Besiedlung der Antarktis durch Arten aus den nördlicheren Bereichen sein können. Erste Hinweise für solche Besiedlungsversuche durch reptante dekapode Krebse wurden während ANT-XIX/5 gefunden.

Die Veränderungen in der Schelfeisdynamik führen einerseits zu Veränderungen in den Stoffflüssen zwischen Pelagial und Benthal in den jetzt unbedeckten Schelfgebieten, andererseits aber auch zu einem erhöhtem Aufkommen von Eisbergstrandungen auf dem Schelf mit entsprechenden Konsequenzen für die benthischen Lebensgemeinschaften und für die demersale Fischfauna. Diese Auswirkungen sind in den Jahren 1996 - 2006 auf verschiedenen Antarktisexpeditionen (EASIZ I-III, BENDEX, LARSEN AB) untersucht worden. Dabei wurden deutliche Fortschritte beim Verständnis der Bedeutung pelago-benthischer Kopplungsprozesse und der Störungsintensität durch Eisbergstrandungen für Besiedlungsmuster und Biodiversität des antarktischen Schelfs erzielt. Vollkommen unklar sind aber immer noch die zeitlichen Abläufe der Wiederbesiedlungsprozesse nach Störungen. Um eine Zeitmarke zu setzen, wurde in der Saison 2003/2004 (ANT-XXI/2, BENDEX) ein Experiment durchgeführt, bei dem in einem definierten Gebiet eine künstliche mechanische Störung des Meeresbodens gesetzt wurde. Das gestörte Gebiet soll auf dieser Expedition wieder aufgesucht werden, um die Wiederbesiedlung zu dokumentieren. Welche Auswirkungen die großflächigen Schelfeisabbrüche in der Westantarktis auf die Biodiversität und Artenzusammensetzung haben, ist ebenfalls wenig bekannt. 2006/2007 wurden während

ANT-XXIII/8 erste Untersuchungen zur Besiedlung der ehemals vom Schelfeis bedeckten LARSEN-A/B - Gebiete an der östlichen Halbinsel durchgeführt. Die begonnenen Arbeiten sollen auf dieser Expedition fortgesetzt werden.

Auf der Expedition ANT-XXVII/3 werden mögliche Auswirkungen von Klimaveränderungen auf die Biodiversität von Lebensgemeinschaften und Ökosystemfunktionen in sub- und hochantarktischen Gebieten untersucht. Die Expedition ist Bestandteil des internationalen SCAR-Programms „Biodiversity and Evolution in the Antarctic: The response of life to change“ (EBA). Aufbauend auf Daten und Ergebnissen von früheren Expeditionen (ANT-XV/3, ANT-XVII/3, ANT-XIX/5, ANT-XXI/2, ANT-XXIII/8), die im Rahmen der Programme EASIZ und EVOLANTA durchgeführt wurden, wird sich diese Expedition auf drei Hauptthemen konzentrieren:

1. Die geographische Verbreitung von Arten in der Sub- und Hochantarktis und die genetischen und physiologischen Steuerungsprozesse, die diese Verbreitung bestimmen.
2. Pelago-benthische Kopplungsprozesse und Auswirkungen von klimabedingten Veränderungen auf das Nahrungsnetz.
3. Auswirkungen von veränderten Schelfeissituationen auf die Biodiversität des Benthos und der demersalen Fischfauna des westlichen und östlichen Weddellmeeres.

Die Arbeiten während der Expedition werden sich auf die Lebensgemeinschaften des Schelfs (ca. 200 - 600 m Wassertiefe) und des Schelfrandes konzentrieren. Die Untersuchungen umfassen sowohl subantarktische Gebiete der Scotia-See und um die Bouvet-Insel, als auch die hochantarktischen Schelfgebiete des westlichen und östlichen Weddellmeeres (siehe Abb. 1.1). Arbeiten zur Biogeographie, Genetik, Ökologie und Physiologie werden in allen 7 Untersuchungsgebieten durchgeführt. Dabei werden sich die Arbeiten zur Genetik, Ökologie und Physiologie auf ausgewählte Arten des Zooplanktons, des Makrozoobenthos, auf Cephalopoden, Dekapoden und Fische konzentrieren. Wie bereits in den vergangenen Jahren sollen Tiere für weiterführende physiologische Untersuchungen lebend nach Bremerhaven transportiert werden.

In den subantarktischen Gebieten (BB, SG, SO, KG und BO, siehe Karte) wird die Arbeitszeit jeweils ca. 2 - 3 Tage betragen. In den Gebieten des hochantarktischen Schelfs [Larsen-AB (LA) und östliches Weddellmeer (EW)] sind Prozesstudien zur pelago-benthischen Kopplung und zur räumlichen Verteilung der Besiedlungsmuster geplant, entsprechend sind hier die Arbeiten jeweils auf ca. 10 - 15 Tage ausgelegt.

Polarstern wird am 08. Februar 2011 zum dritten Fahrtabschnitt der 27. Antarktis-Expedition in Punta Arenas (Chile) auslaufen. Die ersten Stationen werden auf dem Schelf von Südgeorgien und den Südorkneys liegen, danach wird die Antarktische Halbinsel angelaufen. Neben Stationsarbeiten bei King George Island soll die deutsche Dallmann-Station bei Jubany versorgt und lebendes Tiermaterial übernommen werden, das bereits im Januar in der Potter Cove gefangenen wurde. Anschließend wird *Polarstern* die beiden Hauptarbeitsgebiete im westlichen Weddellmeer (LARSEN-A/B) und im östlichen Weddellmeer (BENDEX-Gebiet) anlaufen. In beiden Gebieten wird ein umfangreiches wissenschaftliches Programm durchgeführt. Nach der Versorgung von Neumayer-III wird *Polarstern* als letztes Arbeitsgebiet die Bouvet-Insel ansteuern. Am 18. April geht der dritte Abschnitt der 27. Antarktis Expedition in Kapstadt (Südafrika) zu Ende.

OVERVIEW AND ITINERARY

According to the IPCC (Intergovernmental Panel on Climate Change) 2007 signs of climate change in the Antarctic are less pronounced compared to the Arctic though in some parts of the Antarctic clear and significant changes in temperature regime are detectable. Mean air temperature at the Antarctic Peninsula and in the Bellingshausen Sea increased by approximately 1.5° C since the 1950ies, and by almost 3° C within the last 100 years. Around South Georgia Island water temperatures have clearly increased compared to the beginning of the 20th century, by 3.3° C in winter and by 0.9° C in summer. The temperature rise entailed a drastic disintegration and reduction of various ice shelves along the Antarctic Peninsula; within the last 10 years, e.g., the LARSEN-A/B ice shelves, covering an area of approximately 80 x 80 km, disappeared completely. Changes in the temperature regime as well as changes in the ice shelf dynamics will significantly affect the marine living communities in the respective regions.

Ongoing climate warming will most likely result in shifts in species composition due to extinction of endemic species and invasion of species from adjacent northern regions. Such alterations might involve significant changes in the food web structure. Survival of particular species and persistence of populations under altered abiotic conditions strongly depends on genetic and physiological fitness and plasticity of individuals.

Former expeditions focusing on biogeography and biodiversity in the Scotia Sea and around Bouvet Island identified these islands in the South Atlantic as potentially important step-stones for the colonization of Antarctic waters by northern species. On ANT-XIX/5 the discovery of reptant decapods provide a first evidence for such a process. However, whether these island shelves are also used by other taxonomic groups for invading Antarctic waters, will still have to be verified.

Changes in ice shelf dynamics involve alterations in pelago-benthic flow patterns in the formerly ice-covered regions, and at the same time give rise to an increase in iceberg scouring events, which impacts the benthos and demersal fish communities on the shelf. The investigation of these effects was in the focus of several Antarctic expeditions between 1996 and 2006 (EASIZ I–III, BENDEX, LARSEN-A/B). These studies considerably improved our knowledge on the importance of pelago-benthic coupling processes and the significance of iceberg scouring events for benthic community patterns and biodiversity. However, the timescales of recolonisation phases after disturbance are still completely unknown. To set a time stamp for the investigation of the recolonisation timescale, the artificial disturbance experiment BENDEX was initiated in 2003/04 on the north-eastern Weddell Sea shelf. This area will be revisited during this expedition to document the recolonisation progress after 6 years. The consequences of the tremendous ice shelf disintegrations along the Antarctic Peninsula on biodiversity and community composition are so far unknown, as well. Some first studies focusing on the benthic communities in the formerly ice-covered LARSEN A/B embayments were carried out during ANT-XXIII/8 in 2006/07; these studies will be continued during this expedition.

The expedition ANT-XXVII/3 aims at investigating the potential effects of climate change on biodiversity and ecosystem functioning in sub- and high-Antarctic regions. The expedition is part of the international SCAR programme “Biodiversity and Evolution in the Antarctic: The response of life to change” (EBA). Based on data and results obtained during former

expeditions (ANT-XV/3, ANT-XVII/3, ANT-XIX/5, ANT-XXI/2, ANT-XXIII/8) in the framework of EASIZ and EVOLANTA, this expedition focuses on three main topics:

1. Zoogeography und biodiversity in the Sub and High Antarctic and the genetic and physiological processes regulating species diversity and dispersion.
2. Pelago-bentho-coupling processes and impact of climate induced changes on the food web.
3. Impact of changing shelf ice dynamics on the biodiversity of the benthic and demersal fish communities on the self.

The studies will concentrate on shelf and slope communities down to about 600 m water depth. Investigation areas include the sub-Antarctic islands in the Scotia Sea and Bouvet Island, as well as high-Antarctic shelf areas in the western and eastern Weddell Sea (see Fig. 1.1). In all areas studies on biogeography, genetics, ecology and physiology of zooplankton, benthos and fishes will be carried out. For specific long-term experiments living animals (in particular fishes) will be transferred to the AWI laboratories in Bremerhaven.

In each of the sub-Antarctic areas (BB, SG, SO, KG and BO, see Fig 1.1) the sampling will last 2 - 3 days. Studies in the high-Antarctic shelf areas LARSEN-A/B (LA) and BENDEX (EW) include process orientated work such as flux of organic matter and analyses of the spatial distribution of macro-zoobenthos; these studies will require 10 to 15 days in each of these areas.

The 3rd leg of the *Polarstern* expedition ANT-XXVII will start on 8 February 2011 in Punta Arenas, Chile. The first working station will be located on the shelves of South Georgia and the South Orkney Islands; subsequently *Polarstern* will head southwestwards for the Antarctic Peninsula. Beside some station work in the Bransfield Strait the German Dallmann Laboratory on King George Island will be supplied. After this, the next destination of *Polarstern* will be the main study sites in the Weddell Sea: LARSEN-A/B off the eastern Antarctic Peninsula and BENDEX on the northeastern Weddell Sea shelf. After supply of NEUMAYER III the vessel will head for the last study area around Bouvet Island. Finally, *Polarstern* will move towards Cape Town, South Africa, where the expedition will end on 18 of April 2011.

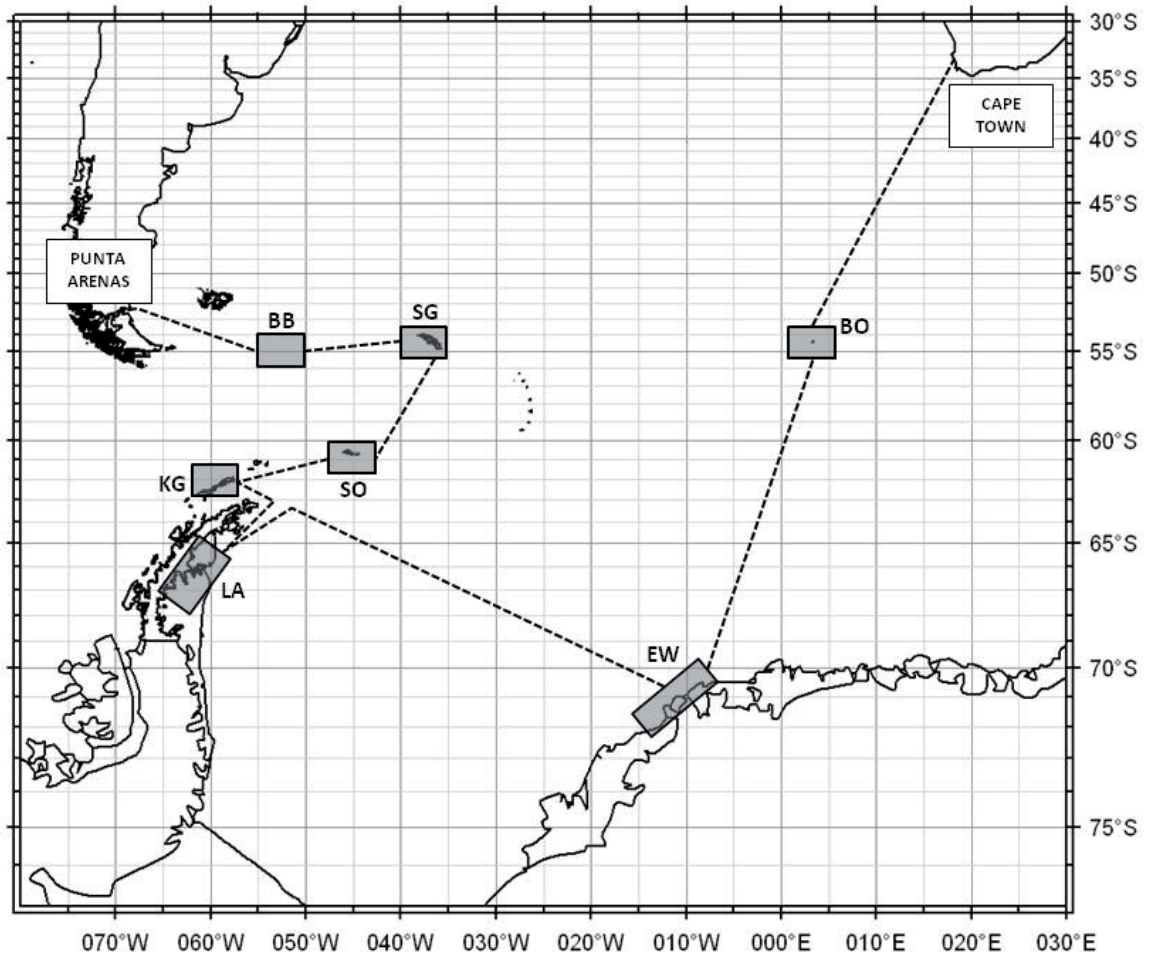

Fig. 1.1: Planned cruise track of RV Polarstern during the expedition ANT-XXVII/3 from 8 February 2011 (Punta Arenas, Chile) to 18 April 2011 (Cape Town, Republic of South Africa)

Abb. 1.1: Die geplante Fahrtroute der Polarstern während der Expedition ANT-XXVII/3 vom 8. Februar 2011 (Punta Arenas, Chile) bis 18. April 2011 (Kapstadt, Republik Südafrika).

