EXPEDITION PROGRAMME No. 82

RV POLARSTERN

ANT-XXV/3
7 January 2009 - 17 March 2009
Cape Town - Punta Arenas

ANT-XXV/4
21 March 2009 - 9 April 2009
Punta Arenas - Punta Arenas

ANT-XXV/5
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Punta Arenas - Bremerhaven

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ANT-XXV/3

7 January 2009 - 17 March 2009

Cape Town - Punta Arenas
Stable Eddy North of South Georgia

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1. ÜBERBLICK UND FAHRTVERLAUF

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7. January 2009 - 17. März 2009, Kapstadt, Südafrika nach Punta Arenas, Chile

Die Fahrt wird gemeinsam durchgeführt vom National Institute of Oceanography (NIO) Goa des Council of Scientific and Industrial Research, Indien, und dem Alfred-Wegener-Institut für Polar- und Meeresforschung, Forschungszentrum der Helmholtz-Gemeinschaft.

In den letzten 10 Jahren haben sich *in-situ* Eisendüngungsexperimente als verlässliche Methode herausgestellt biogeochemische und ökologische Hypothesen zu testen, die durch andere Mittel nicht zugänglich sind. Das interdisziplinäre Experiment LOHAFEX (Loha ist das Hindi Wort für Eisen, Fertilization EXperiment) wird eine Reihe von unabhängigen, aber miteinander verbundenen Hypothesen testen, von denen einige im Folgenden erwähnt sind:

a) John Martins Eisen-Hypothese mit ihren Geo-Engineering Folgen.

b) Die Planktonartenzusammensetzung in einer experimentell induzierten Blüte im produktiven Südwesten des Atlantischen Sektors wird sich von Planktonblüten vorheriger Experimente in Niedrigproduktionsgebieten unterscheiden.

c) Die Krebstiere des Zooplanktons, insbesondere Krill, sind nahrungslimitiert, was den gegenwärtigen Rückgang der Krillbestände erklären könnte.

d) Eisengedüngte Blüten führen zur Produktion schädlicher Gase mit nachteiligen Folgen für die Atmosphäre.

Diese und andere Hypothesen, die in den Unterkapiteln dieses Fahrtheftes behandelt werden, sprechen fundamentale Fragen der Erdsystemforschung an, die relevant für unser Verständnis von der Rolle der marinen Biosphäre für das Klima der Vergangenheit und der Gegenwart ist.

Theoretischer Hintergrund

Alle bisherigen Experimente im Südpolarmeer (SOIREE, EisenEx, SOFEX I und II sowie EIFEX) wurden im landfernen Zirkumpolarstrom durchgeführt mit dem Ziel, die Eisenhypothese von John Martin (1990) zu testen: Höherer Staubeintrag während Eiszeiten stellte ausreichend Eisen zur Verfügung, um die Produktivität und den Kohlenstoffeintrag im Zirkumpolarstrom soweit zu erhöhen, dass diese Region eine global bedeutende CO_2-Senke darstellte. Diese Hypothese wird zurzeit kontrovers diskutiert (Anderson et al. 2002). Verschiedene geochemische Paleo-Proxies aus Meeressedimenten zeigen niedrigere Produktivität während der Eiszeiten südlich der Polarfront, obwohl ökologische Proxies reiche Ablagerungen von Sporen küstennah lebender Diatomeen in dieser Region belegen, die das Gegenteil andeuten. Neue und verlässlichere biologische Proxies und eine verbesserte Validierung bereits bestehender Proxies sind notwendig, um die Kluft zwischen ökologischen und geochemischen Befunden zu überbrücken.

Die erste Bedingung von Martins Hypothese (der Aufbau einer Phytoplankton Blüte) wurde von allen fünf vorherigen Experimenten erfüllt. Die meisten blütenbildenden Arten waren typisch für den Zirkumpolarstrom und durch dicke Schalen (niedrige C:Si Verhältnisse) und ozeanische Lebenszyklen gekennzeichnet. Diese Artgemeinschaften unterscheiden sich stark von denen typisch für küstennahe, produktive Regionen des Südpolarmeeres, die durch kleinere, schwach verkieselte Arten gekennzeichnet sind und unter ungünstigen

Wachstumsbedingungen Dauersporen ausbilden und massenhaft aussinken. Der vertikale Partikelfluss solcher Gemeinschaften ist durch ein höhes C:Si Verhältnis geprägt. Diese Artengemeinschaft muss untersucht werden, wenn man Martins Hypothese angemessen testen will (Smetacek et al. 2004).

Die produktiven Regionen des Zirkumpolarstromes sind auf Bereiche in Nähe der Landmassen beschränkt, mit der größten Hochproduktivitätsregion entlang der Antarktischen Halbinsel, deren Fahne weit in den Südwesten des Atlantischen Sektors hinausreicht. Feldbeobachtungen aus den 30er Jahren (Hart 1942) zeigten hohe Phytoplankton-Biomasse im Frühjahr, die über den Sommer abschwächte trotz vorteilhafter Wachstumsbedingungen. Basierend auf den nachfolgenden Erwägungen nehmen wir an, dass der Rückgang durch Eisenzehrung, analog der Nitratzehrung anderer Kontinentalrandmeere, hervorgerufen wird. Erstens haben alle Experimente eindeutig gezeigt, dass Eisen, wie die anderen Makronährstoffe, sowohl Wachstumsraten als auch Biomasseaufbau von Phytoplankton limitiert. Zweitens basiert die Frühjahrsblüte der Antarktischen Halbinselfahne auf im Winter akkumuliertem Eisen aus Kontakt mit den Sedimenten und der Küste, welches nur ausreicht, einen Teil der Makronährstoffe zu zehren. Eisen aus Süßwassereintrag vom Land gipfelt im Sommer und kann zu massiven Blüten führen, die jedoch auf kleinere Buchten beschränkt sind. Drittens, wenn Eisendüngung im Sommer im offenen Ozean Blüten induziert, dann kann man das Gleiche im Südwest-Atlantik erwarten. Aufgrund der höheren Saatpopulationen als Relikt der Frühjahrsblüte erwarten wir, dass die Sommerblüte höhere Biomasse schneller erreicht als ozeanische Blüten und dass die Artenzusammensetzung charakteristisch für eine kohlenstoff-versenkende Gemeinschaft sensu Smetacek et al. (2004) sein wird.

Das folgende hypothetische Szenario einer Blüte wird während des Experiments getestet: Die Blüte wird schnell heranwachsen und durch schwach verkieselte, schnell wachsende Arten mittlerer Größe, wie *Chaetoceros* und *Thalassiosira* und möglicherweise auch *Phaeocystis*, dominiert sein. Diese Arten werden Biomassen von >5 mg Chlorophyll m^{-3} (ungefähr doppelt so hoch wie in vorherigen Experimenten) aufbauen. Bakterien und das mikrobielle Nahrungsnetz werden Veränderungen durchlaufen und die planktonischen Krebstierchen werden mit erhöhter Eiablage reagieren. Teile der Blüte werden nach 4 - 6 Wochen zusammenbrechen und schnell absinkende Aggregate bilden. Die Größenordnung des Partikelniederschlags wird vom Fraßdruck der Räuber abhängen. Die Aggregate werden mehr Kohlenstoff pro Silikat versenken als während vorheriger Blüten, trotz des geringeren Ballasts, und werden den Meeresboden innerhalb von 10 Tagen nach dem Sinkereignis erreichen. Die Reaktion der Benthosgemeinschaft wird mit *in-situ* Sauerstoffprofilen und Oberflächensedimentbeprobung verfolgt. Die Stabilität des Wirbels über den Verlauf des Experiments ist eine entscheidende Voraussetzung für ein erfolgreiches Gelingen des Unternehmens. Andererseits, sollte sich der Blütenverlauf anders als oben geschildert entwickeln, liefert das Experiment trotzdem neuartige Erkenntnisse. In jedem Fall wird die Blüte Einblicke in die Biogeochemie pelagischer Ökosysteme im Allgemeinen und des Südwest Atlantiks im Speziellen erbringen. Weiterhin wird das Experiment die quantitativen Rahmenbedingungen erbringen, die zur Validierung bestehender und Identifizierung neuer Proxies notwendig sind.