BB	Burdwood Bank
SG	South Georgia
SO	South Orkney Islands
KG	King George Island
LA	Larsen-A/B
EW	Eastern Weddell Sea (BENDEX)
BO	Bouvet Island

2. THE SCIENTIFIC PROGRAMME

2.1 Biodiversity, phylo-geography and phylo-genetics in a latitudinal cline

2.1.1 Species delimitation and the role of dispersal for the genetic structure of marine species in the Southern Ocean

C. Held, S. Agrawal (AWI)

Objectives

In order to understand the distribution of the Antarctic benthic biodiversity and its fate in the rapidly changing environmental conditions, it is imperative to catalogue its entirety using state of the art molecular genetics in addition to the traditional morphometrics. Our previous work has shown that many of the taxa previously thought to be one species in fact consist of cryptic species complexes and that the established paradigm of their circumpolar distribution has to be revised. One aim of our project is to test the species identity of key taxa of the Antarctic benthos using molecular methods, thus contributing to the international barcoding of life initiative. Since the formation of new species starts with variation and differentiation at the population level, we are interested to study the within and between population genetic differentiation for outlining the factors driving the “Antarctic Diversity Pump”.

It is therefore intended to study the role of existing current systems, variable climatic oscillations and variance in the evolutionary history of the Antarctic Southern Ocean benthos at several taxonomic levels. Sampling of benthic crustaceans from disjunct Antarctic (continental Antarctic and South Orkney Islands) and sub-Antarctic (South Georgia and Bouvet Islands) populations and using molecular markers, with varied evolutionary rates, we aim to identify the barriers and conduits of gene flow to elucidate the pathways of colonization and mechanisms of speciation prevalent in the Southern Ocean.

Work at sea

Our group will collect benthic and pelagic crustaceans and other invertebrates and preserve them for subsequent molecular analyses. For some key taxa DNA extractions will take place on board. The molecular barcoding, i.e. sequencing of the cytochrome Oxidase I fragment of the mitochondrial genome, and the characterization and analysis of fast evolving nuclear microsatellite markers for selected species will take place upon return to our lab in Bremerhaven.

2.1.2 Biodiversity and phylogeographic patterns of amphipod crustaceans in West Antarctic Seas

C. Havermans, C. d’Udekem d’Acoz* (IRSNB) * not on board

Objectives

With over 850 described species, amphipods are the most speciose animal group in the Southern Ocean, where it is present at all depths, in all environments, occupying a large range of trophic niches. However, many species are inadequately described, the number of undescribed morphospecies is extremely high and several morphospecies are composed of

genetically heterogeneous species complexes with allo- and sympatric distributions. Hence, there is an urgent need for more in-depth studies on the morphological and molecular systematics and phylogeography of the Antarctic and sub-Antarctic amphipods. Specific topics to investigate comprise:

1. To document and compare the faunistical, zoogeographical and ecological traits of amphipod taxocoenoses from different areas of the western part of the Southern Ocean

2. To contribute to the description of the Antarctic amphipod biodiversity, with a special focus on the Lysianassoidea, the Liljeborgidae and the Eusiridae.

3. To use genetic markers for revealing the cryptic biodiversity, to measure the intra- and interpopulation genetic variability and to compare the phylogeography of target taxa, with high and low dispersal capacities (benthopelagic vs. crawling amphipods)

4. To document the level of genetic isolation and cryptic endemism in amphipod crustaceans from different areas of the continental and insular shelf of West Antarctic, with the hypothesis of genetic isolation in refuges during the Cenozoic glaciations as background.

5. To contribute to the SCAR-MarBIN database (www.scarmarbin.be) in bringing a new dataset of distributional, ecological and photographic information on Antarctic amphipods.

Work at sea

Sampling will be performed at each station by different collecting methods: Rauschert dredges, epibenthic sledges and Agassiz trawls. Baited traps will be used whenever allowed by meteorological, ice conditions and the time schedule of the cruise. The use of the epibenthic sledge would be particularly important within the Larsen areas, where the bottom largely consists of mud, and dredges and trawls have proved to be inefficient. The sorting, preparation of samples, photographing and identification, as well as DNA extractions, will be carried out onboard. Most of samples will be fixed in absolute ethanol at –20° C for further DNA analyses.

2.1.3 Cryptic speciation and population structure within crinoids in the Southern Ocean

M. Eléaume (MNHN)

Objectives

Many crinoid species living on the Antarctic shelf are thought to be circumpolar in distribution. This may be due to the fact that some broad-scale ecological conditions are similar around most parts of the continent, and that a circumpolar coastal current transports food particles and supports the dispersal of juveniles.

Many species share the same evolutionary constraints. This suggests that rapid radiations or species flocks may have occurred independently in various taxonomic groups, including crinoids. Past glacial/interglacial cycles may have had structural effects on population and species diversity and distribution in the Southern Ocean. In-depth knowledge of the timing of speciation across taxa may help evaluate the consequences of the ongoing global warming.

At least three of the most abundant crinoids species, i.e. *Promachocrinus kerguelensis*, *Florometra mawsoni* and *Anthometra adriani* seem to be circumpolar in distribution. They however show very different genetic structure. *Promachocrinus kerguelensis* seems to be

a complex of cryptic species, whereas *Anthometra adriani* show a very low haplotypic and nucleotidic diversity.

Looking at the diversity and distribution of these marine organisms living on the Antarctic continental shelf will increase our understanding of many crucial aspects of Antarctic scientific and environmental issues, such as circumpolarity, species flocks, and the potential effects of global warming and ocean acidification.

Work at sea

I will collect crinoids and other echinoderms as well as tunicates and preserve them for subsequent molecular analyses. The morphological identification, molecular barcoding, and the sequencing of other mitochondrial and nuclear markers for the most common species will take place in my lab in Paris.

2.1.4 Dispersal vs. retention: Genetic population structures of notothenioids along the Scotia Arc

M. Damerau (VTI), M. Matschiner (UBAS)

Objectives

Since the cooling of the Southern Ocean approximately 20 million years ago, a unique ichthyofauna evolved on the shelves of the Antarctic continent and adjacent islands showing low species diversity and high levels of endemism. The majority of fish are bottom dwelling and belong to the suborder Notothenioidei (Perciformes). Their larvae usually develop pelagically over an extended period of several months. During this time, larvae may be dispersed over large distances by strong prevailing current systems, including the Antarctic Circumpolar Current that surrounds Antarctica. Indeed, high genetic homogeneity and low differentiation among populations is often found even for species with circum-Antarctic distributions, highlighting the role of protracted larval phases for gene flow. On the other hand, larvae are often found to be retained in neritic waters by local gyres. Also, oceanic fronts and strong currents may act as barriers hindering gene flow by larval dispersal or migration.

In our planned study, we want to compare the genetic population structures along the Scotia Arc region of at least four notothenioid species with differing life-history strategies and larval durations to elucidate the role of protracted larval phases and prevailing current systems in population structuring and, moreover, the influence of ecology and gene flow on the ongoing adaptive radiation of notothenioids in the Southern Ocean.

Work at sea

Along the shelves of the Scotia Arc islands and the Antarctic Peninsula a bottom trawl will be used to sample demersal notothenioids. After each haul muscle tissue will be collected for genetic analyses from our study species (*Chaenocephalus aceratus, Champsocephalus gunnari, Gobionotothen gibberifrons* and *Lepidonotothen larseni*). In addition, individual data of *C. aceratus* specimen will be collected (sex, length, weight (total, eviscerated, stomach, gonad)) as well as otolith taken for later age determination. The combined data will allow us to thoroughly analyse the spatial and temporal demographic influence on genetic population structuring in these species. We will furthermore collect tissue samples of all caught notothenioid species for phylogenetic investigations.

2.1.5 Relative importance of environmental and dispersal related processes in structuring meiofauna communities in the Southern Ocean

F. Hauquier (UGENT), A. Rose (FIS-DZMB)

Objectives

It is believed that both local environmental factors and dispersion ability play key roles in structuring communities and defining geographic/spatial ranges of organisms (referred to as the 'metacommunity concept'). The main aim of this research is to identify and understand the factors (environmental or dispersal-related) that explain the distribution patterns and biodiversity of Southern-Ocean meiofauna. Furthermore, we are interested in the relative importance of both sets of explanatory variables in determining community structure. The prevailing hypotheses are that for large distances, the legacy of historical separation may transcend any effect of environmental factors on community structure and biodiversity, whereas at intermediate spatial scales, the effect of both historical contingencies and contemporary ecological factors probably shape biodiversity and distribution patterns. At small scales, distance effects would be negligible on community variations. In short, the relative importance of dispersal-related processes becomes more prevailing at larger geographical scales. The validity and generality of these hypotheses for marine benthic organisms remains largely unknown and will be investigated here on free-living marine nematodes and copepods from the Southern Ocean.

Work at sea

Samples will be collected and processed at different spatial scales (1 cm – 1,000 km) in the Southern Ocean for community analysis, including meiofauna (nematodes/copepods) species distribution and biodiversity patterns. Samples will be collected and measurements will be done on board to quantify relevant habitat characteristics (environmental factors) that play a role in either local or regional control of community dynamics. A second part consists of a series of colonisation experiments, set up during the sampling campaign on board of the research vessel, to test selectivity of meiofauna/nematodes for certain habitats when settling down from the water column, thereby characterising habitat preference. The third part focuses on population genetics of some dominant species present at different spatial scales. Both morphological and molecular techniques will be applied in parallel to identify the distribution and connectivity between populations of selected dominant species at local to regional spatial scales.

Sampling will be carried out on board of *Polarstern* duringANT-XXVII/3. Starting from Punta Arenas in South Chile, a transect of thousands of kilometres (approximately 6,500 nautical miles = 12,000 kilometres) will be covered before arrival in the port of Cape Town, South-Africa. Samples will be taken with a multicorer device at several stations along the Scotia Arc at South Georgia and South Orkney Islands, East and West of the Peninsula, near Kapp Norvegia and at Bouvet Island. A total of 10 to 14 stations will be selected: 4 to 6 along the Scotia Arc, 2 to 4 near the Peninsula, 2 at Kapp Norvegia and 2 at Bouvet Island. Each time the same depth range will be sampled to rule out depth as a factor. At each station, samples will be collected for meiofauna community and biodiversity analysis at species level, population genetics and abiotic factors. Samples will be collected at scales of 1 to 100 cm (subsamples within a core), 1 to 10 m (cores from the same MUC deployment), 10 to 100 m (samples from different MUC deployments at the same station) and between 10 to 1,000 km (different stations), because spatial scale has been proven to be an important determinant in structuring meiofauna communities. The benthic samples for community analysis (meiofauna identification and abundance) will be stored on formalin and samples for population genetics will be stored on ethanol for further examination in the lab. Additional cores will be dried or

frozen for abiotic factors, such as grain size, sulphide content (after pore water extraction through rhizons), pigment analysis concentration (as a measure of primary production input) and organic C/N content. At each station, bottom temperatures (CTD), geographic position (to calculate distances between habitats) and depth will be recorded, as well as a description of the topmost layer of the cores, to characterise habitat conditions.

2.1.6 The role of temperature regime for zoogeography and biodiversity of the demersal fish communities

R. Knust, N. Koschnick, K. Mintenbeck (AWI)

Objectives

The Antarctic fish fauna is dominated by a single suborder, the Notothenioidei (Perciformes). Mainly five families within this suborder account more than 50 % of the species and more than 90 % of the fish biomass on the Antarctic shelf. The Notothenioidei, comprising more than 100 closely related species, include a wide range of ecotypes from sluggish demersal benthos feeders to herring-like pelagic shoaling species and large piscivorous predators. Despite the low diversity on higher taxonomic levels, the diversity of species within demersal communities on the high Antarctic shelf is extraordinarily high. One important abiotic factor determining the zoogeography of species and biodiversity of communities is the ambient water temperature. Temperature regimes differ considerably between high Antarctic areas, the Antarctic Peninsula and the Scotia Arc Islands, which is reflected in significant differences in fish species composition, abundance and biomass. Based on the results from previous expeditions in the years 1996 to 2008 the studies on zoogeography and biodiversity of demersal fish communities in Antarctic waters will be continued. The project will be carried out in close cooperation with project 2.1.4 (Dispersal vs. retention: Genetic population structures of notothenioids along the Scotia Arc). The results will help to identify the fish species that are most suitable for the physiological experiments (see projects in topic 2.2 - Physiological adaptations and impact of climate change on cold adapted organisms).

Work at sea

Species composition, biomass and size distribution of the demersal fish fauna will be determined from standard bottom trawl and Agassiz trawl catches at all study sites. The catches will follow the depth strata and will be located in water depths between 600 und 150 m. Water temperature and salinity in the sampling depth will be measured with the on board ship CTD system.

2.1.7 Phylogeny, ecological role and diversification history of selected Antarctic sponge taxa and the recovery of benthic communities at former LARSEN A/B ice shelf and BENDEX, with focus on sponges

D. Janussen (FIS)

Objectives

Porifera (sponges) are ecologically important by structuring the sea floor and creating habitats for other animals, not at least on the Antarctic shelf, where Hexactinellida (glass sponges) grow to very large size and host large communities of associated organisms. After evaluation of the recent ANDEEP-SYSTCO expeditions it has become evident that unexpected high diversities and abundance of Porifera are also found in the deep Antarctic water. This is true especially for the Hexactinellida (which outside the Southern Ocean are deep-sea sponges), Polymastiidae (cosmopolitan and eurybath demosponges) and Cladorhizidae (carnivore demosponges, a

true deep-sea taxon). The evolutionary ecology and distribution history of important key taxa of Antarctic sponges are focus of our research project (JA 1063/14-1+2; DFG SPP 1158). First results from ANT-XXIII/8 expedition (Nov 2006 - Jan 2007) to the disintegrated LARSEN A/B ice shelf areas in the Western Weddell Sea, have proven the presence of faunal deep-sea elements, including sponges, under the former ice shelf. Generally, LARSEN A/B stations provided fewer and smaller sponges than found at the “normal” Antarctic shelf. Part of the sponge fauna appears to be young and obviously settled after the disintegration of shelf ice; e. g. many juvenile Polymastia sp., and small hexactinellids (Anoxycalyx (Anoxycalyx) ijimai and Bathydorus spp.), but only few larger hexactinellids were observed. In the beginning of 2008, five years after disintegration of the Larsen ice shelf, the sponge fauna was still in a highly dynamic state.

Unresolved issues to be taken on during the ANT-XXVII/3 expedition are following: As commonly observed in the polar and other deep sea environments, specific sponge associations occur within restricted areas. This phenomenon is also observed on the Antarctic shelf, where a patchy occurrence of sponge species (and other sessile taxa) is commonly related with re-colonization processes (e. g. after iceberg scouring). New investigations and re-sampling in 2011 of the BENDEX experimental disturbance sites, as well as the LARSEN A/B area, will provide important information on the development of the sponge fauna within a few years. This will help elucidating the role of sponges as pioneer fauna, structuring the sea bottom for other benthic fauna, on a short time scale. On a long time scale, tectonic and climatic events are important factors for the Poriferan colonization of oceanic environments. Paleontological and zoogeographical data indicate that the Southern Ocean (SO) may be a refuge of formerly widely distributed sponge taxa, e. g. the hexactinellid Rossellidae, genus Rossella, and presumably the Demospongid family Polymastiidae. But to which degree is the present distribution of Antarctic sponge taxa a result of historical processes? To answer this question, we investigate the phylogenetic relationships of Antarctic Porifera key taxa in comparison with the sponge faunas of the adjacent seas. Since the phylogenetic status of many allegedly cosmopolitan or bi-polar genera is still unresolved (e. g. Acanthascus, Bathydorus, Caulophacus, Polymastia, Suberites, Tentorium, Asbestopluma, Cladorhiza), we also need to compare our sponge taxa with the Arctic fauna. Furthermore, uncertainty prevails about the bathymetric boundaries of sponges, and some Antarctic eurybathic sponge species probably contain cryptic taxa.