Die mehrschichtige Fraßdruck-Hypothese, die von Smetacek et al. (2004) entworfen wurde, beinhaltet die Rolle des Zooplanktonfraßes bei der Gestaltung von Phytoplanktongemeinschaften auf Skalen, die sich von evolutionären bis hin zur unmittelbaren erstrecken. Eisendüngungsexperimente ermöglichen die Überprüfung dieser Hypothesen unter natürlichen Bedingungen, weil sie die Untersuchung von Interaktionen innerhalb des Ökosystems bei Anwesenheit der gesamten Bandbreite des Zooplanktons von Protozoen bis hin zum Krill

und zu Salpen erlauben. Der Einfluss der Eisendüngung auf höheren trophischen Ebenen hängt von der Region und Dauer des Experiments ab. Die Ergebnisse von EisenEx zeigten eine signifikante Zunahme der Biomasse kleinerer Copepoden und der Anzahl von Kotballen, die auf eine Nahrungsbegrenzung des ozeanischen Zooplanktons hindeuten (Henjes et al. 2007). Eine künstlich erzeugte Phytoplanktonblüte im Südwesten des Atlantiks wird wahrscheinlich Krill anlocken. Die Dezimierung einer natürlichen Blüte durch einen Krillschwarm wurde während einer früheren Polarsternfahrt beobachtet, die zu einer Veränderung der Phytoplanktongemeinschaft führte (Treguer und Jacques 1992). Wir erwarten eine ähnliche Wirkung auf einen Teil der LOHAFEX-Blüte falls Krillschwärme im Wirbel vorhanden sind. Allerdings, da unser Untersuchungsgebiet am nördlichen Rand des Hauptverbreitungsgebiets des Krills liegt, und angesichts des alarmierenden Rückgangs der Krillbestände in den letzten Jahrzehnten, ist es möglich, dass wir keinen größeren Schwärmen begegnen werden.

Die Durchführbarkeit von großräumiger Eisendüngung des Südlichen Ozeans als Maßnahme zur Sequestrierung von Kohlendioxid wird seit der Veröffentlichung von John Martins „Eisenhypothese“ und deren experimentellen Überprüfung heiß diskutiert. Einige Firmen hatten seinerzeit ihr Interesse an dieses Verfahren im Rahmen des Kyoto-Protokolls bekundet. Die wissenschaftliche Gemeinde betrachtet die Eisendüngung mit Skepsis, teilweise wegen der negativen Folgen einer Kommerzialisierung. Falls die Düngung funktioniert und ein beträchtlicher Teil der Algen aussinken würde, könnten maximal eine Milliarde Tonnen Kohlenstoff (eine Gigatonne, Gt) jährlich von der Atmosphäre entfernt werden, vorausgesetzt, dass der gesamte Südliche Ozean mit mehreren Millionen Tonnen Eisensulfat gedüngt wird (Smetacek und Naqvi 2008). Diese Menge ist nicht viel im Vergleich zur jährlichen Zunahme von ca. 3.5 Gt, aber zu viel, um ignoriert zu werden, vor allem angesichts der erheblich höheren Kosten anderer Techniken zur Entfernung vom atmosphärischen CO_2. Vor kurzem haben mehrere wissenschaftliche und internationale Organisationen kritische Stellungnahmen zur Eisendüngung veröffentlicht und dazu aufgerufen, ein besseres Verständnis zu verschaffen, bevor großräumige Maßnahmen in Erwägung gezogen werden. LOHAFEX ist der Anfang von künftiger engen Kooperation zwischen Deutschland und Indien auf diesem Sektor der Meeresforschung.

Auswahl des Untersuchungsgebietes

Das LOHAFEX Untersuchungsgebiet wurde anhand zweier Kriterien ausgewählt: Erstens ist es im Krillverbreitungsgebiet angesiedelt und hat eine etwas andere Planktonzusammensetzung zum Rest des Südpolarmeeres, wo vorherige Experimente durchgeführt wurden. Die Auswirkungen der Düngung werden sich daher wahrscheinlich unterscheiden. Zweitens ist die Region durch stabile Wirbel gekennzeichnet, die für Monate ortstreu bleiben. Wirbel sind langsam rotierende, kreisförmige Wassermassen von 50 – 100 km Durchmesser, die bis zum Meeresboden in 4 km Tiefe reichen und von einer schnell fließenden Schleife des Frontenstroms umschlossen sind. Das Wirbelzentrum stellt daher den idealen „Behälter“ für das Düngungsexperiment dar, weil es ermöglicht die sinkenden Partikel in der tiefen Wassersäule zu verfolgen. Wirbel können über ihre gesamte Lebensspanne durch Satellitenaltimeterbilder identifiziert und verfolgt werden, wo sie als stationäre, annähernd kreisförmige Erhebungen oder Senken erscheinen. LOHAFEX wird im best-geeigneten Wirbel entlang der Polarfront platziert werden, etwa 300 km nördlich der Insel Südgeorgien.

Durchführung des Experiments

Nach der Ankunft im ausgesuchten Wirbel werden Oberflächen- sowie Tiefenbojen ausgesetzt, um das Zentrum des Wirbels festzustellen. Bei den Tiefenbojen handelt es sich um zu

Sinkstofffallen umgewandelte Argosbojen, die in verschiedenen Wassertiefen treiben werden, bevor sie wieder auftauchen. Während der 5 Tage, die hierfür gebraucht werden, wird der Wirbelkern mit dem undulierenden Instrumentenpaket Scanfish sowie mit Zooplanktonakustik vermessen. Danach wird eine lange Station (s. unten) im Zentrum durchgeführt, um die Situation vor der Düngung zu erfassen. Anschließend wird vom in konzentrischen Kreisen fahrenden Schiff eine Lösung von angesäuerten Eisensulfat (20 Tonnen) über eine Fläche von 300 km^2 ausgebracht. Der Eisenlösung wird, wie in früheren Experimenten, eine geringe Menge Schwefelhexafluorid (SF_6) beigesetzt, das in sehr niedriger Konzentration noch nachweisbar ist, um den gedüngten Fleck zu markieren. Der Fleck wird sich durch horizontale Vermischung ausbreiten. Gegebenenfalls wird eine zweite Düngung nach ca. 2 Wochen im Zentrum des Flecks vorgenommen. 3 - 4 Wochen nach der ersten Düngung wird eine Fläche von 150 km^2 erneut mit SF_6 (diesmal ohne Eisen) markiert, um Verluste durch Ausgasung (SF_6 ist ein Gas) zu kompensieren. Weil LOHAFEX 10 Tage länger dauern wird als EIFEX wird etwa die doppelte Fläche gedüngt, um die Verdünnung durch Vermischung auszugleichen. Wir erwarten, dass gegen Ende des Experiments die Blüte von der Oberfläche verschwunden sein wird.

Lange Stationen werden regelmäßig im Zentrum des Flecks und im ungedüngten Wasser außerhalb durchgeführt. Zwischendurch wird der Fleck mit Scanfish und Krillakustik mehrmals während des Experiments vermessen. Die 5 frei treibenden Sinkstofffallen werden ständig überlappend im Einsatz sein. Die *in-situ* Sauerstoffzehrung an der Sedimentoberfläche wird in regelmäßigen Intervallen gemessen sowie Proben der Grenzschicht entnommen. Die Messungen werden durch Deckinkubationen zur Ermittlung von Wachtums- und Remineralisierungsraten verschiedener Planktongruppen ergänzt.

Drei Stationstypen werden durchgeführt:
Lange Stationen: 3 bis 4 CTD-Durchläufe (wenn Wasser für Experimente benötigt wird) mit Go-Flo-Flaschen (an einem Kevlardraht befestigt) und ein Multinetz sowie Bongo- und RMT-Netze vorzugsweise bei Nacht. Oberflächensedimente werden mit einem Multicorer beprobt.
Mittlere Stationen: 2 bis 3 CTD-Durchläufe mit Go-Flo und Multinetz.
Kurze Stationen: Ein kurzer CTD-Durchlauf.

Der Fahrtabschnitt ist ein Beitrag zu POGO, der Partnership for Observation of the Global Oceans, http://www.ocean-partners.org/aboutPOGO.html.

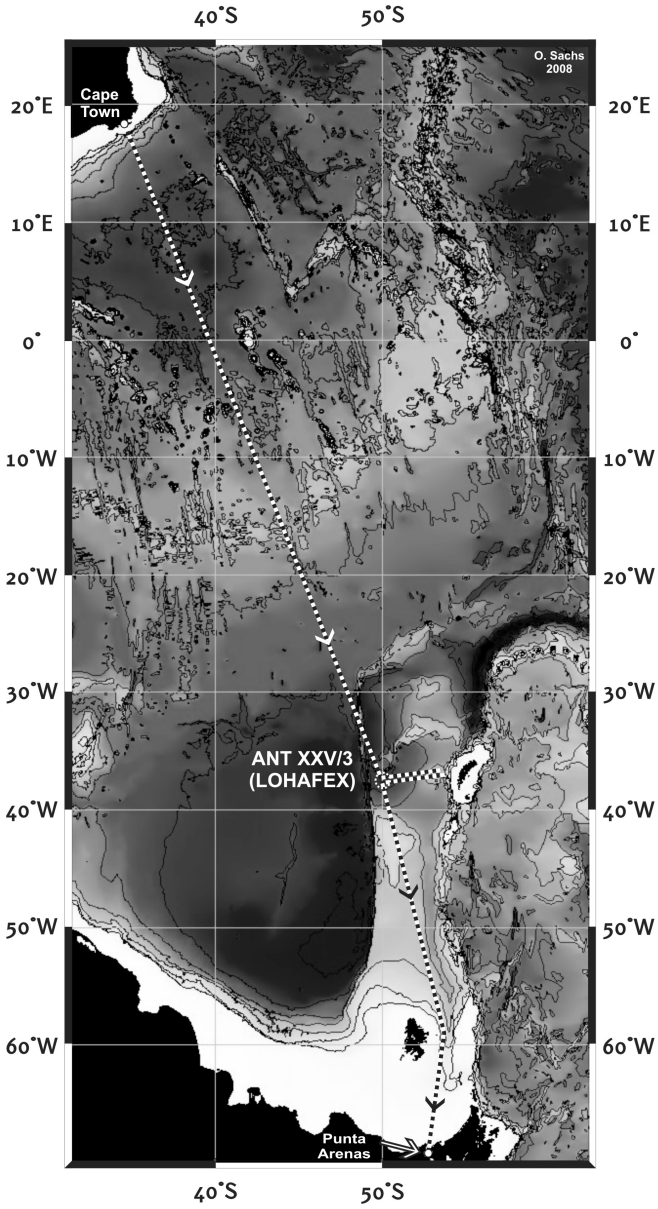

Abb. 1: Fahrtroute während ANT-XXV/3
Fig. 1: Cruise track during ANT-XXV/3

ITINERARY AND SUMMARY

7 January 2009 - 17 March 2009, Cape Town, S. Africa to Punta Arenas, Chile

The cruise will be jointly carried out by the National Institute of Oceanography (NIO) Goa of the Council of Scientific and Industrial Research, India, and the Alfred Wegener Institute for Polar and Marine Research, member of the Helmholtz Association of German Research Centres.

In-situ iron fertilization experiments have emerged in the last 10 years as a reliable method for testing biogeochemical and ecological hypotheses not accessible by other means. The interdisciplinary experiment LOHAFEX (Loha is Hindi for iron, Fertilization EXperiment) will test a range of independent yet interconnected hypotheses of which some are mentioned here: a) The iron hypothesis of John Martin with its geo-engineering corollary. b) Plankton species composition in an experimental bloom induced in the more productive southwest Atlantic Sector will differ from the plankton in blooms stimulated by previous experiments carried out in low productivity waters. This will have a strong effect on sinking of the bloom and on the ratio of carbon: silica of the sinking flux. c) Crustacean zooplankton, including krill, is food limited, with its perspectives for explaining the current decline in krill stocks. d) Iron-fertilized blooms lead to production of noxious gases with harmful effects on the atmosphere. These, and other hypotheses dealt with in the subchapters of this booklet, address fundamental questions of integrated earth system science that are relevant to our understanding of the role of the marine biosphere in past and ongoing climate change.

All Southern Ocean experiments (SOIREE, EisenEx, SOFEX 1 and 2, EIFEX) were carried out in the land-remote ACC with the aim of testing the iron hypothesis of Martin (1990): Higher levels of dust during glacials provided enough iron to enhance productivity and carbon drawdown in the ACC rendering this region a major glacial CO_2 sink. This hypothesis is currently under intense debate (Anderson et al. 2002). Several sedimentary geochemical palaeoproxies indicate lower levels of glacial productivity south of the Polar Front although ecological proxies – abundant spores of coastal diatoms in the land-remote glacial ACC - indicate the opposite. New and more reliable biological proxies and improved validation of the current ones are necessary to break the impasse between ecologists and geochemists and the experiment we propose will provide such information.

The first condition (build-up of a phytoplankton bloom) was met in all five experiments. Most of the species dominating these blooms were typical ACC species characterised by thick frustules (low C:Si ratios) and open ocean life cycles. This species assemblage is very different to those typical of the land-near, productive regions of the Southern Ocean which tend to have smaller, weakly silicified cells that form resting spores under unfavourable conditions and sink out en masse. Vertical flux from this assemblage will have high C:Si ratios. Smetacek et al. (2004) argue that it is this assemblage that needs to be studied if Martin´s hypothesis is to be adequately tested.

The productive regions of the ACC are restricted to the vicinity of landmasses, with the largest high productive region located along the Peninsula and extending as a plume along the south-western Atlantic Sector. Field observations dating back to Hart (1942) indicate high phytoplankton biomass in the spring which tends to fade out in the course of the summer despite apparent favourable conditions for growth. We hypothesize, based on the following considerations, that the decline is caused by iron exhaustion analogous to nitrate exhaustion in other continental margins. Firstly, the experiments have all demonstrated unequivocally

that iron, like the other macronutrients, limits both growth rate and biomass build-up of phytoplankton. Secondly, the spring bloom in the Antarctic Peninsula Plume (APP) is based on winter-accumulated iron emanating from contact with the sediments and coasts which will suffice to enable uptake of only a fraction of the macronutrients. Iron from land run-off peaks in the summer can result in intense blooms which, however, are restricted to the coastal embayments although their extent due to seaward advection needs investigation. Thirdly, if fertilization in the summer induces blooms in HNLC waters then there is good reason to expect the same in the SW Atlantic. Because of the larger seeding stock left behind by the spring bloom, we expect that this summer bloom will attain higher biomass more rapidly than the open ocean blooms and that the species composition will be characteristic of the carbon-sinking community sensu Smetacek et al. (2004).