This leads us to the central issue of our project: Phylogeographic origin of the Antarctic sponge fauna. Because of the patchy distribution of Antarctic sponges, our priority is the Porifera key taxa, which are characterized by high diversity, wide distribution and relative abundance in the SO. Currently, our phylogenetic investigations focus on the families Rossellidae (Hexactinellida), Polymastiidae-Suberitidae and Cladorhizidae (Demospongiae). By analysis of C- and N-isotope from the representative key taxa, we furthermore want to gain a better understanding of the functional ecology of the Antarctic Porifera, their role in the food-web and the benthic-pelagic dynamic system.

Work at sea

Whenever possible, a combination of ROV observation and sample collection in combination with other benthic gears (such as the AGT) will be used to optimal information on the benthic fauna and communities structures. During observation and re-sampling of the Austasen benthos disturbance experiment area (BENDEX), we will investigate the recovery state and development of the benthic communities, and to identify sponge pioneer taxa and their successions. If possible, this will be done also for selected sites of the LARSEN A/B shelf, where we already have basic data from the 2007/08 expedition. During the expedition, Porifera are caught by most of the classical benthic sampling gears, especially the AGT, the gear implementation of which will be my responsibility. AGT-catches need to be washed, sieved

and sorted immediately with participation of experienced scientists, who are able to quickly recognize and sort out all specimens. For this work, which takes place mainly on the deck and later will be continued in the large wet lab, we will need manpower and the assistance of scientists from the benthos team(s). As a Porifera specialist, I am responsible for preliminary identification and sorting of the sponges by morphotaxa and for making adequate decisions for each specimen concerning freezing or types of fixation for isotopes, RNA, taxonomy and meio-infauna. The sponges are photographically documented (prior to any fixation, which inevitably changes the form and colour). Provided the biomass is sufficient, samples will be taken from each sponge type for: Histology and skeletal preparations, electron microscopy, genetics and biochemical and isotope investigations. Fragments will be preserved in RNALater (Sigma) to allow for a variety of subsequent molecular approaches, e.g. RNA isolation and cDNA synthesis and library construction. Samples fixation and later in the home lab skeletal preparation and investigations of morphology will be done. Also the meio-infauna of the larger sponges should be preserved. If enough time is available, pieces of larger sponges will be washed out already on board over a fine-meshed sieve, and fixated and/or frozen for later identification and further investigations. Furthermore, directed collection of sponges including their substrates, allow detailed study of the faunal community associated with the sponge basal attachment. Also, the access to well preserved and non-polluted sponge tissue is important for genetics and stable isotopes investigations. Underwater video/photography of the benthic communities will be conducted; these documents will be integrated in the taxonomic analysis as well to obtain the highest possible resolution of the diversity and ecology of the Porifera fauna and its consortium of other animals at each locality.

2.2 Climate depending processes in pelago-benthic coupling and food webs

2.2.1 Pelago-benthic coupling on the Weddell Sea's continental shelf

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Objectives

The marked environmental differences at the sea surface and close to the seabed inspire interesting questions about how the pelagic and benthic ecosystems work and connect between each other, especially in polar conditions where seasonality is intense in the upper layers of the water column and more constant in the benthic realm. These conditions have been studied at the high-latitude southeastern Weddell Sea, where for thousands of years there have developed complex epiphytic benthic communities with high biomass and diversity. In contrast, at the western boundary of the Weddell Sea the assumed anthropogenic influence on the global climate has triggered the collapse of ice shelves, which limited primary production in the pelagic system and consequently the development of macrobenthic communities.

Given the accelerating pace of climate change and the still poorly understood functioning of the Antarctic system, studies on pelago-benthic coupling are becoming urgent to understand how the Antarctic shelf ecosystems will cope with ongoing changes. The ICM/CEAB attempts to analyze environmental characteristics which enable to identify the climate-induced changes and its consequences for the benthic communities dwelling in the Weddell Sea. Based on the fact that Antarctic ice is especially sensitive to climate change, the general working hypothesis is that different ice regimes determine the differences found at the benthic realm on the continental shelf. Thus, changes at the sea surface would be reflected at the seabed. On the one hand, previous studies on pelago-benthic coupling on the high-latitude Weddell Sea continental shelf have shown that the particles exported from the sea ice and the upper layers

of the water column settle onto the seabed and constitute a reservoir of nutritive sediment or “food bank” (also described as “green mats”), which fuels the benthic fauna even during the dark winter months when primary production and sea ice releases are negligible. On the other hand, it has been demonstrated that ice shelves hampered the arrival or fresh organic matter to the seabed and that this situation dramatically changed after the ice shelf collapses. Under this frame several activities will be carried out during ANT-XXVII/3.

The ICM/CEAB/ICTA group is constituted by people working in different research areas such as marine geology, marine biology, and chemistry with the common aim of assembling several compartments of the pelagic and benthic systems by combining information from climate, sea ice, settling particulate matter (e.g., plankton detritus, lithogenic debris), the chemical and physical characteristics of the water (e.g., dissolved nutrients, salinity, temperature, current velocity and direction, turbidity) and sediment columns (e.g., grain size, organic contents) and benthic fauna distribution, biomass and trophic ecology features. The idea is to produce a comprehensive pelago-benthic coupling interpretation of a poorly known ecosystem such as the recently opened area beneath the former Larsen A and B ice shelves and to enrich the data set we already have on the high-latitude eastern Weddell Sea enabling comparisons between both regions.

The main research activities to develop on board will be based on the following proposals:

1) Lipids have been identified as an important link in this trophic chain; however, their trajectory throughout this path has not been fully tracked and it may provide important information on the velocity and intensity of the pelagic-benthic coupling in polar environments. The aim of the work will be to analyze the total lipid, carbohydrate and protein content together with the fatty acids and stable isotopes of different gorgonians, briozoans, ascidians, sponges and other sessile or near bottom organisms in the different sampling areas to compare the results with previous data (i.e. spring - summer time ANT-XXI/2, and autumn - winter time ANT-XVII/3) to infer different strategies to cope with the winter impoverishment of the Antarctic water column. The possibility to compare different places separated by long distances (South Georgia and South Orkney Islands, Larsen A and B embayments, King George Island, southeastern Weddell Sea and Bouvet Island) will be an interesting approach to the dynamics of the different populations. Fatty acid trophic markers and stable isotopes will complement the analyses of stomach contents as a tool for investigating the trophic links of benthic organisms. Fatty acid composition integrates feeding behaviour over longer time scales than stomach contents, and it is not biased by digestion times. Changes in environmental conditions that affect metabolic rates can alter the production, storage or conversion of fatty acids, so it is important to complement the information with an appropriate stable isotope analysis.

2) Some proteins (genes) that are involved in silicon fixation in sponges are known for both demosponges and hexactinellids. Some sponge species do not produce several types of spicules under low concentrations of silicon (e.g., those found in the shallow Mediterranean Sea). In contrast, sponges produce heavy siliceous skeletons where the silicon concentration in water is high (such as in Antarctic waters). This contrast opens questions on the pelago-benthic coupling in Antarctic waters such as whether silicon is taken from the water column or diatoms are also involved, besides as organic matter suppliers. The working hypotheses are:

A) The massive spicule formation is preceded by gene expression which is triggered by high silicon concentrations.

B) Antarctic sponges use their capacity to polymerise silicon in the form of spicules not only for their body building, but also to remove silicon excess from their tissues.

C) The diatoms entrapped in the sponge tissue can be used by the sponges as a supplementary silicon source in absence of dissolved silicon in the water.

To assess those hypotheses it is planned to carry out on board experiments to identify:

a) Whether the gene expression (silicateins) of siliceous sponges is triggered by the presence of a given concentration of silicon in the water and increases as a function of increasing concentration.

b) Whether there are differences in gene expression between Demosponges and Hexatinellids under the same silicon concentration (given the highest spicule density in the later):

c) Whether sponges are able to recycle silicon from the frustulae of the captured diatoms, to build their siliceous skeletons.

3) Benthic communities and pelagic primary production determine the biochemical characteristics of the sediment column. Based on previous results of the working group we attempt to revisit former sampling stations to assess the pace of chemical changes along the upper sediment column (30 cm) and especially to identify how the changing conditions of the Larsen A and B embayments are reflected in the biochemical characteristics of the sediment.

Work at sea

Ice

Total and organic carbon, nitrogen, biogenic silica, nutrients and biochemical variables (protein, lipid, carbohydrates, chlorophyll, EHAA, THAA) will be measured in sea ice to quantify available organic matter. Stable isotopes (^{13}C and ^{15}N) of targeted fatty acids will be used to estimate energy transfer from one link to the other in the trophic chain. Selected samples will be photographed with optic and electronic microscopes.

Nutrients and some biochemical variables will be analyzed on board with a spectrophotometer following standard techniques for oceanography and biochemistry.

Ice analyses are intended to identify the importance of sea ice as microalgae and bacteria provided to the surrounding sea water. Further, to estimate the proportion of microorganisms arriving to the seabed and its relation to the carbon, nitrogen and silicon cycles. At this point stable isotopes analyses will be particularly useful as molecular markers especially in selected fatty acids. This technique has been successfully used in marine and lacustrine environments and will be applied to sea ice to better estimate its role in the biogeochemical cycles.

Plankton

Plankton samples will be collected with plankton nets to identify potential food sources for zooplankton through feeding experiments on board.

Water column

Water samples will be taken from Niskin bottles attached to a CTD rosette. CTD profiles will include fluorescence and turbidity (CTDFT). Water will be typically sampled in 5 to 6 depths, one bottle 5 m above the seabed (or the deepest possible depth), one at the fluorescence maximum, another one 5 m below sea surface and two to three more in between the mentioned depths or depths where something interesting is detected in the CTDFT profiles. The set of

variables measured in the ice samples will be analyzed in water column samples as well, plus the quantification of suspended particles.

The aim of analyzing this set of variables in the water column is to detect differences in concentrations between the surface and bottom layers due to the influence of ice, sediment and benthic communities. These measurements will enable to determine relationships between the water column, the environment and the benthos.

An array of two conical SMT 234 (K.U.M. Meerestechnik, Kiel) sediment traps coupled to an Aanderaa RCM9 current meter will be moored at approximately 450 m depth. The sediment traps will be placed at 270 and 420 m depth and the current meters at 320 and 440 m depth, respectively. These instruments will be operating for approximately 20 days. Total mass fluxes and its principal constituents (lithogenics, organic and inorganic carbon, nitrogen, biogenic silica) and ^{210}Pb will be measured to estimate the transport intensity of organics. Radionuclide analyses will allow identifying the importance of ice, sediment and plankton contributions to the total mass flux. Current velocity and direction will enable to relate transport of particles to resuspension and tides. This information will be related to the availability of particles for benthic fauna, especially suspension feeders.

Benthos

Agassiz Bottom Trawl and box corer will be used to collect samples from representative benthic groups (e.g., cnidarians, molluscs, sponges, ascidians). Biochemical variables will be measured in addition to stable isotopes and fatty acids. With this approach we will estimate the healthy state of the organisms through their organic matter storage capability and the availability of food and its sources. Taxonomic and feeding experiments will also be performed. Photographs of the living specimens will be taken.

Feeding experiments

Depending on the status of the samples obtained with the trawls feeding experiments will be conducted. After an acclimation period in a cooled room, fragments of colonies in good conditions will be placed in experimental aquaria, with a known concentration of natural zooplankton (previously collected by plankton net). Gorgonian fragments before and after the ingestion period as well as plankton samples will be also taken to evaluate the phyto- and zooplankton capture using trophic markers. Zooplankton and gorgonian samples will be fixed for further studies at the ICM-CSIC facilities.

In the case of hexatinellids and demospongiae a set of experiments on gene expression (silicateins) under several treatments: total absence of silicon (artificial seawater), total absence of silicon with added diatoms, filtered Antarctic water, filtered Antarctic water plus artificial seawater (to reduce natural silicon concentration to a half), filtered Antarctic water plus artificial seawater (to reduce natural silicon concentration to a quarter) will be developed. Samples from all the individuals subjected to experimentation and fixing them in RNAlater for rtPCR gene expression quantification and for the electron microscope analyses (spicule and skeleton characteristics) will also be taken.

Sediment

Surface sediment and sediment cores will be recovered with a giant box corer, a multibox corer and a MUC, respectively. Sediment cores will be subsampled on board in slices 0.5 cm to 2 cm thick to measure in each of them carbon, nitrogen, biogenic silica, ^{14}C and biochemical variables. In addition, ^{14}C and ^{210}Pb activities will be measured to calculate sedimentation rates and burial budgets for several variables. Grain size will also be measured to analyze the

sedimentary dynamics in each zone and the availability of sediment for benthos as a potential food source. Sediment incubations will be set to measure the oxygen and nutrient demand across the sediment-water interface.

2.2.2 Mineral and food supply to Antarctic sponge communities

C. Richter, L. Fillinger, T. Funke, J. Gutt, C. Roder (AWI), T. Lundäv (GU-LOVEN),

Objectives

The Antarctic harbours hotspots of rich benthic life in spite of an overall low and extremely variable pelagic productivity in both, time and space. The factors contributing to these hotspots of biodiversity and biomass are so far unknown. Independent lines of evidence suggest that biophysical mechanisms may play a potentially important role in explaining the patchy distribution of these suspension-feeder (sponges, ascidians) dominated Antarctic communities. In addition to sinking phytoplankton, currents near the seabed due to upwelling, cascading of dense surface waters and breaking internal waves may sustain flows of dissolved minerals and suspended food for spicule production (silica), tissue growth and reproduction. Further, behavioural responses of holoplankton and meroplankton larvae in response to vertical entrainment in slope currents may lead to local aggregations, enriching the boundary layer waters with potential food for suspension feeders. All these processes may be modulated by topography, exposing crest communities to higher horizontal flows, whereas much of the gravity flows of dense and potentially silicate-rich sub ice-shelf waters may be gated along channels, grooves and canyons carving across the Antarctic continental shelf and slope.

It is perceivable that changes in water temperature, ice shelf and sea ice extent will have profound effects on regional and local hydrography, primary production and the magnitudes and pathways of minerals and food to the benthos. Geochemical changes may impose additional constraints on mineralizing organisms, e.g. ocean acidification potentially reducing calcification and growth of stylasterid corals with subsequent loss of habitat space.

The aim of the expedition will be to explore the distribution, biomass and biodiversity of the sessile benthos in selected areas of the Antarctic continental shelf, in relation to bottom topography and oceanographic processes, assess the bottom boundary layer flows of minerals and food, and the uptake of silicate and food by the sponge species dominating the suspension feeder community. The results will be important to assess the function of benthic suspension feeders in habitat creation, utilization of resources, species richness, and the resilience of these communities to local disturbance (iceberg scouring) and regional change (ice shelf collapse, warming). The research will cover the entire ANT-XXVII/3 area with observations and mooring work in South Georgia, South Orkneys, South Shetlands (Jubany), Antarctic Peninsula (Larsen A/B), East Weddell Sea (Bendex), and Bouvet Island.