The following hypothetical scenario of the bloom will be tested in this experiment: The bloom will grow rapidly and be dominated by weakly silicified, fast-growing species of medium-sized, spore-forming diatoms such as Chaetoceros and Thalassiosira, and probably also Phaeocystis. They will build-up biomass to levels > 5 mg chlorophyll m^{-3} (about double the values in previous experiments). Bacteria and the microbial food web will undergo changes and crustacean zooplankton will respond by laying eggs. Parts of the bloom will crash forming aggregates which will sink out rapidly after 4 - 6 weeks of growth. The magnitude of fall-out will depend on the grazing pressure (see below). The aggregates will sink more carbon per silicon than previous blooms, despite the lower ballast, and will reach the deep-sea floor within 10 days of initiation of mass sinking. Sinking aggregates will be monitored in the deep water column with an *in-situ* profiling camera system, a fluorometer and a transmissometer. They will be collected with neutrally buoyant sediment traps in addition to filtration of large volumes of water. The response of the benthos will be monitored by *in-situ* oxygen profiles and surface sediment sampling. Stability of the eddy over the time course of the experiment is a crucial prerequisite for successful monitoring of these processes. On the other hand, if the course of events in the bloom runs differently, the experiment will yield novel information. In either case the bloom will provide insights into the biogeochemistry of pelagic ecosystems in general and the SW Atlantic in particular and provide the quantitative framework necessary to validate current proxies of deep-ocean carbon sequestration and identify new ones.

The multi-level grazing hypothesis, reviewed in detail by Smetacek *et al*. (2004) comprises the role of grazing in shaping the structure of phytoplankton assemblages at scales ranging from evolutionary (ultimate levels) to that of specific water mass and season (proximate levels). *In-situ* iron fertilization experiments represent a powerful new methodology to test this series of hypotheses because they enable the study of interactions within ecosystems with their full complement of grazers and pathogens. The effect of iron fertilization on higher trophic levels will depend on the locality and duration of the experiment. The results of EisenEx indicated a significant increase within 3 weeks in biomass of small copepods and the numbers of faecal pellets relative to outside waters indicating that the open ocean zooplankton were food limited (Henjes et al. 2007). An artificially induced phytoplankton bloom in the SW Atlantic is likely to attract krill. Decimation of a natural phytoplankton bloom by a roving krill swarm was observed during the European Polarstern Study (EPOS) in the Weddell-Scotia Confluence in 1988/89 which resulted in a shift in the species composition of the phytoplankton (Treguer and Jacques 1992). We anticipate similar responses of krill swarms in the area on the induced bloom. However, since the experimental site is located at the northern end of the region of high krill biomass, it is possible that none are encountered.

The feasibility of large-scale ocean iron fertilization as a means to sequester atmospheric CO_2 has been hotly debated ever since the "Iron Hypothesis", and ocean fertilization experiments to test it, was proposed by John Martin in 1990. Several companies announced their interest in ocean fertilization in the framework of the carbon credit market specified in the Kyoto Protocol. The scientific community has tended to view fertilization with scepticism, partly because of the negative side effects of uncontrolled commercialization. If fertilization works and a significant proportion of the phytoplankton bloom sinks out, then a maximum of 1 billion tonnes (1 Gigatonne or Gt) of carbon could be annually sequestered from the atmosphere by fertilizing the entire Southern Ocean with a few million tonnes of iron sulphate powder (Smetacek and Naqvi 2008). This is not much compared with the annual increase of CO_2 of around 3.5 Gt but it is again too much to ignore, particularly in view of the enormous costs associated with other techniques of CO_2 removal. Recently, various scientific and international organisations have issued critical statements on ocean iron fertilization and called for better understanding before embarking on large-scale operations. LOHAFEX is the beginning of close cooperation between India and Germany in the field of ocean research.

Site selection
The LOHAFEX experimental site has been selected on the basis of two considerations. It is located within the krill habitat, albeit at its northern boundary, and has a somewhat different plankton composition to the rest of the Southern Ocean where earlier experiments were conducted. The effects of fertilization are likely to differ accordingly. Second, it is a region where stable eddies form and are maintained for several months. Eddies are slowly rotating, circular water masses of 50 – 100 km diameter that extend to the sea floor at 4 km depth and are enclosed by a loop of swiftly flowing, frontal-jet currents. The closed eddy core hence provides an ideal container to carry out fertilization experiments because it is possible to track sinking particles through the underlying deep water column. Eddies can be identified and followed through their life time in satellite images of sea-surface height where they appear as stationary, roughly circular bulges or depressions. LOHAFEX will be placed in the most suitable eddy along the Antarctic Polar Front, about 300 km north of the island of South Georgia.

Procedure of the experiment
On arrival in the eddy selected from daily satellite altimeter images, the location of its closed core will be verified from ship-based measurements of current speeds and direction as well as from the tracks of surface and deep buoys deployed for the purpose. The surface buoys are fairly small but the deep buoys are autonomous, neutrally buoyant sediment traps that sink to a pre-programmed depth and surface after a few days. Confirming the location of the eddy centre will take about 5 days. After locating the centre and carrying out a long station (see below) to obtain baseline measurements of the region to be fertilized, the ship will steam around a drifting buoy in concentric circles 2 km apart while releasing a solution of iron sulphate in the ship's propeller wash. The iron solution will be mixed with the inert tracer sulphur hexafluoride (SF_6), which can be accurately measured in trace quantities, in order to mark the fertilized water. A circular patch of 20 km diameter (300 km^2) will be fertilized with 20 tonnes of iron sulphate powder dissolved in weakly acidified sea water. The patch will spread to well over 1,000 square kilometres during the experiment.

LOHAFEX will fertilize an area about double that of EIFEX. This will reduce the dilution effect due to admixture of water from outside the patch. Iron fertilization of the patch centre will possibly be carried out once again during the first half of the cruise depending on patch spread and bloom development. After about 3 weeks the centre of the patch (150 km^2) will

again be marked with SF_6 (but not iron) to compensate for loss to the atmosphere (SF_6 is a gas).

On several occasions during the cruise, the patch and the unfertilized water surrounding it will be surveyed with the towed undulating instrument package Scanfish and with zooplankton acoustics to estimate the spatial patterns of phytoplankton and zooplankton stocks respectively. The spatial mapping will be followed by grids of Medium and Short Stations (see below) to calibrate the Scanfish measurements and assess small-scale heterogeneity in nutrients, suspended particulates and species composition of plankton.

Research accent will be focussed on Long Stations, which will be carried out in the zone of highest biomass in the centre of the patch, marked with a drifting buoy, to minimise the dilution effect. These central stations with regular casts to the bottom will take about 12 hrs to conduct. Reproducibility of the various casts will be ensured by keeping the ship close to the drifting buoy. Long stations will also be carried out outside the patch. Neutrally buoyant sediment traps (that have to be retrieved when they surface) will be deployed routinely throughout the experiment at intervals of about 5 days. A bottom-lander will also be deployed and retrieved regularly to measure oxygen profiles in surface sediments and infer the organic carbon flux to the sea floor. *In-situ* observations will be furthermore supplemented by deck-board incubation experiments to study grazing, faecal pellet production and nutrient cycling by different zooplankton species and viability of copepod eggs.

Three types of stations will be carried out:
Long station: 3 – 4 CTD casts (when experimental water is needed) with Go-Flo bottles (mounted on Kevlar wire) and Multinet as well as Bongo and RMT nets, the latter preferably at night. Surface sediments will be sampled with a multicorer.
Medium station: 2 – 3 CTD casts with Go-Flo + Multinet.
Short station: 1 CTD dip.

The various approaches and measurements conducted during LOHAFEX are detailed in the following subchapters.

The experiment will depend on behaviour of the patch. We should expect rough weather about every 5 days with relatively calm spells in-between, although longer periods of favourable weather are also possible. There will be little sunshine but not much rain and outside temperatures will be ~ 4°C.