Work at sea

The bathymetry of the study sites (unless known) will be assessed using the new hull-mounted HYDROSWEEP multibeam echo sounder. Benthic survey will be carried out with a ROV rated to 500 m or more, equipped with manipulator, sample storage, CTD, video- and still photography. Moorings containing temperature loggers, acoustic current meters, water and plankton samplers as well as conductivity, fluorescence and depth sensors will be deployed to determine water properties such as temperature, current regimes, light availability, phyto- and zooplankton abundance and behaviour, as well as nutrient and dissolved or particulate matter concentrations. Live samples for experimental work will be taken with the ROV, additional material will be taken by grab samplers and bottom trawls. On board incubations will be carried

out in cold rooms to determine metabolic rates [respiration, feeding, growth, silicate uptake and (stylasterid) calcification]. Samples will be returned to AWI for analyses (isotopic composition of tissue and spicules, biomass, lipid and protein contents).

2.2.3 Trophic structure of antarctic marine ecosystems

W.E. Arntz, T. Brey*, R. Knust, K. Mintenbeck, (AWI), U. Jacob*, C. Möllmann*, L. Rath (UHH-IHF) * not on board

Objectives

Antarctic ecosystems are vast, complex, dynamic networks of species directly and indirectly interacting with each other. It is the intricacy of these multi-species systems that makes understanding and predicting disturbance effects a major ecological challenge. Food web characterization is an initial step in understanding an ecosystem, as structure affects function. The stable isotope signatures $\delta^{13}C$ and $\delta^{15}N$ signatures serve as proxies of the trophic distance of an organism from the primary food source of the corresponding food chain and can be used to determine the relative trophic position of taxa/groups within the community. The isotope approach can contribute to elucidating food web processes at two different scales that are particularly difficult to study using traditional techniques: that of whole food webs such as the mean number of trophic transfers between the bottom and the top species, the structure of a food web (i.e. the proportion of species at each level above the basal species), or, if some of the basal species have isotopic signatures that are different enough, the existence of separate or confluent pathways of matter transfer as well as trophic variability occurring at the intra-population level. During this cruise we attempt to fill gaps in our stable isotope database across the different shelf communities ranging from the Scotia Arc islands, the Antarctic Peninsula, the Weddell Sea shelf and up to Bouvet Island which will be the focus of this study.

Due to its geographical isolation Bouvet Island represents a pristine environment and has been identified as an important case study for the conservation of intact ecosystems. However, information on the marine community species inventory, functional diversity and trophic functioning of the Bouvet Island system is scarce, i.e., the present food web model of Bouvet Island shows some obvious gaps which will be filled during this cruise.

Work at sea

All organisms sampled for stable isotope analysis will be measured according to their length and weight. Small organisms will be sampled whole, whereas pieces of body wall or muscle tissue will be sampled from macro and megafaunal specimens. All samples will be kept frozen at −30° C until further analysis. During sampling at Bouvet Island, additionally gut and stomach contents of various species will be sampled and analysed for identification of prey taxa.

2.2.4 How to disentangle the high trophic complexity observed in Antarctic food webs?

L. Rath (UHH-IHF), K. Mintenbeck (AWI), C. Bock (AWI), U. Jacob* (UHH-IHF), T. Brey* (AWI), C. Möllmann* (UHH-IHF), O. Petchey* (USHEF) * not on board

Objectives

The marine food web of the high Antarctic Weddell Sea ecosystem is characterized by a highly complex trophic structure with most consumers able to extend their trophic niche. If climate change impacts upon a number of trophic levels, then changes in the trophic structure may become evident. This may be apparent as a ‘regime shift’ or as changes in the food web as

new species interactions or predator–prey interactions develop and/or important functional interactions get disrupted. Functional responses describe how the rate of consumption changes in response to a change in the density of resource species and can be used to link functions between consumers and their resources in generic multi-species food web models that predict community dynamics over multiple generations. Furthermore, functional response curves are an ecologically important tool because they allow inferences about rates of resource depletion, predator preferences for certain prey types, and competitive hierarchies among consumers. The literature currently contains few if any functional responses of marine Antarctic organisms. We will (i) set up preliminary feeding trials and (ii) use predator-prey functional response experiments to gain insights in the mechanistic explanations for the complex interaction pattern observed in the Weddell Sea system.

Work at sea

Feeding Trials

Given the diversity of consumer species, i.e. herbivores, scavengers and predators, as well as the assumed differences in feeding activity, we will employ a range of different predator/prey in feeding trials to estimate consumption preferences and capacities for different predators.

Functional response experiments

The functional responses describe the per capita consumption of a predator-prey interaction depending on prey abundance. The experiments will be performed in small aquaria. All experiments will be carried out with different prey densities for each predator species. We will set up control units without predators for each prey density in each project. These control units ensure that natural mortality of the prey and counting errors by the experimenter do not affect the experimental results. The prey densities can be varied according to the predators' consumption capacities that the maximum prey density is within the saturation part of the functional response.

2.2.5 Life cycle strategies in calanoid copepod species – with special emphasis on buoyancy regulation by ammonium

H. Auel (UHB), F. J. Sartoris, S. Schiel (AWI)

Objectives

Studies on the life cycle strategies of dominant copepod species have been carried out in the Weddell Sea since the 1980s. One of the most interesting aspect is how the dominant herbivorous species are adapted to the distinct seasonality in light, ice cover and hence, to primary production. It has been shown that copepods have developed specific adaptations to utilise short-term food pulses and to endure the periods of food scarcity in the water column. Ontogenetic and seasonal vertical migrations associated with a diapause are known as an adaptation to escape temporarily from unfavourable conditions and food scarcity during the unproductive winter season. Many species of polar copepods migrate mainly as late copepodite stages to greater depths where they reside for several months in diapause characterized by low swimming activity, cessation of feeding, arrested development and reduced metabolic rates. These copepods accumulate large amounts of depot lipids during spring and summer, almost exclusively composed of wax esters, in order to fuel diapause and reproduction in the following spring partly independent of food intake. Two main questions concerning diapause in calanoid copepods are still unanswered: (i) what controls the beginning and the end of diapause and (ii) how diapausing copepods with a reduced swimming activity regulate their buoyancy in order to remain at a certain depth over a long period of time.

Our preliminary studies on ion composition and concentration during *Polarstern* cruise ANT-XXIII/7 in September - October 2006 showed high concentrations of ammonia/ammonium (NH_3/NH^+_4) in the haemolymph of two pelagic species: *Calanoides acutus* and *Rhincalanus gigas*. All other species investigated did not show elevated ammonium concentrations in their haemolymph. The finding that high levels of ammonia are only found in species, which undergo vertical ontogenetic migrations is evidence that ontogenetic migration is related to and/or relies on ammonia aided buoyancy. Dependent on the pH, ammonia exists in solutions as both, NH_3 and NH_4^+. NH_3 is more toxic than NH_4^+ and in contrast to NH_4^+ it easily penetrates cell membranes. Due to the toxicity and the higher diffusivity of NH_3, we predict a low haemolymph pH in diapausing copepods to favour the formation of ammonium (NH_4^+).

Our studies during ANT-XXVII/3 aim to test the hypotheses on the role of ammonia for triggering metabolic depression and regulating buoyancy during the diapause of polar calanoid copepods during the transition from the summer to the autumn state.

Work at sea

Quantitative sampling of sympagic and pelagic copepods

As standard devices for the quantitative collection of the pelagic copepods two multiple opening and closing nets (multinet, 0.25 m^2 and 0.5 m^2 mouth opening) equipped with 5 and 9 nets, respectively, of 100 µm will be used. The multinet will be towed vertically, sampling standard layers between 2,000 - 1,000m and the surface, at the shelf between sea floor and surface. The samples will be preserved in 4 % buffered formalin. For molecular genetic purposes, additional samples will be preserved in absolute ethanol and stored at 0° C.

Species composition, abundances, vertical distribution patterns and population structure of the pelagic copepod community will be analysed from these samples as well as the maturity stage of gonads and the gut contents of dominant species.

Physiological and biochemical studies

Live pelagic specimens will be caught by different opening and closing nets (Nansen net and multinet) from different depth layers to study the metabolic activities. Studies on physiological and biochemical parameters will include experimental work on feeding, excretion, respiration and reproduction as well as metabolic indicators such as digestive enzymes, electron transfer system (ETS), C:N ratio, stable isotopes, lipid and protein contents. The experimental work will be conducted on board in a cooled container (0° C). Specimens for the analysis of metabolic activities will be sorted on board and stored at -80° C.

Ammonium content in the haemolymph

Under a dissecting microscope, haemolymph will be extracted manually from individual animals by use of glass capillaries and transferred into a plastic cap filled with 40 µl of distilled water, before freezing. Haemolymph samples will be analysed at AWI by ion chromatography. The measurements will include inorganic ions, especially NH_4^+, Mg^{++}, K^+, Ca^+, Na^+, Cl^-, and SO_4^{--}.

pH value of the haemolymph

Haemolymph samples will be collected on board to measure extracellular pH. The pH will be measured either by micro-optodes or by micro-electrodes installed in the Pasteur pipette and moved towards the tip of the pipette, until the pH sensitive tip is immersed in the haemolymph. When the pH signal is stable the pH sensor will be removed and the resting haemolymph sample used for ion measurement.

Experimental manipulations of the pH to induce diapause or provoke activity

We will conduct incubations with a variation of seawater pH by approximately one pH unit in both directions (acidification and alkalisation) in order to provoke behavioural changes of the copepods. Acidification could be done by adding approximately 1 % carbon dioxide to the seawater, which will result in a pH of 6.85. CO_2 itself, however, might have an inhibitory effect on respiration and metabolism and will give only a first insight, whether pH manipulation has an effect on diapause. Alternative pH changes could be achieved by adding weak acids and bases to the incubation medium. Changes in extracellular pH and ammonium content will be recorded as well as the effect on activity level. In addition, ammonium excretion rates will be controlled during alkalisation. Activity will be determined by respiration measurements with either optical oxygen sensors or the Winkler titration method.

2.2.6 Compound specific stable isotope ratio analysis in lipids of Antarctic zooplankton organisms

M. Graeve (AWI)

Objectives

Our study aims at investigating the carbon flux and lipid biosynthesis of Antarctic herbivorous copepod species that represent a major part of the mesozooplankton biomass in sub-Antarctic and Antarctic waters. Many of the large calanoid copepod species in Polar Regions are able to biosynthesize large amounts of neutral lipids either as wax esters or as triacylglycerols. Accumulation of large lipid reserves via different biochemical pathways enables species to utilize different ecological niches. *Calanoides acutus* exhibits the deposition of wax esters with long chain fatty acids and alcohols, *Calanus propinquus* as omnivorous species biosynthesizes triacylglycerols, consisting of long-chain fatty acids.

By using ^{13}C-labelled algae as food together with compound specific stable isotope analysis, we are able to gain data on the assimilation of lipid and non-lipid components but also to obtain information on the assimilation and turnover of individual fatty acid and alcohol compounds. Preliminary experiments with Arctic copepods have shown that the amount of wax esters did not increase significantly during feeding. However, the chain length and unsaturation of the wax esters moieties changed and the molecules were exchanged within short periods. Little is known so far about turnover of lipids in Antarctic copepods, including data on triacylglycerol storing copepods. In our home laboratory we will analyze the lipid class and fatty acid and alcohol composition of the copepods. We will further determine the total ^{13}C enrichment of single copepods, total lipids and of individual fatty acid and alcohol compounds.

An additional aspect of our lipid investigations is to support a study on the turnover of lipids in Antarctic scavengers. The background of this analysis is to follow the incorporation of dietary fatty acids into lipids, which is a rather new approach to study the carbon transfer and biosynthesis of lipids in Antarctic amphipods. In scavenging amphipods both isomers of the octadecenoic acid are among the major fatty acids. They exhibit high portions of the Δ11-octadecenoic acid (18:1(n-7) fatty acid) and less amounts of the Δ9-isomer, which is totally unusual in contrast to

other animals. The application of ^{13}C-labeled fatty acids makes it possible to follow directly the pathway and transfer of carbon and individual compounds. This work will have a major impact of understanding the biosynthetic processes of Antarctic scavengers and to reveal on transfer of organic matter in the Antarctic food web.

2.2.7 Ecophysiology of peracarid scavengers

H. Robert (IRSNB / ULG), F. Nyssen* (ULG) * not on board

Objectives

With over 850 named species, amphipods are the most speciose animal group in the Southern Ocean, where it is present at all depths, in all environments and where it occupies a vast array of trophic niches. The high species richness of amphipods and the dominant role they play in the (sub-) Antarctic ecosystems justifies in depth ecological and biological studies on these crustaceans. Such studies should be carried out without delay, since the biota of the Southern Ocean is expected to undergo major anthropogenic alterations in the near future.

There is strong evidence that large food particles (“large food falls”) play a significant role in the vertical flux to the sea bottom. On the one hand, there are, albeit few, reports of the encounter of such large food items on the sea floor such as big marine mammal carcasses, fishes, large pelagic invertebrates or their remains. On the other hand, well-developed associations of highly mobile scavengers are present on shelf and deep sea bottoms throughout the world oceans. Those associations are composed mainly of peracarid crustaceans, amphipods and isopods. For about 10 years, University of Liege, in close collaboration with the Royal Belgian Institute of Natural Sciences (RBINS) has been involved in the study of amphipods of the Southern Ocean. Our team is particularly interested by the trophic ecology of amphipods belonging to this pre-cited scavenging trophic guild. Because of the importance of some isopod species in scavenging activities, we have extended our interest to peracarid in general. The trophic link between the pelagic and benthic scavenger assemblages formed by large food falls has been understudied in marine ecological and carbon/energy cycling research, despite its potentially great significance in marine systems, especially at greater depths. Trophic ecology of scavengers is quite particular and they show some interesting features as, for example, a strong resistance to starvation, a very low turnover as well as a unique fatty acid composition, which appears to be a constant.

For an improved understanding of the fate of organic matter in marine food webs, investigation is needed to obtain specific trophic markers. Such markers should be stable during their transfer through the food chain. Unfortunately, stable markers are probably not available, and a combination of different methods, such as fatty acid trophic markers, stable isotope ratios, gut contents, and genetic markers, as well as lipophilic anthropogenic substances (e.g. PCB), appears to be more useful to overcome problems that may arise using a single method. A promising approach in the evaluation of the fate of lipids during feeding is the use of labeled specific fatty acid in diets. The aim of this proposal is to study the carbon transfer from diet to scavengers at different levels by the use of a ^{13}C labeled diet. Special emphasis will be placed on assimilation and incorporation of dietary fatty acids into scavengers lipids and on de novo fatty acid biosynthesis. The application of ^{13}C labeled food makes it possible to follow directly the pathway and transfer of carbon and individual compounds into crustaceans in contrast to previous studies where only changes in composition were taken as evidence for these processes. Our experiment will focus on oleic acid that dominates drastically the fatty acid composition in scavenging crustaceans.

Work at sea

At all stations, material will be collected with trawling gears and with baited traps every time it is allowed by the meteo/ice conditions and the time schedule of the cruise. All animals will be immediately sorted, transferred in cool container and identified. A. Large part of the material will be devoted to experimental task:

1. Labeling experiment: scavengers will be fed with a diet first enriched in ^{13}C labeled oleic acid during 2-4 weeks. Individuals will be sampled regularly all along the experiment and store properly for compound-specific isotope analysis.

2. Starvation experiment to follow the modification of the isotopic and fatty acid composition.

3. If time and sampling allow it, parallel trophic experiments will be conducted with amphipods from other trophic guilds to determine lipidic and isotopic turnover.