This leg is a contribution to POGO, der Partnership for Observation of the Global Oceans, http://www.ocean-partners.org/aboutPOGO.html.

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2. PHYSICAL OCEANOGRAPHY/HYDROGRAPHY

V.S.N. Murthy, P.V. Narvekar, A. Almeida, A. Methar, A. Kankonbar (NIO),
M. Ribera (SZN) and D. Wolf-Gladrow (AWI)

Objectives

The main task of the physical oceanography group will be to collect data necessary for defining the physical environment of the experimental site. It will also play the central role in experimental site selection and in tracking the spreading and movement of the fertilized patch as well as the flux of particles emanating from it through the deep water column.

Work at sea

The various planned activities of the group are summarized below:

2.1 IDENTIFICATION OF A SUITABLE EXPERIMENTAL SITE

Selection of an appropriate experimental site will, of course, be paramount for success of the LOHAFEX experiment. Initial selection is being done on the basis of satellite altimeter (sea surface height) data. As in the case of EISENEX and EIFEX, LOHAFEX will also fertilize a stationary, cold-core eddy. An important criterion for selection of such an eddy will be its stability. Examination of altimeter images for the past several years has enabled us to identify the best candidate for the experiment. This feature, occurring in the Polar Front region north of South Georgia, recurs every year and is fairly stable and stationary unlike eddies in the region to the south of the island which move very fast with the Antarctic Circumpolar Current. Such a priori information needs to be verified by *in-situ* measurements, which will be made during the first part of the cruise. For this purpose, we plan to (a) deploy drifting buoys with GPS senders tethered to subsurface drogues and monitor their movement, (b) deploy neutrally buoyant sediment traps attached to ARGOS floats primed for a range of depths that will monitor vertical coherence of the water column (c) undertake towed undulating scan fish surveys across the eddy, and (d) use the vessel-mounted acoustic Doppler current profiler (ADCP) to get a good idea of the current field. We hope that with these different approaches we will be able to identify the centre of the eddy with reasonable accuracy.

2.2 TRACKING THE FERTILIZED PATCH

Constant tracking of the fertilized patch is essential for fertilization experiments. During LOHAFEX, besides satellite data, we plan to achieve it by monitoring changes in chemical and biological parameters – SF_6, pCO_2, chlorophyll, phytoplankton photosynthetic efficiency (Fv/Fm) measured by the FRRF (Fast Repetition Rate Fluorometer) – and also through the deployment of surface buoys drogued at mid depth of the mixed layer and tracked by radio

and satellite telemetry transmitting its GPS position. One of these buoys will be at the centre of the eddy to begin with and will be used for the relative navigation of the ship during iron release along a spiral path around the buoy. In order to monitor the dynamics of the patch and to determine the eddy's velocity and density field Scanfish surveys will be carried out at regular intervals and these data will be used along with the ADCP data. Such surveys along with chemical measurements will also allow us to determine the degree of mixing with surrounding waters and ascertain the integrity of the patch (if, for example, a part of the stimulated bloom is detrained from the eddy's interior through lateral shear or is subducted).

2.3 MEASUREMENTS DURING THE EXPERIMENT

The three-dimensional velocity field will be continuously studied with the vessel-mounted ADCP and the drift trajectories of surface buoys and neutrally buoyant sediment traps "parked" in subsurface and mesopelagic depths. Repeated runs by the towed Scanfish equipped with suitable sensors will provide sections of physical variables (temperature, salinity, density, transmittance, fluorescence, etc.). In addition, standard CTD casts will be carried out 1-2 times a day to a depth of at least 1,000 m and at least once every 2 - 3 days down to the maximum depth. Most of these stations will be located close to the centre of the eddy/fertilized patch, but less frequently we will also take samples from outside the fertilized patch for reference purposes. Measurements of salinity will be carried out on a few water samples collected from each cast for calibration. Profiles of the state variables will inter alia be used for calculating vertical stratification. The ship's CTD will also support auxiliary instruments such as a fluorometer for measuring the chlorophyll concentration and a transmissometer for measuring light transmission. The ship's CTD will be integrated with a rosette frame holding 24 12-litre bottles, for various biological and chemical measurements.

3. TRACING THE FERTILIZED PATCH WITH SF_6

V. Desai and S.W.A. Naqvi (NIO)

Objectives and work at sea

Like most previous Ocean Iron Fertilization (OIF) experiments LOHAFEX will also make use of SF_6 as a conservative tracer for marking the fertilized patch and to get a measure of the degree of dilution of the originally fertilized patch of water. The SF_6 saturated seawater from a saturation system kindly provided by Dr. Phil Nightingale (PML, Plymouth, UK) will be mixed with the $FeSO_4$ solution prior to release. The SF_6 concentration in the surface water will be regularly monitored using a GC-ECD system on board ship. Given the longer duration of LOHAFEX compared to all previous OIF experiments, marking the patch with SF_6 may have to be repeated during the course of the experiment.

4. MACRO- NUTRIENTS

A.K. Pratihary, Maya Muthirenthy, and H. Naik (NIO)

Objectives

Cycling of major nutrients (nitrogen, phosphorus and silicon) will be studied in detail during the LOHAFEX expedition. Iron fertilization is expected to promote rapid utilization of these nutrients in the surface water as phytoplankton biomass builds-up, and so their

concentrations and forms will be monitored throughout the cruise both within and outside the fertilized patch. All water samples collected during the expedition will be run for inorganic nutrients, whereas organic nutrients will be measured on a more selective basis. These data will help understand production and recycling of organic matter in the water column as a result of iron fertilization.

Work at sea

Samples for nutrient analyses will be taken from the ship's flow-through system, from all CTD casts and from experiments carried out on board. We will be carrying two auto-analyzers with us for measuring inorganic nutrients (nitrate, nitrite, ammonium, phosphate and silicate) as well as organic fractions (urea and dissolved organic carbon, nitrogen and phosphorus through measurements of total nitrogen and total phosphorus) on board ship following standard procedures. Samples for total nitrogen and total phosphorus will also be collected and preserved for later analysis in the home laboratory (NIO, Goa).

5. CO_2-SYSTEM

G. Narvenkar, Maya Muthirenthy, and S.W.A. Naqvi (NIO)

Objectives

Previous iron fertilization experiments have revealed that the addition of iron to surface waters of the HNLC regions, including the Southern Ocean, results in drawdown of the surface pCO_2 levels thereby leading to uptake of CO_2 from the atmosphere. However, uncertainty remains as to what is the ultimate fate of the carbon fixed in the surface layer (i.e. whether it is largely recycled in the surface layer or a significant fraction of it is vertically exported out of the surface layer). Most of the OIF experiments have, however, been carried out for much shorter duration than the planned period of LOHAFEX, and so monitoring of various components of the CO_2 system during LOHAFEX is expected to improve our understanding of the fate of carbon produced due to iron enrichment.

Work at sea

The work plan includes continuous underway pCO_2 measurements as well as discrete analysis of samples collected with the CTD rosette sampler. CO_2 related parameters to be analyzed for the latter component are dissolved inorganic carbon (DIC) by coulometry, alkalinity by acid titration, and pH by the photometric method.