The rest of the material will be stored properly in order to develop other specific trophic markers:

1. stable isotopes analysis
2. fatty acids analysis
3. genetic analysis
4. PCBs analysis

2.3 Impact of climate change on cold adapted organisms

2.3.1 The impact of environmental change on the Antarctic silverfish Pleuragramma antarcticum

K. Mintenbeck, S. Krägefsky (AWI)

Objectives

The Antarctic silverfish, *Pleuragramma antarcticum* (Notothenioidei), is one of the few truly pelagic fish species in the high Antarctic and represents a key component in the food web by providing a major trophic link between zooplankton, piscivorous fishes and warm-blooded predators (seals, seabirds and penguins). Just as most seas all over the world the marine Antarctic is increasingly threatened by environmental alterations due to climate change, but we know little about how key species such as *P. antarcticum* might be affected on the individual level and on the population level. Individuals might be affected directly by alterations in abiotic conditions (e.g. temperature) and/or indirectly by alterations in prey availability and composition. Negative effects on the individual level will in the long run result in a stock reduction, with possibly drastic consequences for higher trophic level consumers that rely on *P. antarcticum* as a food source. *P. antarcticum* was found to dominate local pelagic fish biomass in many high Antarctic shelf areas by more than 90 %, but reliable biomass estimates of the entire pelagic stock are scarce. Studies carried out during previous expeditions indicated that *P. antarcticum* is a shoal forming species that undertakes vertical migrations within the water column, and patchy distribution and movements of shoals (horizontal as well as vertical) make it difficult to evaluate actual biomass using only data from fisheries. As knowledge of the current state is crucial to detect future changes, further information on shoaling and migration behaviour, and more reliable data on stock biomass are urgently required. To provide the essential basis for evaluating the impact of environmental alterations on *P. antarcticum* on the individual as well

as on the population level, this project integrates traditional fisheries, modern hydro-acoustic methods, and experimental studies.

Work at sea

A combination of trawling with a bentho-pelagic net (BPN) and hydro-acoustic devices (multifrequency echosounders and multibeam imaging sonar) will be used to determine biomass of the pelagic fish stock and to investigate distribution patterns as well as vertical migration pattern and horizontal movements of *P. antarcticum* shoals in the western and north-eastern Weddell Sea. Individuals for experimental studies (all available developmental stages, i.e. post-larvae, juveniles, adults) will be collected using various gears (e.g. BPN, rectangular midwater trawl, Bongo net). Fish will be held in tanks in cooling containers on board. The planned experiments include (i) studies on the physiological sensitivity of *P. antarcticum* to changes in temperature and salinity, and (ii) studies on the impact of changes in prey availability (i.e. starvation) and energy content on fish survival and condition. Experiments will start on board and will be continued after the expedition in the home lab at the AWI.

2.3.2 Lipid metabolism and oxygen diffusion in the cold

T. Sandersfeld, C. Bock, T. Hirse , N. Koschnick , R. Knust (AWI)

Objectives

Circulatory performance is one of the bottlenecks in temperature limitation of Antarctic fish. Briefly, oxygen delivery provided by the circulatory system does not match the temperature dependent increase of oxygen demand of an organism. Recent results might indicate that oxygen diffusion and the capillary system might be responsible for the mismatch during warming. In the cold circulatory performance is drastically reduced, what might have consequences on lifestyle (pelagic vs. benthic) and limit the abundance of polar fish species. High Antarctic fishes for instance might have oxygen delivery specially adapted to these temperatures in comparison to fish species living at the Antarctic Peninsula. It is suggested that tissue capillarisation and tissue lipid content may facilitate oxygen delivery in organs (especially muscle tissue) under low temperatures. Lipids also are an important substrate for oxidative energy production and support neutral buoyancy for a pelagic mode of life. For instance, it is proposed that the high lipid content in the muscle of the Antarctic silverfish *Pleuragramma antarctica* is responsible for the specific swimming ability of these pelagic fish species under extremely low temperature conditions. Lipids are stored in the form of triglycerides in either adipose tissue (extramyocellular lipids) or in lipid droplets in the cytoplasm of muscle cells (intramyocellular lipids). Our main objective during this cruise is therefore to investigate and compare animal oxygen consumption with tissue perfusion and capillarisation of cold eurythermal and highly stenothermal Antarctic fish under acute warming. Furthermore, we will collect blood and muscle samples of the different fish species to analyse the specific content of glycogen and lipids as metabolic substrates.

Work at sea

Fish caught from bottom or Agassiz trawls and baited traps will be collected and kept at habitat temperatures in the Aquarium container on board *Polarstern*. Oxygen consumption, heart rate and blood perfusion levels (a measure of tissue oxygen content) of different organs will be measured *in vivo* in these animals by use of Laser Doppler flowmetry (LDF). The effects of temperature on heart rate, blood flow velocity, local hematocrit changes and tissue perfusion will be investigated after adequate periods of recovery. Additionally, blood and tissue samples will be collected for further analysis of hematocrit and blood lactate, glucose, glycogen and

lipid levels and composition, muscle fibre thickness and capillary bed. The ratio of muscle type specific intra- and extramyocellular lipids will be determined.

2.3.3 Cellular sensitivity of Antarctic fish species to environmental parameters

A. Tillmann, T. Hirse, C. Bock, G. Lannig* (AWI) * not on board

Objectives

The project aims to extend our knowledge on the metabolic adaptability of cold eurythermal versus more stenothermal Antarctic fish species (Zoarcidae and Nototheniidae) with special emphasis on the Antarctic silverfish *Pleuragramma antarctica*. Cellular processes strongly depend on temperature and organisms have developed several compensatory mechanisms that enable them to adjust and regulate their cellular energy budget. Ion regulation is one of the key processes contributing to the temperature dependent cellular energy budget. For instance, acid base status and pH regulation is strongly influenced by temperature known as alpha-stat pH regulation. Previous experiments have shown that alpha-stat pH is strongly regulated by active and passive cellular processes. Various active energy dependent mechanisms are involved to drive ions into and out of the cell for intracellular pH regulation: proton pumps (H^+-ATPases), proton channels and ion transporters (Na^+/H^+ exchanger, Na+ -dependent HCO_3^- exchanger and Cl^-/OH^- exchanger). Hochachka proposed elevated ion pump capacities in polar compared to temperate zone fishes to maintain balance between pumps and leaks as these processes are differentially affected by temperature changes. The project aims to test the thermal response in active pH regulation, which may be crucial in defining e.g. CO_2 sensitivity. Additionally, we want to investigate temperature dependent changes in cellular catabolic processes using ^{13}C-labelled specific substrates on isolated cells during acute temperature changes.

Work at sea

Fish caught from bottom or Agassiz trawls and baited traps will be collected and kept at habitat temperatures in the Aquarium container on board *Polarstern*. After a sufficient recovery period, cells from liver, gills and heart, respectively, will be isolated from different fish species for two experimental approaches:

1. Approach: On-line profiling of cell metabolism will be performed by using Bionas 2500 analyzing system (CMOS chip technology). The effects of temperature on cellular pH regulation and associated energy costs will be investigated during acute (*in vitro*) and – if possible - during chronic (*in vivo*) incubation. Additionally, blood samples will be collected for further analysis of blood hematocrit and ion concentration. Blood plasma and tissue samples will be stored in liquid N_2 for further analysis at the AWI.

2. Approach: Isolated hepatocytes will be prepared on board of *Polarstern* and incubated with ^{13}C-labelled substrates under different temperatures. The cells will be deep frozen at -80° C rapidly after different incubation periods and different temperatures, then shipped to the AWI for an analysis of specific metabolic pathways in the cold. Briefly, uptake rates of the specific substrates and incorporation into the glycolytic pathway or TCA-cycle will be determined using NMR spectroscopy at the AWI.

2.3.4 Mitochondrial and metabolic plasticity in response to changing abiotic factors in Antarctic fish and cephalopods

A. Strobel, F. Mark* (AWI) * not on board

Objectives

Mitochondria are a key element in shaping whole organism energy turnover and functional capacity. Recent insight into the special molecular characters of Antarctic fish mitochondria provides a unique opportunity to develop and test hypotheses explaining the role of these characters in setting thermal tolerance. In this project we focus on the responses of Antarctic fish and cephalopods to changing ambient temperature at the mitochondrial level. Fishes of the sub-order Notothenioidei inhabit polar, sub-polar and in part cold temperate waters and therefore are good comparative model organisms for studies of thermal plasticity among closely related Antarctic fish species. This holds also true for the octopods (order: Cephalopoda), which are found from tropical to polar latitudes. In Antarctic waters, these highly developed animals share the same spatial and ecological niche as benthic notothenioids and thus directly compete for the same resources in the ecosystem. Elaboration of the contribution of mitochondria to the special features of stenothermy and climate sensitivity in Antarctic fishes and cephalopods appears as a highly relevant and timely contribution to the field of climate sensitivity of Antarctic ecosystems. We intend to investigate the effects of temperature on mitochondrial metabolism of cephalopods and fish, specifically addressing the effects of thermal acclimation and adaptation on mitochondrial capacities and proton leakage.

Work at sea

By means of bottom trawls (BT) and/or bentho-pelagic nets (BPN) we aim to catch sub-Antarctic octopods and notothenioids in the stations along the Scotia Arc (SG/SO) during the first days of the cruise towards King George Island (JU) and on the way back at Bouvet Island (BO). In the high-Antarctic waters east of the Antarctic Peninsula (Larsen A/B, LA) and in the Weddell Sea (BENDEX Site, BE), we aim to catch high Antarctic notothenioids and octopods for further comparative work. On board, animals will be kept in aquaria systems and acclimated to higher temperatures. We intend to analyze how the standard metabolic rate is affected when the Antarctic animals are exposed to thermal challenges. The effect of temperature change on the respiration rate of the animal will be measured via flow-through respirometry, and in this way a potential oxygen limitation of thermal tolerance of notothenioids and octopods will be elaborated. Furthermore, changes in mitochondrial metabolism after long-term acclimation of the whole animal and at acute thermal challenge (mitochondria) will be analyzed. For this purpose, we will measure mitochondrial respiration, membrane potential and proton leakage with an oxygraph (octopus) and in mitochondrial respiration chambers (notothenioids).

2.3.5 Evolution of haemocyanin and its influence on thermal sensitivity in cold adapted cephalopods

M. Oellermann, F. Mark* (AWI) * not on board

Objectives

Our research topic aims to shed light on the links between physiological adaptation and the phylogeny of octopod haemocyanin during the adaptive radiation of these animals into Antarctic waters and to assist in explaining the recent biogeography of Antarctic octopods. By means of an integrative physiological and molecular genetic approach, this study will investigate the evolution of this Antarctic group in the light of changing climatic conditions and the radiation of cephalopods into the Southern Ocean. Temperature, pH and oxygen concentration are the three most important parameters that influence oxygen-binding capacities of cephalopod blood and for survival at nearly -2° C, a cephalopod requires a highly specialised blood-gas exchange.

By using extracellular haemocyanin, cephalopods possess a less effective respiratory protein than fish (which have intracellular haemoglobin). In order to successfully compete with fish, cephalopods have developed a high level of haemocyanin adaptability. Despite their prominent position in Antarctic food webs and being highly abundant, very little is known about Antarctic octopod physiology in general and specifically of the role of haemocyanin as a mediator between the organism and an extreme environment. The aim of the experiments on board is to physiologically characterise the ability of haemocyanin to adapt to varying environmental temperatures. Blood samples from octopods caught in bottom trawls in sub- and high-Antarctic waters will be used for determination of pH and temperature dependent *in vitro* oxygen-binding curves. Tissue samples will be preserved for molecular studies of haemocyanin expression that will be performed upon return to Bremerhaven and linked to the oxygen-binding curves generated on board *Polarstern*.

Work at sea

By means of bottom trawls (BT) and/or bentho-pelagic nets (BPN) we aim to catch sub-Antarctic octopods in the stations along the Scotia Arc (SG/SO) during the first days of the cruise towards King George Island (JU) and on the way back at Bouvet Island (BO). In the high-Antarctic waters east of the Antarctic Peninsula (Larsen A/B, LA) and in the Weddell Sea (BENDEX Site, BE), we aim to catch high Antarctic octopods for further comparative work. On board, animals will be kept in aquaria systems and acclimated to higher temperatures. We intend to analyze if and how oxygen-binding capacities of haemocyanin can adapt to changing environmental conditions. We will conduct *in vitro* oxygen-binding analysis under different thermal, pH and pO_2, as well as native and denatured PAGE gel electrophoresis on fresh haemolymph samples. We will further take tissue samples for further expression analysis upon return to Bremerhaven.

2.3.6 Thermal tolerance of live history stages and their relevance for the biodiversity and biogeography of decapod crustaceans

W.E. Arntz , C. Held , R. Kathöver , D. Storch (AWI), G. Lovrich*, C. Romero*, N. Schvezov (CADIC-CONICET), * not on board

Objectives

The latitudinal gradient of increasing biodiversity from the poles to the equator is one of the most prominent but least understood features of life on Earth. Reptant decapod crustaceans for example are found in high abundance throughout all world oceans on a wide latitudinal cline from tropical to polar waters, with the exception of Antarctic waters. Natant decapoda, amphipoda and isopoda, in turn, are very abundant in the extremely cold waters of the Antarctic shelf. One reason for this pattern could be that the group of reptant decapoda mainly exhibits planktotrophic larvae and taxa exhibiting extended planktotrophic developmental modes always show a clear decrease toward high latitudes. In turn, lecithotrophic larvae seem to be favoured at high latitudes. Interestingly the King crabs (Lithodidae), which can be found in sub-Antarctic and Antarctic waters, mainly show lecithotrophy with abbreviated larval developmental modes and might be able to recolonize Antarctic waters. Global warming, especially along the Antarctic Peninsula, opens up the possibility of extinct species like the reptant decapod crustaceans to recolonize Antarctic waters. It has been hypothesized that the Scotia Arc can be considered as a key zone for the study of changes in decapod life history and distribution patterns. The Scotia Arc and Bouvet Island could be potential invasion ways for the recolonization of cold adapted sub-Antarctic species. The aim of this proposal is to detect the distribution and biodiversity of the decapod crustaceans along the Scotia Arc, Weddell Sea and Bouvet Island, to identify the reproductive and energetic conditions of the adults, their developmental modes and to test the thermal tolerance of various stages by sampling all life history stages, including eggs, larval

stages and adult species. Our goal is to unravel the relevance of developmental modes and thermal tolerance for the biodiversity and biogeography of decapod crustaceans in the study area and to identify potential invader species. Furthermore, we would like to compare our findings of this cruise to earlier distribution and biodiversity patterns to see if we can already observe changes in the study area.

Work at sea

Our group will collect benthic and pelagic crustaceans. The species will be identified by DNA barcoding and/or morphological. The adults will be tested on their reproductive and energetic conditions. The thermal tolerance of females with eggs, eggs and larvae will be detected in the area. Main focus will be given to sub-Antarctic decapod species, which might be able to recolonize the Antarctic shelf.

2.3.7 Cardiovascular system in Antarctic Amphipods

F. Giomi (AWI), F. Bartolini (UNIFI)

Objective

The circulatory system of Amphipoda, not only in the anatomy but also in other aspects such as the innervations of the heart and the lacunar system, is particularly well studied. The ground pattern of amphipods' circulatory system is constituted by a heart that extends from the posterior border of the cephalothorax to the seventh thoracic segment, leading into a posterior aorta, three pairs of posterior cardiac arteries and three pairs of ostia, as well as an anterior aorta with myoarterial formation and a pair of anterior lateral arteries. This description corresponds to the arrangement of the hemolymph vascular system of Gammaridae, which is believed to be the ancestral clade of amphipods. Derivation of this pattern concerns mainly the absence of certain details (e.g. cardiac arteries in Caprellidea), or appears within monophyletic groups (e.g. the presence of only two pairs of ostia in Platyscelidae within Hyperiidea). Besides to the phylogenetic inference the study of amphipods' hemolymph vascular system provides important insight on their respiratory physiology. A series of capillary network in proximity of regions with a thinner cuticle is an indication of oxygen exchange surfaces. The coxal plates of Gammaridea, as example, are perfused by a meshwork of sinuses and most likely act as accessory respiratory structures. Despites the evident importance of this biological aspect, to date, nothing is known on the hemolymph vascular system of Antarctic amphipods. This gap appears particularly relevant in consideration of several factors. Life in Antarctic sea shows an astonishing biodiversity of species and forms and at the mean time displays remarkable adaptive mechanisms at morphological and physiological levels. The circulatory system of different taxa, in particular, displays a high degree of plasticity and adaptability, as for example the lack of oxygen carrier in certain fishes or the evolution of shielding mechanisms as the antifreeze glyco-proteins. Moreover, Antarctic amphipods show a marked radiation of species and forms with peculiar cases of gigantism and ecological specialization. The combination of a highly selective ecosystem with the plastic response of amphipod taxon constitutes an extremely interesting condition for the study of anatomy and evolution of their hemolymph vascular system. In conclusion, this study could provide important data on the anatomy and structure of amphipods' hemolymph vascular system, with important outcomes in at least three fields of biological sciences. From a phylogenetic point of view, in fact, we will be able to support the current systematic of amphipod groups, taking advantage of these new morphological characters. Secondly, we will define important aspects of respiratory and circulatory physiology in Antarctic amphipods and, last but not least, we will test the current hypotheses on the evolutionary trends and convergent adaptations in species colonizing polar environments.

Work at sea

Specimens will be collected with trawl net and traps during the cruise. Living animals will be kept in aquaria until use. The cast of the hemolymph vascular system will be obtained injecting into the heart of specimens the acrylic casting resin Mercox CL-2R/2B (Vilene Comp. Ltd, Tokyo, Japan). In a first step, the resin will be mixed with approximately 0.05 mg MA initiator and placed in a 5 mL syringe just before use. Micropipettes for the injection will be filled using the syringe and pricked through the intersegmental membrane between segments into the vascular system. The resin will be then injected and the specimens left for several minutes to allow for the polymerization and tempering of the resin. Specimens will be subsequently macerated for 1 – 2 days by repeated baths in 10 % potassium hydroxide at room temperature followed by washing with a solution of 2 g pepsin in 10 mL 2 % HCl. The casts will be analyzed with scanning electron microscopy while a three-dimensional reconstruction will be carried out though sectioning of the casts, digitalization of the sections and alignment of the images. This part of the project will be carried out in collaboration with the University of Jena. Further analyses will be carried out on the hemolymph samples to characterize the hemocyanin presence, concentration and affinity. Respiration rates, as well as blood oxygen content will be further collected on board in order to fulfill the characterization of respiratory physiology of Antarctic amphipods.

2.3.8 Male and female reproductive apparatus: a comparative analysis on Antarctic fish

F. Giomi (AWI), C. Mazzoldi* (UNIPD) * not on board

Objectives

Teleost fish present large variability in reproductive apparatus and gametes. Variation in morphology of male reproductive apparatus and investment in sperm has been shown to be related to reproductive modalities. On the other hand, females present wide interspecific variability in fecundity and egg size. For what is known about their reproductive strategies, Antarctic fish, in particular notothenioids

appear to show high reproductive investment, documented by high gonadosomatic indices, large egg sizes and, in some cases, long male parental care. The comparative study of male and female reproductive apparatus and investment in gametes is particularly interesting from an evolutionary biology point of view, given the adaptations shown by Antarctic fish to their peculiar environment. This study is aimed to comparatively analyse male and female reproductive apparatus of Antarctic fish in terms of: structure, function, gametogenesis, egg size.

Work at sea

According to species and samples availability, samples of gonads or whole body cavity or trunks of males and females of different species will be removed from fish and fixed in Dietrich solution. Each sample will be marked with species name, date and site of collection, sex (if visible) and size, and stored at room temperature. In order to relate reproductive status (mature vs immature) to size and age of fish, heads of samples will be removed and frozen for collection of otoliths. For each species, a minimum of 5 individuals per sex should be preserved, although if individuals of different sizes are available, larger numbers will allow the estimation of size at sexual maturity.

2.4 The role of climate induced changes in ice conditions and iceberg disturbances on the benthal biodiversity

2.4.1 The role of ice disturbance and changing ice conditions on the biodiversity

D. Gerdes, J. Gutt, R. Knust (AWI), H. Bohlmann (ISITEC), T. Lundäl (GU-LOVEN), A. Montiel (UMAG), E. Quiroga (ECM-UCV)

Objectives

The two main study areas for our work at sea are the LARSEN A/B embayments at the eastern coast of the Antarctic Peninsula and the BENDEX site on the southeastern Weddell Sea shelf. The international *Polarstern* expeditions EASIZ (Ecology of the Antarctic Sea Ice Zone) I to III have shown iceberg strandings on the Antarctic shelves to play an important role in structuring benthic biodiversity. Iceberg scours inflicts substantial damage on established communities of endo-, epi- and the demersal fish fauna. In the course of recovery, it is possible to distinguish different successional stages of recolonization although these never could be placed yet in an absolute temporal sequence. As a general result appears an enhancement of diversity on larger scales due to the co-existence of a variety of recolonization stages with different sets of species inventories. Beside this effect on biodiversity, the time scale of the process recolonization after a disturbance is considered as an important question, because in comparison with community recovery in lower latitudes it illustrates the vulnerability and resilience capacity of polar systems. To set a time stamp for recolonization processes an artificial mechanical disturbance experiment (BENDEX) was carried out during *Polarstern* expedition ANT-XXI/2 in December 2003. To simulate the impact of grounding icebergs on benthic and demersal fish communities, we destroyed a seabed area of approximately 100 x 1000 m artificially by means of 11 densely placed hauls with a modified bottom trawl. As a result benthic biomass and abundance as well as composition of the fauna were drastically changed. The goal of our planned studies is to follow the recolonisation and succession processes in the disturbed area thus getting insights into the spatially and temporally recovery of benthic communities in a high Antarctic environment after ice induced disturbance. Another widespread habitat in Antarctic water lies beneath floating ice shelves. Such sub-ice ecosystems belong to the least known on earth. In 2007 the Larsen A/B embayments were the targets of the first macroecological study of this formerly sub-ice-shelf habitat. As a result an impoverished benthic fauna was found including various deep-sea species which are presumed to reflect a former oligotrophic sub-ice-shelf system being covered for thousands of years by shelf ice. During this expedition we plan to repeat the benthic studies in order to follow the succession of the benthic communities after the abrupt climate induced ice-shelf disintegration. Further benthic sampling campaigns are planned in the Scotia Arc area and around Bouvet Island. These studies performed mainly with AGT will provide data for comparison of benthic communities along latitudinal gradients

Work at sea

Our studies basically comprise the following aspects:

a) evaluation of the recolonization process on the BENDEX experimental site.

b) high resolution UW still photograph transects of experimental and control sites,

c) UW-guided multi box corer sampling in and outside the experimental site (macrofauna, infauna),

d) to characterize the benthic communities and compare its standing stock and size structure before and after the disturbance experiment,

e) to compare the size distribution of benthic biomass along latitudinal gradient (from Bouvet Island to SE Weddell Sea Shelf).

2.4.2 Meiobenthic succession in the Larsen A and B areas after ice shelf collapse

A. Rose (FIS-DZMB), F. Hauquier (UGENT)

Objectives

Due to its functional distinctness and intermediate size between macrofauna and microbiota, meiofauna is assumed to play an important role in marine benthic food webs. Few is known about benthic meiofaunal communities living beneath the Antarctic ice shelves. Is a suggested lower productivity limiting diversity in those environments? The disintegration of Larsen A and B (mainly 1995, 2002) gave way to study benthic areas formerly covered by ice shelves for several thousand years, and to compare these with long-term uncovered and probably more productive reference areas. Main goal is to investigate the succession of meiobenthic communities in the Larsen A and B areas. A first benchmark study in January 2007 showed that nematode communities near the former Larsen B ice shelf margin differed from those in the innermost parts in terms of diversity and composition. The same was true for Harpacticoida family composition. All stations from this first study, including a mud volcano site, are intended to be repeated during ANT-XXVII/3 in order to see how things have developed since then. Results will enhance our understanding of meiofaunal colonisation speed after catastrophic events caused by regional climate warming. Comparisons with other oligotrophic areas (ANDEEP samples from the Antarctic deep sea) will be of special interest according to diversity models (e.g. productivity-diversity relationship). Also environmental factors correlating strongest with meiofaunal major taxa abundance and harpacticoid species diversity are to be untangled. Furthermore, diversity differences will be evaluated on multiple scales. Finally, unknown species and life forms are to be expected which will enhance our understanding of Antarctic biodiversity.

This study will contribute to a deduction of general rules concerning the resilience of Antarctic marine benthic ecosystems in times of increased climate change.

Work at sea

Five multicorer (MUC) stations from the Larsen A and B areas (*Polarstern* expedition ANTXXIII/8, January 2007) are to be re-sampled. Repetition of the benchmark study includes replicative sampling (five replicates) in order to get statistically meaningful results. An additional reference station outside the former Larsen B ice shelf at 300 m to 400 m depth would be desirable. For comparative purposes (first study and ANDEEP programmes), the MUC6 (12 tubes: inner diameter 57 mm) has to be used. MUC cores will be sliced at 5 cm sediment depth (more layers optional: 1, 2, 3, 4, 5, 10, 15 cm), and samplings will be fixated in 5 % buffered formol on board. Additional qualitative meiofauna samplings by sieving rinse water, sponges, and sediment from other gear are optional. These samplings will be preserved with 70 - 80 % ethanol and partly investigated at major taxa level on board. All organisms sampled quantitatively with the MUC will be sorted and counted on major taxa level at the DZMB (Wilhelmshaven, Germany). Unused material will be made available to other research groups for systematic, biogeographic, and other analysis.

2.4.3 Impact of an experimental benthic disturbance event on High Antarctic meiobenthic assemblages: developments after 7 years

F. Hauquier (UGENT), A. Rose (FIS-DZMB)

Objectives

Few papers deal with the influence of iceberg disturbance on meiobenthos. These demonstrated that catastrophic iceberg disturbances lead to impoverished meiofaunal assemblages in fresh scours. Meiofaunal abundance and taxonomic diversity were significantly reduced in those. Older scours showed highest abundance and diversity values, even higher than those for an undisturbed area. The return of major meiofauna groups was accomplished 30 days after a disturbance event, compared to a control site. Since under normal circumstances it is difficult to assess the age of natural iceberg scours and the time scale of the ongoing succession, an experimental approach was chosen that was supposed to lead to a disturbed area with a defined starting point in time (December 2003, ANT-XXI/2). The BENDEX (benthos disturbance experiment) area was intended to be visited by later expeditions in order to assess the time scale of the ongoing succession of benthic organisms and the development of environmental parameters. This will be done during the actual cruise leg. BENDEX was mainly designed for the removal of macrofauna. It is suggested that a lot of meiofauna were whirled into the water column during bottom trawling and re-sedimentated afterwards. Hence, at least for meiofauna bottom trawling did not resemble a real iceberg disturbance event. Since it was not possible to remove all material from the area and some stripes had been left undisturbed, central stations of the area probably resembled marginal stations in so far that edge effects occurred. Therefore, the process of trawling did not allow a clearly defined disturbed area. Finally and taking into account the mentioned literature, seven years is probably a too long interval to assess the process of meiobenthic succession after a disturbance of this scale.

Work at sea

Near Austasen (Weddell Sea, Antarctica), a 1,000 m x 100 m area of approximately 300 m depth with an old sponge community was disturbed by 11 bottom trawls, removing much of the macrofauna (ANT-XXI/2, December 2003). Three benchmark sample series had been taken in order to assess the impact of the experimental disturbance on meiobenthic assemblages. Since the preferred multicorer did not work properly due to thick sponge spicule mats, other gears were used. Within the experimental area stations were located both in central and marginal parts. Two of five pre-disturbance stations and three reference stations were sampled around the disturbed area in 50 m to 800 m distance. The pre-disturbance series consisted of three multiboxcorer (MG) hauls taken on 11 December, 2003 (PS65/116, 124, 125), of which 8 subcores á 10 cm^2 were taken out of two adjacent boxes, and two giant boxcorer (BC) hauls on 10 and 11 December, 2003 (PS65/107, 123), of which the same number of subcores was taken. Two stations (116, 124) were positioned outside and three stations (107,123,125) inside the subsequently disturbed area. The initial post-disturbance series one week later consisted of four MG hauls taken (PS65/183, 187, 199, 202), of which 8 subcores á 10 cm^2 were taken out of two adjacent boxes, and one BC haul (PS65/203) with the same number of subcores. In the surrounding of the experimental area three reference MGs were deployed after the disturbance. 8 resp. 7 subcores out of two adjacent boxes, and 4 cores out of one box were taken and processed on 17 to 18 December, 2003. Resampling of these initial BENDEX stations during the actual cruise leg is intended to be restricted to the 7 MG hauls of the post-disturbance and reference sampling series. Preferably 6 - 8 subcores will be taken out of 1 - 2 MG boxes at each station. These are to be processed as follows: Up to three cores will be prepared for quantitative morphological analysis of meiofaunal diversity and fixated with formaldehyde (4 %). One of these should be split into 5 layers (0 - 1, 1 - 3, 3 - 5, 5 - 10, 10 -

15 cm), the other ones taken as a bulk (0 - 5 cm). One core is reserved for molecular analysis of nematode diversity (conservation with ethanol 98 %) and taken as a bulk (0 - 5 cm). Above standing water will be sampled together with the uppermost layer for all of these 2-4 cores. The last three cores will be processed for analysis of chemical and physical parameters. The stable isotope core should be split into two layers (0 - 1, 1 - 2 cm; deep-frozen at –20° C, best at –80° C). One core will be prepared for analysis of phytopigments (layers: 0 - 1, 1 - 2 cm, deepest possible cm), another one for organic matter and sediment structure (layers: 0 - 1, 1 - 2, 2 - 3, 3 - 4, 4 - 5 cm, deepest possible cm). These two cores will be kept deep-frozen (–20° C, best at –80° C).