6. DISSOLVED GASES OTHER THAN CO_2

H. Naik, R. Roy, B. Thorat, K.B. Sujith, G. Narvenkar, H.S. Dalvi and S.W.A. Naqvi (NIO)

Objectives

Of the biogenic gases of interest, dissolved oxygen will be routinely analyzed in all discrete samples collected with the CTD using an automated titration system. Nitrous oxide (N_2O) analysis will also be carried out at most stations using a GC-ECD system. Distribution of this gas is of particular interest because of widespread concerns that degradation of organic matter produced as a result of large-scale OIF could result in a substantial decrease in subsurface oxygen levels, thereby promoting the production of this powerful greenhouse gas

and offsetting in part the gains due to CO_2 sequestration. Of the OIFs conducted in the Southern Ocean N_2O was measured during SOIREE and EIFEX. An increase in N_2O was recorded in the thermocline during SOIREE, but not during EIFEX in spite of its longer duration. Additional measurements are therefore needed to reconcile these differences. Another biogenic gas of climatic significance is dimethyl sulphide (DMS). Previous OIF experiments have been found to typically increase concentrations of DMS and its precursor DMSP (dimethylsulphoniopropionate) by a factor of 3. Increases of this magnitude, if occurring globally, could lead to atmospheric cooling by 1 - 2° C, and so its production has potentially beneficial effects for the environment.

Work at sea

Measurements of DMS, DMSP and DMSO (dimethylsulphoxide) will be made on a regular basis on LOHAFEX using a GC-FPD (explain abbreviation) system. The concentration of methane (CH_4) will also be measured using GC-FID. This will be particularly important at the later stage of the experiment when degradation of the organic matter is expected to occur. Finally, volatile halogenated organic compounds (VHOCs) such as chloroform, carbon tetrachloride and 1-iodopropanol will also be measured during the cruise to investigate the effect of OIF on their production by phytoplankton.

7. NATURAL ISOTOPE ABUNDANCE

A. Sarkar and Maya Muthirenthy (NIO)

Objectives

The Southern Ocean has a large pool of non-utilized nitrate because of iron limitation of primary productivity. Nitrate uptake following iron enrichment is expected to cause a change in the isotopic composition of nitrate (enrichment of ^{15}N) that should be easily detectable during the course of the experiment. This effect has not been looked for in previous OIF studies.

Work at sea

During LOHAFEX we intend to monitor not only the isotopic composition of nitrate in surface waters, but also the composition of suspended and sinking particulate material to study the changes arising from iron enrichment which will provide insights into carbon cycling. Surface samples will be collected and stored in acidified condition for analysis of the natural isotope abundance of nitrate.

8. IRON CYCLING

L. Laglera, R. Martinez (CSIC–IMEDEA), H. Naik (NIO) and A. Bansiwal (NEERI)

8.1 TRACE METALS AND FE CONCENTRATION, PARTITION AND SPECIATION. THE ROLE OF KRILL IN METAL CYCLING

Luis M. Laglera and Regino Martinez (CSIC–IMEDEA)
Collaborators not on board: Antonio Tovar-Sánchez and Carlos M. Duarte (CSIC–IMEDEA), Susana Agustí (IMEDEA)

Objectives

The contribution of the IMEDEA group will be the determination of changes in the concentration of trace metals and the partition and speciation of iron. The analyses will be performed in seawater samples from the fertilized patch and in samples obtained from the equilibration of grazers (krill, salps and copepods) with seawater under controlled experimental conditions.

Work at sea

For this purpose a voltameter supplied by Hema Naik from NIO will be used for onboard analysis of iron in seawater by CCSV (catalytic cathodic stripping voltammetry). Samples will be partitioned by filters of progressively smaller pore size (0.22 and 0.05 µm) for the analysis of dissolved, colloidal and truly dissolved iron concentrations. The organic speciation of iron will be determined by iron titrations of samples and detection of the labile part by CCSV. This will be carried out partially on board and partially after the cruise on frozen samples. Ag, Cd, Co, Cu, Fe, Ni, Mn, Mo, Pb and Zn will be acidified (pH<1.5) on board and determined after cruise in the laboratories of the IMEDEA by ICP-MS (Inductively Coupled Plasma mass spectrometer).

8.2 SOLUBILITY AND SPECIATION OF IRON IN AN HNLC AREA (STUDY AREA NOT TRULY HNLC CHARACTER) AFTER FERTILIZATION

Objectives

Iron is extremely insoluble at natural seawater conditions and it is necessary to check the effectiveness of the iron fertilization in increasing the concentration of non-particulate iron in the experimental area. Samples from the water column will be collected by means of a trace metal clean sampling system (NIO and IMEDEA) to follow the dispersion and solubility of the excess iron added during the fertilization.

Work at sea

The organic speciation will be analyzed to monitor changes in solubility caused by the possible release of ligands by the local biota. Ligand concentrations and the stability of their complexes will be obtained from iron titrations. The determination of Fe(II) will be attempted by the voltammetric method although this technique could be not sensitive enough if iron concentrations remain at subnanomolar levels.

8.3 QUANTIFICATION OF TRACE METALS AND KINETICS AND SPECIATION OF THE IRON PRESENT IN THE EXCRETION PRODUCTS OF KRILL, SALPS AND COPEPODS

Objectives

Antarctic krill *(Euphausia superba)* has been widely studied because of its important role in the dynamics of the Antarctic food web. Most of those studies have focussed on the life cycle and ecology of this pelagic organism. They are long-lived organisms (> 9 years) which migrate seasonally, and are widely distributed within the entire water column. Krill also ingest a broad range of materials (from nano- and micro-phytoplankton to detritus), and because of their high excretion rates, they provide a major source of regenerated nitrogen and iron (Tovar-Sanchez et al., 2007). Furthermore, because of their schooling behaviour (mega swarms reaching several kilometres in length) krill can also modify the chemical composition of the surrounding environment. These characteristics suggest that krill may play an important role in the biogeochemical cycling of various chemical constituents in the Southern Ocean, such as trace metals.

Work at sea

Three or four randomly selected individuals will be transferred using a plastic spoon, into each of 6 acid-washed 2-l opaque polycarbonate experimental bottles. Each experimental bottle will be filled with filtered (< 0.22 µm) surface seawater. Experimental bottles, including control bottles without krill, will be incubated in the dark at surface water ambient temperature ± 4 ºC. In a class-100 HEPA hood, unfiltered and filtered water samples from each experimental bottle will be collected at 2-h intervals, from 1 h up to 6 h from the onset of each experiment. Seawater from each experiment will be acidified with sub-boiled, quartz-distilled HCl (Q-HCl) to a pH less than 1.5 and stored for at least 1 month prior to analysis. We will monitor changes in the partition, redox speciation (the voltameter method should be suitable for the expected concentration range) and organic speciation of Fe. The study will be repeated with other local zooplankton (i.e. Salps and copepods).

8.4 INCUBATION EXPERIMENTS TO ESTIMATE THE IMPACT OF KRILL EXCRETION PRODUCTS ON PRIMARY PRODUCTION

The effect of krill excretion products on the metabolic balance and net production of planktonic communities has been examined in the ICEPOS project (Duarte, Agusti, Arístegui and co-workers), but the evidence gathered at that cruise needs to be strengthened with additional experiments. We propose to run a series of experiments on LOHAFEX, which will represent a joint venture with parallel experiments run on board RV *Hesperides* under the ATOS cruise (Duarte, Agustí, Tovar-Sánchez, Arrieta, and co-workers), to examine the impact of krill excretion products on planktonic communities.

Work at sea

We will carry out experimental additions of krill metabolites to test the effects of krill excretion products on phytoplankton abundance and production. These experiments will follow a unified design, after the experience of experiments run at the ICEPOS 2005 cruise.

Susana Agustí provides a detailed protocol, so we can conduct coordinated parallel experiments. At least two such experiments will be conducted at each of LOHAFEX and ATOS, delivering a total of four experiments in addition to the two experiments already available from the ICEPOS 2005 cruise.

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9. NATURAL RADIONUCLIDES

9.1 ^{234}TH AS TRACER OF EXPORT PRODUCTION OF POC

R. Rengarajan (PRL), Melena Soares (NIO) and Michiel Rutgers van der Loeff (AWI)

Objectives

An essential parameter of the progress of the induced plankton bloom is the rate at which particulate matter, and especially POC is exported from the surface mixed layer to greater depths. Apart from the measurements by carbon budgets and sediment traps, we wish to quantify this flux by the measurement of the depletion of ^{234}Th in the surface waters. Repeated measurement of the integrated ^{234}Th depletion will allow the calculation of the downward flux of particulate ^{234}Th out of the surface water. In order to convert this flux to a carbon flux we will determine the POC/^{234}Th ratio of large suspended and of sinking particles.

Work at sea

^{234}Th and POC samples will be collected and processed during this cruise. Ideally about one depth profile of ^{234}Th will be sampled per day, thus producing a time series inside and outside the fertilized patch. An aliquot of 4-L of seawater will be collected at 0, 25, 50, 75, 100, 150 and 200 m depth. At selected stations, large suspended particles will be collected at several depths down to the sea floor by deployment of in-situ pumps using size-fractionated filtration. Nitex screens of various mesh size (10 and 50µ) with particulate matter are ultrasonicated and the suspension is filtered through a 25 mm precombusted QMA filter. Subsamples from the NB Sediment Traps will also be filtered over 25 mm precombusted QMA filters for ^{234}Th and POC analysis. The particulate and the total ^{234}Th samples will be counted onboard using RISO beta counters mounted in the geochemistry container.

In parallel, ^{234}Th will be measured with an automated system. This will allow the measurement in surface water at a temporal resolution of up to once every 2 hours.

9.2 RADIUM ISOTOPES

R. Rengarajan (PRL) and Michiel Rutgers van der Loeff (AWI)

Objectives

Four radium isotopes are supplied to the ocean by contact with the continent or (deep-sea)-sediments: ^{223}Ra, (half-life 11.4 d); ^{224}Ra (3.7 d), ^{226}Ra (1620 y) and ^{228}Ra (5.8 y). The distribution of these isotopes in seawater has been shown to be most helpful to evaluate shelf-basin exchange and water residence times. They can therefore help us to determine whether the water masses have been influenced by natural iron enrichments by contact with shelf sediments in preceding months (^{228}Ra), weeks (^{223}Ra) or days (^{224}Ra). This study will be concentrated on our visit to the shelf of South Georgia.

Work at sea

Large volume surface water samples will be collected for radium isotopes using the *Polarstern's* seawater intake, filtered through a 1 µm cartridge filter. For $^{228}Ra/^{226}Ra$, 1-2 m^3 of filtrate is passed over MnO_2-coated polypropylene cartridges. The isotope ratio is quantified in the home laboratory by Soxhlet leaching and subsequent gamma spectroscopy; ^{226}Ra is quantified by occasional co-precipitation of Radium on $BaSO_4$ from 20-l samples. ^{226}Ra in other samples will be interpolated from a relationship we expect to derive between ^{226}Ra and dissolved silicate.

For short-lived radium isotopes, the filtrate is transferred to 250 l tanks. Each sample is pumped at ca 1 L/min using a peristaltic pump through MnO_2-impregnated acrylic fibre to scavenge radium isotopes. Fibres are partly dried using compressed air, and short-lived ^{223}Ra and ^{224}Ra measured at-sea using RaDeCC detectors. Longer-lived ^{228}Ra will be measured on the fibres by gamma counting $^{228}Ra/^{226}Ra$ ratio in the shore-based lab and/or by recounting the ^{224}Ra activity after ingrowth of ^{228}Th. For occasional deeper (i.e. below surface) sampling, large-volume samples require multiple (2-3) CTD casts and filling barrels or, if time allows, the deployment of in-situ pumps.

10. PRIMARY PRODUCTION, NEW AND REGENERATED PRODUCTION, SIZE-FRACTIONATED PRODUCTION

Mangesh Gauns (NIO), Christine Klaas (AWI), Gauri Mahadik, Sunita Mochemadkar, Shrikant Patil and Amit Sarkar (NIO)

Objectives

The rate of carbon fixation by autotrophs will be measured by inoculating radioactive $NaHCO_3$ into 250 ml seawater in polycarbonate bottles for tracing the uptake of radioactive ^{14}C from the dissolved inorganic to the particulate form. The method involves incubation of samples at different depths from the euphotic zone, which include a set of five bottles (3 light +2 dark) at each depth from a vertical profile of 8 - 10 depths for each station. Deck board incubators (acrylic) will also be used using neutral density screens to mimic *in-situ* light conditions (100 %, 50 %, 10 % ad 1 %). Incubator temperature will be maintained by a continuous flow of surface seawater. Size fractionated primary productivity of various size classes [pico / nano / micro) will also be measured simultaneously along with the total primary productivity (>0.7micron; GF/F filters will be used). Samples will be later analyzed using a scintillation counter at NIO/AWI.

Work at sea

The study of nitrogen cycling in the surface oceans provides information to better understand primary production and its export flux. During the LOHAFEX expedition in addition to carbon fixation (primary production), nitrate uptake (new production), urea and ammonia uptake (regenerated production) will also be studied in detail using ^{15}N-labelled tracers. Samples will be collected from selected stations inside and outside the fertilized patch within the photic zone before sunrise. Addition of labelled tracers ($^{15}N\text{-}NO_3^-$, $^{15}N\text{-}NH_4^+$ and ^{15}N-Urea) will be done in order to obtain 10 - 20 % enrichment of the ambient concentration based on real-time measurements. The nutrient amended samples will be incubated just after the tracer addition before dawn in deck incubators. Neutral density light filters of different dimensions will be used to cover the bottle in order to control the light penetration and the incubation

temperature will be maintained using continuous sea water flow through the incubators. After 24 hr (dawn to dawn) incubation final concentration of NO_3^-, NH_4^+ and urea will be measured and the rest of the samples will be filtered using pre-combusted selective filter papers at low vacuum pressure. The filter paper will be dried in the oven and stored dry. Isotopic measurements will be done in the shore laboratory (NIO, Goa).

11. PHYTOPLAKTON PIGMENTS, DILUTION EXPERIMENTS

R. Roy and M. Gauns (NIO)

Objectives

To overcome some of the inadequacies of microscopy, high performance liquid chromatography (HPLC) pigment method has been used in recent years to obtain accurate chlorophyll *a* data as well as detailed information (for sure not as detailed as microscopy) about the composition of phytoplankton communities. This method is based on the premise that different algal classes have specific signature, or marker pigments. For example, fucoxanthin, zeaxanthin, and chlorophyll *b* have been selected as taxonomical pigments for bacillariophyta (diatoms), cyanobacteria (blue-green algae), and chlorophyta (green algae), respectively. HPLC phytoplankton pigment measurements will be carried out on board ship.

Work at sea

Dilution experiments will be carried out for studying phytoplankton growth and grazing by microzooplankton. These experiments will be undertaken twice a week. Acrylic incubators with continuous flow of surface seawater will be used for onboard incubations.

12. POC, PON, ^{13}C, ^{15}N, TOC, TON

Mangesh Gauns (NIO), Christine Klaas (AWI), Amit Sarkar, Divyashree Barniya, Kanta Reshma and Maya Muthirenthy (NIO)

Objectives

Pools of particulate and total organic carbon and nitrogen will increase following fertilization and then decrease during the demise phase of the bloom due to sinking out of particles. Comparing these values with the measured losses in DIC and dissolved nitrogenous nutrients will enable us to derive budgets of these elements for the surface patch in order to obtain ratios for iron added and organic matter produced in and sunk from the surface layer. Analyses of the stable isotopes of ^{13}C and ^{15}N in surface pools will help to interpret ratios ($\delta^{13}C$ and $\delta^{15}N$) measured in the sediments where they are used as palaeoproductivity proxies.