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5. SCHIFFSBESATZUNG / SHIP'S CREW

Name	Rank
Pahl, Uwe	Master
Grundmann, Uwe	1.Offc.
Ziemann, Olaf	Ch.Eng.
Hering, Igor	2.Offc.
Peine, Lutz	2.Offc.
NN	2.Offc.
Rudde-Teufel, Claus	Doctor
Koch, Georg	R.Offc.
Kotnik, Herbert	2.Eng.
Schnürch, Helmut	2.Eng.
Westphal, Henning	2.Eng.
Holtz, Hartmut	Elec.Tech.
Nasis, Ilias	Electron.
Dimmler, Werner	Electron.
Hebold, Catharina	Electron.
Feiertag, Thomas	Electron.
Clasen, Burkhard	Boatsw.
Neisner,Winfried	Carpenter
Kreis, Reinhard	A.B.
Schultz, Ottomar	A.B.
Burzan, G.-Ekkehard	A.B.
Schröder, Norbert	A.B.
Moser, Siegfried	A.B.
Hartwig-L., Andreas	A.B.
NN	A.B.
Kretzschmar, Uwe	A.B.
Guse, Hartmut	A.B.
Scheel, Sebastian	A.B.
Beth, Detlef	Storekeep.
Kliem, Peter	Mot-man
Fritz, Günter	Mot-man
Krösche, Eckard	Mot-man
Dinse, Horst	Mot-man
Watzel, Bernhard	Mot-man
Fischer, Matthias	Cook
Tupy,Mario	Cooksmate
Völske, Thomas	Cooksmate
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Hennig, Christina	Stwdss/KS
Streit, Christina	2.Steward
Hischke, Peggy	2.Stwdess
Wartenberg, Irina	2.Stwdess
Möller, Wolfgang	2.Steward
Chen, Quan Lun	2.Steward
Ruan, Hui Guang	Laundrym.

ANT-XXVII/4

20 April 2011 - 20 May 2011

Cape Town - Las Palmas - Bremerhaven

Chief Scientist

Saad El Naggar

Contents

1. ÜBERBLICK UND FAHRTVERLAUF

Am 20. April 2011 wird *Polarstern* den letzten Fahrtabschnitt der Antarktisreise ANT-XXVII von Kapstadt nach Bremerhaven antreten. Die Fahrt wird zur kontinuierlichen Untersuchung atmosphärischer und ozeanischer Eigenschaften sowie der Energie- und Stoffflüsse zwischen Ozean und Atmosphäre genutzt. An verschiedenen Stationen werden Messungen vorgenommen und Geräte getestet. Die Reise wird in Bremerhaven am 20. Mai 2011 nach einem kurzen Stopp in Las Palmas enden.

Um die experimentelle Erfassung von Stoff- und Energieaustausch zwischen Ozean und Atmosphäre auf eine solide Basis zu stellen, ist im Rahmen des OCEANET-Projektes mittels der Vernetzung der Expertisen des IFM-GEOMAR (CO_2-/O_2-Flüsse, photosynthetischer Status, Energiehaushalt, Fernerkundung), des IfT (Lidarmessungen), des GKSS Forschungszentrums („FerryBox“ und Fernerkundung der marinen Biologie mit ENVISAT/MERIS) und des AWI-Bremerhaven (CO_2-System, marine Infrastruktur von *Polarstern*) die Entwicklung autonomer Messsysteme geplant, die langfristig für den operationellen Betrieb an Bord verfügbarer Fracht- und Forschungsschiffe vorgesehen sind.

Kontinuierliche Messungen der kosmischen Teilchen dienen der Untersuchung der Breitenabhängigkeit auf Grund des Erdmagnetfeldes und der Untersuchung des „kosmischen Wetters“. Im Zusammenhang mit Wolkenbeobachtungen soll der Zusammenhang zwischen Wolken und der Anzahl der kosmischen Teilchen untersucht werden.

Stabile Kohlenstoff-Isotope der Methan-Halogen-Verbindungen werden kontinuierlich während der Fahrt gemessen, um die Abhängigkeit ihrer Verteilung von den Breitengraden zu bestimmen.

Lebende Tiere, die während ANT-XXVII/3 für Forschungszwecke gefangen wurden, werden an Bord auf ANT-XXVII/4 fachgerecht gehältert und versorgt.

Auf der Rückreise von Las Palmas bis Bremerhaven wird eine Schulung am Parasoundsystem P-70 erfolgen.

SUMMARY AND ITINERARY

On 20 April 2011 *Polarstern* will start its Atlantic transfer from Cape Town to Bremerhaven as the last leg of the Antarctic cruise ANT-XXVII. The cruise will be utilized for continuous investigations of atmospheric and marine properties as well as for energy and material fluxes between ocean and atmosphere. The cruise will end in Bremerhaven on 20 May 2011 after a short stop in Las Palmas.

In order to provide a solid basis for the observational monitoring of energy and material exchange between ocean and atmosphere it is planned in the context of the OCEANET project to develop an autonomous observation system for operational use onboard available cargo- and research vessels. The project is based on a network of expertise from IFM-GEOMAR (CO_2-/O_2-fluxes, photosynthetic status, energy budget, remote sensing), IfT (lidar measurements), the GKSS research center (ferry box, remote sensing of marine biology with ENVISAT/MERIS) and AWI-Bremerhaven (CO_2-system, marine infrastructure of *Polarstern*).

Continuous rate measurements of cosmic particles allow to estimate their dependency on latitude due to the Earth's magnetic field. Simultaneous cloud observations allow to investigate whether the concentration of cosmic particles influences cloudiness or vice versa.

The concentrations and stable carbon isotope distribution of methyl halides will be measured in air and surface water along a South-North transect from Cape Town to Bremerhaven.

Living animals which have been caught during ANT-XXVII/3 will be kept in the aquarium and the laboratory containers at 0°C water temperature to be transferred alive to Bremerhaven. Besides first measurements of enzyme activities, the main task will be to keep up the water quality in the aquaria.

On the way from Las Palmas to Bremerhaven a training course on the Parasound system P-70 will be held.

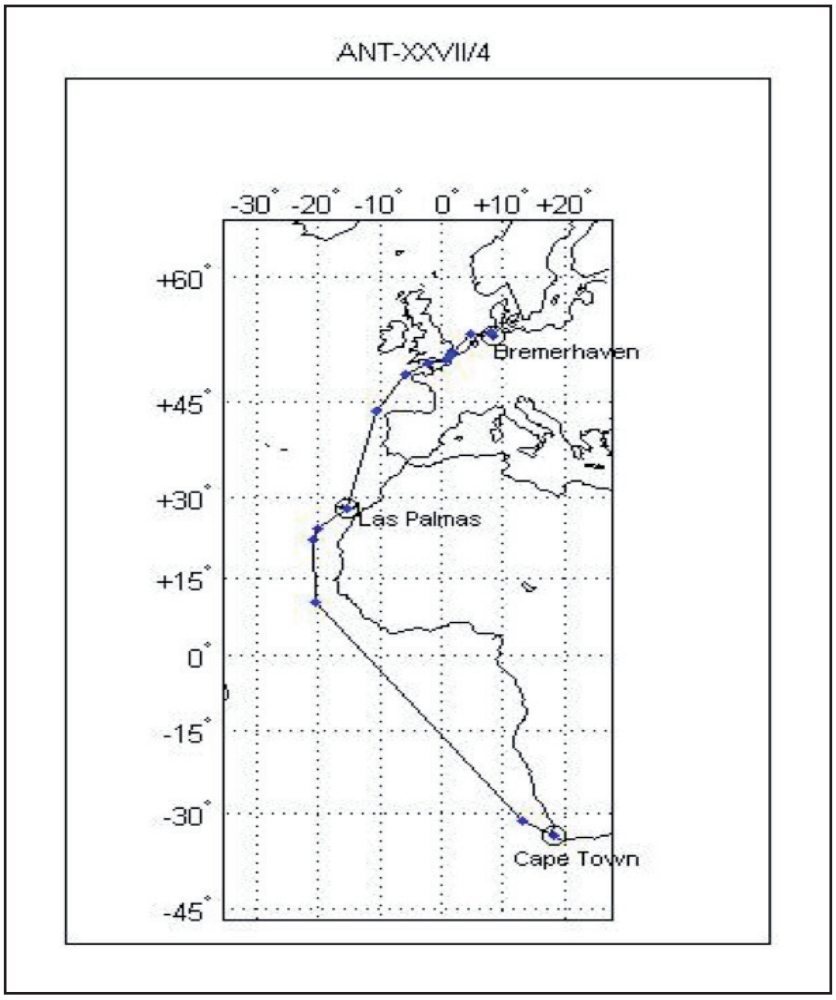

Abb.1: Reiseroute ANT-XXVII/4 Kapstadt-Bremerhaven vom 20.04.2011 bis 20.05.2011
Fig: 1: Route of cruise ANT-XXVII/4 Cape Town – Bremerhaven, 20 April 2011 – 20 May 2011

2. AUTONOMOUS MEASUREMENT PLATFORMS FOR ENERGY AND MATERIAL EXCHANGE BETWEEN OCEAN AND ATMOSPHERE (OCEANET): ATMOSPHERE

K. Bumke (not on board) Y. Zoll, NN (IFM-GEOMAR),

A. Macke, D. Althausen (not on board), T. Kanitz, L. Poulain, A. Nowak, M. Brückner, W. Fomba, NN (IfT)

Objectives

Radiation & microwave remote sensing

The net radiation budget at the surface is the driving force for most physical processes in the climate system. It is mainly determined by the complex spatial distribution of humidity, temperature and condensates in the atmosphere. The project aims at observing both the radiation budget and the state of the cloudy atmosphere as accurate as possible to provide realistic atmosphere-radiation relationships for use in climate models and in remote sensing. While similar experiments have been performed from land stations, only few data from measurements over ocean areas exist. The present project is part of the “Meridional Ocean Radiation Experiment” MORE which uses Atlantic transfers of various research vessels for the combined measurements of the atmospheric state since 2004. The main project behind this cruise is the WGL-PAKT Initiative OCEANET.

A multichannel microwave radiometer will be applied to continuously retrieve temperature and humidity profiles as well as cloud liquid water path over the ocean. Time series of these profiles will show small scale atmospheric structures as well as the effects of the mean state of the atmosphere and its variability on the co-located measurements of the downwelling shortwave and longwave radiation. The atmospheric profiles will also be used to validate the satellite based profiles from the IASI instrument onboard the new European polar orbiting satellite MetOp. Atmospheric aerosol optical thickness will be measured by means of hand held sun photometer and spectral solar radiometer. Most instruments will be integrated in the new container-based atmosphere observatory.

Air-sea interaction and fluxes

Great emphasis has to be put on air-sea fluxes of momentum, sensible and latent heat to improve numerical models of weather forecast and climate simulations since oceans cover 71% of the earth’s surface. The fluxes of sensible and latent heat are also of importance for the energy budget of the ocean and the atmosphere. Due to the steady increase of many trace gases in the atmosphere like CO_2, *in-situ* gas flux measurements are required to establish parameterizations that provide flux estimates in climate models.

To estimate the turbulent fluxes of momentum, sensible heat, latent heat, and CO_2 a sonic-anemometer and an open path LiCor will be mounted. Measurements are taken at a sampling rate of 20 Hz (LiCor) respectively 30 Hz (sonic-anemometer) allowing to derive the fluxes by applying the inertial dissipation method. This method relies on measurements at high frequencies, less distorted by the motion and the superstructure of the ship than the covariance technique. Additional measurements of the sea surface temperature (SST) in combination with observations of the standard meteorological parameters and measurements of the CO_2 con-

tent in ocean and atmosphere at a lower data rate performed by marine chemist (see section 2) flux parameterizations can be derived.

Lidar observations

The high temporal and spatial variability of atmospheric aerosol characteristics, i.e. in number concentration, size distribution, shape and chemical ingredients, complicates their exact specification and consideration in radiative transfer models.

The Raman lidar measurement technique is able to provide main information about the vertical profiles of aerosols. With this technique the particle backscatter and extinction coefficient can be determined, i.e. the aerosol optical properties can be described in a quantitative way. Furthermore the use of three backscatter coefficients and two extinction coefficients enable an inversion method to estimate the main microphysical properties at any measured height

24-h measurements by the 3+2+1 Raman lidar system PollyXT aboard*Polarstern* at its transit cruises imply the opportunity to characterize the optical and microphysical particle properties above the Atlantic Ocean. These particles in the several layers of the atmosphere above the Atlantic are lifted up and are intercontinentally transported from certain source regions like anthropogenic emissions from North America, dust from Saharan region or smoke from biomass burning in South America or Africa.

Enhanced research is focused on the aerosol properties, due to their variable effects on down- and upwelling radiation, which are still uncertain. The determined optical and microphysical particle data will be used in the height resolved radiative model LibRadtran This model allows an estimation of the radiative influence of different aerosols, even if they occur in separated layers.

The height resolved results will be compared by simultaneous column integrated ship and space borne measurements, also in the case of vertically separated aerosol layers.

Aerosol measurements

The portfolio of the Aerosol Group at IfT includes the *in-situ* characterisation of atmospheric aerosols in urban as well as remote background atmospheres, the characterisation of regional and urban air quality, the examination of hygroscopic particle properties, the measurement and simulation of *in-situ* aerosol optical properties, the investigation of atmospheric transport processes, and the development of new and improved instruments for physical aerosol characterisation. Onboard *Polarstern* all measurements will be conducted inside a temperature-controlled container laboratory, and focus on the particle characterisation using high-end scientific instruments in order to study:

- physical aerosol properties using an Aerodynamic Sizer (APS) and Tandem Differential Mobility Analyser (TDMPS) for particle number size distributions from 3 nm to 10 µm, and a Humidifying Differential Mobility Particle Sizer (HDMPS) for the hygroscopic growth of the particles;

- optical properties using a nephelometer and an absorption photometer to measure the particle light scattering and absorption coefficients, respectively; and

- particle chemical composition using a High Resolution Time of Flight Aerosol Mass Spectrometer (HR-ToFAMS) for the non-refractory PM1.

Sea surface chemistry

The main objective of the chemical analysis is to characterise the chemical composition of the ocean surface film in parallel to the chemical

and physical characterisation of the marine aerosol in order to identify the particle-based exchange of organic compound and hence carbon.

Work at sea

Upon departure both container-based atmosphere observatories will be installed on the observation deck of *Polarstern*. All measurements will be performed underway and continuously. The following individual instruments are combined:

1) Multichannel microwave radiometer HATRPO. The instruments require occasional calibrations with liquid nitrogen as well as tipp-calibrations under calm sea and homogeneous atmospheric conditions.

2) Multichannel Raman-Lidar Polly for aerosol measurements. PollyXT is designed as standalone portable Raman Lidar System. It will operate whenever weather is appreciable and placed in the OCEANET container at the Peildeck.

3) Whole sky imager for cloud structure measurements

4) Handheld sun photometer (Microtops) for aerosol and cloud optical thickness

5) Sonic anemometer USA-1 to measure the wind components and temperature

6) LiCor to measure water vapor and CO_2

7) M-100 absorption hygrometer to measure water vapor

8) KT-19 radiometer to measure SST and the brightness temperature of the atmosphere

9) *in-situ* aerosol measurements

Marine aerosol particles will be sampled and chemically analyzed in detail in parallel to physical particle characterization. During ship stops the ocean surface film will be sampled and chemically analyzed according to the current state-of-the-art.

Expected results

1) Two dimensional structure of the clear sky atmosphere and corresponding net radiation budget.

2) Horizontal structure of the cloud water path and its effect on the downwelling shortwave and long wave radiation

3) Vertical structure of temperature and humidity as well as its variability for validation of satellite products

4) Vertical profiles of tropospheric aerosols and their effect on radiation

5) Turbulent fluxes of momentum, sensible, and latent heat

6) Flux of CO_2 between ocean and atmosphere

7) Near-surface aerosol size distributions and their physical and chemical compositions

8) Chemical composition of surface films and relation to evaporated organic materials and their aggregation in aerosols.

3. RATE MEASUREMENT OF COSMIC PARTICLES IN DEPENDENCE ON LATITUDE AND WEATHER CONDITIONS

M. Walter (DESY, Zeuthen)

Objectives

The astroparticle physics group at DESY (Deutsches Elektronen-Synchrotron, member of the Helmholtz society) performs within international cooperations the experiments IceCube/IceTop at the Amundson-Scott South Pole Station and MAGIC at La Palma to search for galactical and extragalactical sources of high energy cosmic particles.

An outreach programme was started in 2004 to allow students and scholar girls/boys (9th to 13th classes) to perform measurements with cosmic particles within project weeks and periods of practical training supported by scientists of the DESY astroparticle group. Goal of the project is to interest young people for modern physics and for experimental and analysis methods. See our web-site:

http://physik-begreifen zeuthen.desy.de/angebote/kosmische_strahlung/index_ger.html.

The cosmic particle detector installed at *Polarstern* consists of two scintillation counters working in coincidence mode. In addition there are three other devices to measure the GPS coordinates and time, the temperature and air pressure as well as the inclination of the detector correlated with the vessel movement. A python programme runs under Linux on a notebook to control data taking and storage on disk.

Work at sea

It is planned to run the detector during the whole expedition ANT-XXVII. The data will be made public via a web-interface, so that they can be analyzed also by students within the outreach project.

Expected results

The scientific goals of the experiment are:

- The investigation of the cosmic particle rate in dependence on the latitude. The rate is smallest at the equator and increases to poles due to the influence of the Earth magnetic field. This geomagnetic cut-off will be measured.

- The possible measurement of sudden increase of the cosmic particle rate due to sun flares. Such flares of high particle intensities influence the “cosmic weather” and especially electronics systems installed on Earth or in satellites. It exists a net of detectors installed in different countries for an early warning system of such dangerous events. Our measurements can contribute to possible future extensions of this warning system.

- The investigation of the influence of cosmic particles on cloud formation. There are measurements which seem to show an influence on cloud formation with increasing rates of cosmic particles. But the existing data are not good enough to establish this hypothesis. Also here our measurements could contribute to clarify the situation.

4. OCCURRENCE, DISTRIBUTION AND STABLE CARBON ISOTOPE COMPOSITION OF METHYL HALIDES ALONG A SOUTH-NORTH TRANSECT OF THE ATLANTIC OCEAN

F. Laturnus, E. Bahlmann (not on board), R. Seifert (not on Board), (University of Hamburg)

Introduction

The widespread use of chloro- and chlorofluorohydrocarbons (CFCs) and other volatile organohalogens in our industrialised society cause a large annual release of these compounds into the environment. Besides atmospheric pollution, some volatile organohalogens, for example chloroform, tri- and tetrachloroethene, also constitute a risk for drinking water resources as they can be transported to the groundwater from contaminated field sites or even from atmospheric deposition. These volatile organohalogens have been under scrutiny the recent years as they are a source for halogen radicals involved in various catalytic atmospheric reaction cycles, including the destruction of the stratospheric ozone layers. To avoid further depletion of the protecting ozone layer against solar ultraviolet radiation, the production and consumption of man-made ozone depleting substances is now controlled by international regulations (e.g. UNEP 1987). Besides the industrial emission, also natural emissions of volatile organohalogen compounds by several marine and terrestrial sources have been identified. Interesting is that extrapolations of global emissions of volatile organohalogens from natural sources into the atmosphere revealed source strengths comparable to the industrial input**.** For the terrestrial environment, several natural sources, such as wetlands, peatlands, salt marshes, rice fields, soil, forests, vulcanos have been found to release mainly chlorinated compounds . Although the terrestrial environment is only 29 % of Earth’s surface, it is a major contributor to the occurrence of methyl halides and other volatile reactive halogen-containing compounds in the environment. For example, salt marshes may contribute up to 20 % of the global methyl halide flux to the atmosphere. However, those numbers are still rough estimates since many sources are only partially understood. A relevant source for volatile organohalogens too may be mangroves, recently found by a greenhouse experiment to produce chloromethane in substantial amounts. These plants cover approximately 60 - 70 % of the tropical coastline, and may, thus, be central sources for methyl halides in the natural environment. However, field studies on emissions of halomethanes from mangroves are still not available.

In the marine environment, the oceans are major sources for volatile organohalogens released into the atmosphere. However, the origin of these compounds inside the oceans has not yet been fully explored. At present, marine macro algae and microalgae have been identified as

a producer of volatile organohalogens. However, they are responsible for only 0.7 to 16 % of the total amount of volatile organohalogens annually emitted from the oceans. Thus, other so far unknown sources must still exist to balance the global halogen budget. Therefore, identification and quantification of marine sources and sinks of organohalogenes are a topic of particular interest.

Recently, signatures of carbon stable isotopes appeared to be a powerful tool to identify the dynamics of low molecular weight organohalogenes. Information from this tool may allow to distinguish between different sources, to trace transport processes, and to estimate life time cycles of selected organohalogenes.

Natural sources have been found to be significant contributors to the input of volatile organohalogens to the environment. However, compared to industrial sources, natural sources can hardly be controlled. Thus, it is important to complete the picture of natural sources contributing to the environmental input of volatile organohalogens. It has been shown that changes of abiotic factors, such as nutrient concentration, temperature, salinity, ultraviolett radiation, can alter the release of volatile organohalogens by natural sources. Therefore, human influences on the environment resulting in eutrophication or further global warming can change the emission of volatile organohalogens by natural sources. For example, the investigations of marine macro algae showed evidence for a significant increase in the release of these substances when the macro algae are exposed to elevated levels of ultraviolet radiation. Therefore, increasing emission of volatile organohalogens may be expected in future from natural marine and terrestrial sources, when ultraviolet radiation levels reaching the Earth's surface still elevates due to a weakening stratospheric ozone layer. This would alter the global atmospheric input and in turn the stratospheric ozone chemistry, and has to be considered when predicting future scenarios in global climate changes.

Objectives

The aim of this project is to measure the concentrations and stable carbon isotope distribution of methyl halides in air and surface water along a South-North transect from Cape Townto Bremerhaven. Therefore, information on South-North distribution, on a biogenic or anthropogenic origin and on possible coastal impacts on methyl halide concentrations in seawater and air can be determined.

Specific objectives are to

- specify the halogenated compounds and to determine the concentrations of methyl halides in surface water and ambient air.

- calculate their fluxes and to identify places of sources and sinks of methyl halides in the Atlantic Ocean.

- determine the stable carbon isotopic signatures of methyl halides and their mixing ratios, both for marine and coastal terrestrial sources, and to identify the origin of the methyl halides.

- record spatial patterns of the isotopic composition of methyl halides in the atmosphere and in the upper water column along the North-South transect.

- improve our understanding of the land-to-ocean and land-to-atmosphere fluxes of organohalogens in the vicinity of the African upwelling regimes.

The project will contribute to ongoing projects on studying the occurrence and distribution of volatile organohalogens at the West coast of Africa (SOPRAN) and Brazil (CliSAP). Furthermore, the project will deliver additional data to results of a West-East transect of volatile organohalogens done during a cruise with the German research vessel Meteor (M78/2) and a North-South transect from Bremerhaven to Punta Arenas (Chile) with *Polarstern* (ANT-XXVI/1).

Work at Sea

For the determination of methyl halides, ambient air and surface seawater samples, and for the determination of chlorophyll, surface water samples, will be continuously collected and analysed 6 times a day directly in the laboratory during the whole cruise. Additionally, once a day a large-volume air sample (200L) will be collected on adsorbent tubes on the upper deck for isotope distribution analysis. The sample tubes and the chlorophyll samples need to be stored at -80° C and -20° C, respectively.

5. ROLE OF TEMPERATURE, CO_2 AND OXYGEN IN EVOLUTION: INTEGRATIVE ECOPHYSIOLOGICAL STUDIES ON MARINE ANIMALS

T. Hirse, J. Mönich (AWI)

Objectives

The scientific background of our work base on our research goals of the *Polarstern* expedition ANT-XXVII/3, which can be summarized as followed:

Temperature is considered to be one of the most important abiotic factors shaping marine ecosystems due to its major impact on all biological processes. Focusing on life in cold oceans, our research addresses the question of how boundary conditions are defined from a physiological point of view and which physiological or biochemical characteristics or processes are responsible for limiting survival. Those key processes may comprise oxygen uptake and transportation, energy provision or maintenance of ionic and acid-base balance. Our work onboard will deal with the basic mechanisms that allow Antarctic fish to maintain a high aerobic capacity and the capacity for growth and reproduction in the cold. Our studies will be carried out on Antarctic fish species from different climatic regions (Sub Antarctic waters / High Antarctic waters). These species may serve as a model to investigate the differences between seasonal and latitudinal cold adaptation. Previous investigations suggest that an increase of aerobic capacity in the cold is achieved by increasing the number of mitochondria in the tissues. We will investigate if indeed the number of mitochondria does change during cold adaptation and if the characteristics of the individual mitochondrion are altered. We will determine the activity of the key enzyme of the oxidative phosphorylation (cytochrome c oxidase) and the aerobic capacity of the mitochondria. For comparative analyses of the temperature dependence of ion regulatory capacities and acid-base regulation, growth, fecundity fishes will be collected using suitable traps and bottom trawls and transported to the AWI for further physiological investigations. A second aim is to collect tissue samples from fishes freshly caught in bottom and pelagic trawls and freeze them for further analysis, partly onboard the vessel, partly for molecular biological analysis at the AWI (e.g. for gene expression studies).

During ANT-XXVII/3 cold-adapted animals (fishes, mainly Notothenioidei, decapods, cephalopods) will be caught in different areas of Antarctic waters and will be kept in our aquarium container onboard of *Polarstern* to transport them during ANTXXVII/4 for further experimentations on living animals in Bremerhaven.

Work at sea

Living animals, which have been caught during ANT-XXVII/3 will be kept in the aquarium container (AWI 024) and the laboratory containers (AWI 031 - 033) at 0°C water temperature and will have to be transferred alive to Bremerhaven. Beside first measurements of enzyme activities, the main task will be to keep up the water quality in the aquaria.

6. PARASOUND: SYSTEM TESTING AND TRAINING UNDER EXPEDITION CONDITIONS

G. Kuhn, F. Niessen and 8 POLMAR students (all AWI) (from Las Palmas, Canary Islands to Bremerhaven)

Objectives

The aim of the cruise participation is to train participants for self-efficient operation of the new hull-mount Parasound system P-70. This will ensure sufficient Parasound surveys for geological projects carried out on forthcoming expeditions of the RVs *Polarstern* and other ships during the next years. The aim of the system test is to check the Parasound system after the latest software updates and bug fixes in order to make improvements possible if needed. Student training will be part of the POLMAR Graduate School.

Work at Sea

For the work at sea no extra ship time is required. Also, it is efficient to work along the line of the routinely planned transit track and ship velocity. The area at sea along the routine course track from the Las Palmas roadstead to eastern British Channel is particularly suitable for Parasound system training because the range of sea-floor topography, sediment penetration and water depth allows using all possible modes of operation. The work includes 24-hour operation during which participants are running the system under expedition conditions.

7. BETEILIGTE INSTITUTE / PARTICIPATING INSTITUTES

	Adresse/Address
AWI	Alfred-Wegener-Institut für Polar- und Meeresforschung Am Handelshafen 12 27570 Bremerhaven/Germany
DESY	Deutsches Elektronen-Synchrotron DESY Platanenallee 15738 Zeuthen/Germany
DWD	Deutscher Wetterdienst Geschäftsbereich Wettervorhersage Seeschiffahrtsberatung Bernhard-Nocht-Str. 76 20359 Hamburg/Germany
Fielax	Fielax Gesellschaft für wissenschaftliche Datenverarbeitung mbH Barkhausenstr. 4 27568 Bremerhaven/Germany
IFM-GEOMAR	Leibniz-Institute for Marine Sciences Düsternbrooker Weg 20 24105 Kiel/Germany
IfT	Institute for Tropospheric Research Permoserstraße 15 04318 Leipzig/Germany
Laeisz	Reederei F. Laeisz (Bremerhaven) GmbH Brückenstr. 25 D-27568 Bremerhaven/Germany
MPI	Max-Planck-Institut für Meteorologie Bundesstrasse 53, 20146 Hamburg/Germany
University of Hamburg	University of Hamburg, Institute for Biogeochemistry, 20146 Hamburg/Germany

8. FAHRTTEILNEHMER / PARTICIPANTS

Name/ Last Name	Vorname/ First Name	Institut/ Institute	Beruf/ Profession
Brückner	Marlen	IfT	Meteorologist
Bult	Klaus	DWD	Technician/ Meteorology
El Naggar	Saad	AWI	Physicist Chief Scientist
Gerchow	Peter	AWI	Engineer
Hirse	Timo	AWI	Technician
Höpner	Friederike	IfT	Student
Kanitz	Thomas	IfT	Physicist
Kuhn	Gerhard	AWI	Geologist
Laturnus	Frank	University ofHamburg	Chemist
Loeppke	Petra	AWI	Logistics
Miller	Max	DWD	Meteorologist
Mönich	Julian	AWI	Student
NN		IfT	
Niessen	Frank	AWI	Geologist
Nowak	Andreas	IfT	Meteorologist
Poulain	Laurent	IfT	Chemist
Wadinga Fomba	Khanneh	IfT	Chemist
Walter	Michael	DESY	Physicist
Zoll	Yann	IFM-GEOMAR	Meteorologist
8 NN		AWI	POLMAR students

9. SCHIFFSBESATZUNG / SHIP'S CREW

Name	Rank
Pahl, Uwe	Master
Grundmann, Uwe	1.Offc.
Ziemann, Olaf	Ch.Eng.
Hering, Igor	2.Offc.
Peine, Lutz	2.Offc.
NN	Doctor
Koch, Georg	R.Offc.
Kotnik, Herbert	2.Eng.
Schnürch, Helmut	2.Eng.
Westphal, Henning	2.Eng.
Holtz, Hartmut	Elec.Tech.
Hofmann, Jörg	Electron.
Dimmler, Werner	Electron.
Hebold, Catharina	Electron.
Feiertag, Thomas	Electron.
Clasen, Burkhard	Boatsw.
Neisner,Winfried	Carpenter
Kreis, Reinhard	A.B.
Schultz, Ottomar	A.B.
Burzan, G.-Ekkehard	A.B.
Schröder, Norbert	A.B.
Moser, Siegfried	A.B.
Hartwig-L., Andreas	A.B.
NN	A.B.
Kretzschmar, Uwe	A.B.
Beth, Detlef	Storekeep.
Kliem, Peter	Mot-man
Fritz, Günter	Mot-man
Krösche, Eckard	Mot-man
Dinse, Horst	Mot-man
Watzel, Bernhard	Mot-man
Fischer, Matthias	Cook
Tupy,Mario	Cooksmate
Völske, Thomas	Cooksmate
Dinse, Petra	1.Stwdess
Hennig, Christina	Stwdss/KS
Streit, Christina	2.Steward
Hischke, Peggy	2.Stwdess
Wartenberg, Irina	2.Stwdess
Sun, Yong Sheng	2.Steward
Hu, Guo Yong	2.Steward
Ruan, Hui Guang	Laundrym.

FS POLARSTERN

ANT-XXVII/1	**25.10.2010 - 26.11.2010**	**Bremerhaven - Cape Town**
ANT-XXVII/2	**28.11.2010 - 05.02.2011**	**Cape Town - Pta Arenas**
ANT-XXVII/3	**08.02.2011 - 18.04.2011**	**Pta Arenas - Cape Town**
ANT-XXVII/4	**20.04.2011 - 20.05.2011**	**Cape Town - Bremerhaven**