Work at sea

Samples for measurements of POC, PON and for natural isotope abundance ($\delta^{13}C$ and $\delta^{15}N$) will be collected on a routine basis from the CTD casts. These parameters are not only important for characterizing primary production, but will also serve as control for nutrient uptake (tracer addition) work described in section 11. Appropriate volumes of sea water (~1-2 l) will be filtered through pre-combusted GF/F filters (25 mm diameter) and filters will be stored deep frozen for analysis at NIO. Similarly an *in-situ* filtration pump capable of filtering

several tens of litres of water at selected depths will also be used for larger volume sampling. Part of these samples will be analyzed for stable isotopic analysis ($\delta^{13}C$, $\delta^{15}N$) at NIO. Samples for TOC and TON will be stored after acidification with phosphoric acid for analysis in the shore laboratory following high temperature catalytic oxidation. The remaining part of the samples will be utilized for measurement of characteristic biomarkers at NIO.

13. PHYTOPLANKTON PHOTOPHYSIOLOGY AND BIO-OPTICS

Maurizio Ribera D'Alcalà (SZN)

Objectives

Measurements based on chlorophyll fluorescence are a sensitive tool to determine alga biomass and photophysiological characteristics of phytoplankton. The quantum efficiency of photochemistry (Fv/Fm) measured by variable chlorophyll fluorescence can be used to prove iron-limitation of plankton algae. During former iron fertilisation experiments a response of the phytoplankton was observable by variable chlorophyll fluorescence in between the first 2 days after the iron addition. Therefore it should be possible to detect a patch of iron-replete water by measurements of variable chlorophyll fluorescence only.

Work at sea

During this cruise different methods for the determination of variable chlorophyll fluorescence (FRRF, PAM, Pump & Probe) will be used to determine basic photophysiological parameters of the phytoplankton and its photosynthetic performance. *In-situ* measurements of the fluorescence yield and photosynthetic parameter will be conducted continuously in a flow-through cuvette and during CTD casts using Fast Repetition Rate Fluorometry (FRRF). Total water column primary production will be calculated from the data of each depth-profile. This will be compared with modelled primary production using photosynthesis-light curves and the *in-situ* irradiance. Therefore photosynthesis-light curves will be determined for single water samples in the lab using PAM- and Pump & Probe-fluorescence and the radiocarbon method (^{14}C). In addition this calculation needs the determination of the ambient light climate and the light absorbed by the phytoplankton itself. *In-situ* irradiance will be measured with a light profiler and water samples will be taken to determine the particular absorption. The data will be combined to determine the changes in phytoplankton photophysiology and photosynthesis of the induced algae bloom until its expected breakdown.

14. MICROBIOLOGY

14.1 BACTERIAL PRODUCTION

N. Ramaiah and Sanjay Singh (NIO)

Measurements of bacterioplankton production and abundance will provide a realistic estimate of bacterial growth yield. Previous results have shown that iron fertilization brings about major changes in the expression of bacterioplankton beta-glucosidase and aminopeptidase activity. In addition, increased bacterioplankton abundance and production were also observed without altering the richness of the bacterioplankton community. Whether the uptake of dissolved organic matter (DOM) by bacterioplankton following the Fe-release

was stimulated by iron alone making already existing but not utilized DOM available, or by a combination of iron and stimulated dissolved organic matter release by phytoplankton remained unclear.

Work at sea

In addition to the parameters already measured during EISENEX, in order to investigate preferential uptake during LOHAFEX we will focus on measuring leucine and thymidine incorporation rates. In addition, for ascertaining if the metabolically active fractions of heterotrophic bacteria undergo variations during the experiment, samples from within the patch and outside it will be analyzed for enumerating direct viable counts. Through these measurements, we hope to recognize the inter-relationship between the proliferation and metabolic performance during the time series observations. Moreover, we plan to extract microbial DNA for DGGE analysis in order to profile the changes in assemblage composition as a consequence of iron fertilization as well as altered primary (and secondary) production.

14.2 BACTERIAL BIODIVERSITY

V.R. Sundareswaran, G.S.N Reddy (CCMB)
Collaborator not on board: S. Shivaji (CCMB)

Objectives

The fact that OIF leads to a phytoplankton bloom has been well documented. But, comparatively little is known as to what ocean iron fertilization does to the bacterial communities after fertilization and after the phytoplankton bloom sinks out of the mixed layer. To investigate these changes, various methods will be adopted to monitor both the viable cultures and also the total bacterial biodiversity using the culture dependent rRNA approach.

Work at sea

Water samples will be collected from all the casts / various depths and after some crude screening through pre-filter pads, the collected water will be passed through a 0.22 μm filter to trap all the microbial matter. DNA will be extracted from this bacterial mass and the same will be preserved as pellets in suitable medium (alcohol), till further analysis in the home laboratory. On shore, 16S rRNA typing will be carried out on these DNA samples and communities / individual bacteria present in the region of OIF as also those affected by the OIF would be determined through various molecular approaches.
Also, duplicate filters will be placed on various growth media (such as Antarctic Bacterial Medium, etc.) and the same incubated at ambient / various temperatures for several days. The colonies that show up will be re-patched to get pure cultures. On shore, later, these bacteria will be classified using the polyphasic approach. A small quantity of water samples from each cast, both before and after OIF, would also be brought ashore to document both the culturable as well as non-culturable bacterial communities present through a polyphasic taxonomic approach.

14.3 BACTERIOPLANKTON COMPOSITION

Bernhard Fuchs and Jörg Wulf (MPI Bremen)

Objectives

The marine bacterioplankton community is strongly dependent on the primary production of the phytoplankton. Phytoplankton in turn is dependent on sufficient nutrients in the water column. During spring time blooms of mostly large eukaryotic algae develop in higher latitudes which in turn promote growth of specific groups of bacterioplankton. *Coccolithophore* blooms for example often induce an increase in *Roseobacter*-related bacteria in the North Sea. *Roseobacter* is able to incorporate and degrade the osmolyte dimethylsulfoniopropionate (DMSP) released by coccolithophores (Zubkov et al. 2001). Another algal group, *Phaeocystis*, has been found to bloom in Antarctic waters. Fluorescence *in-situ* hybridisation (FISH) have revealed a tight association of *Phaeocystis* colonies with *Bacteroidetes*, which are known to resemble polymer-degrading specialists (Simon et al. 1999). Iron-fertilization experiments are well suited to follow induced shifts in community composition and to establish links between the different plankton groups. Recently it has been shown, that the bacterioplankton community inside a naturally fertilized area at the Kerguelen upwelling plateau was qualitatively and quantitatively different from the outside community (West et al. 2008). We hypothesize that in artificially fertilized patches similar community shift in bacterioplankton will be observed.

Work at sea

During LOHAFEX we want to closely follow the bacterioplankton community composition by FISH and try to find key players in the degradation of the freshly produced organic matter. Fluorescently labelled oligonucleotide probes specific for different groups of bacterioplankton will be used to follow the community composition during the course of the fertilized patch. Bacterioplankton samples will be counted on board and correlated to nutrients and to phyto- and zooplankton counts. We would like to monitor the fertilized patch, the bloom and decay of the bloom through the water column down to the sediment. To assess the metabolic potential of specific groups of bacterioplankton we will incubate the bacterioplankton samples with isotopically labelled substrates and trace them in different groups of bacterioplankton. For example ^{15}N labelled amino acids will be used as well as ^{13}C labelled short organic compounds. Simultaneous detection of identity and uptake of substrates will be possible through a technique called Nano-SIMS – a next generation mass spectrometer with submicron spatial resolution. The later samples will be analysed back home at the institute. Additionally at chosen time points during the course of the experiment large volumes of water (>100 l) will be sampled for later on analysis of the metagenomes. A screening for key genes will help to reveal the metabolic potential of the bacterioplankton community present at a certain point during the phytoplankton bloom induced.

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dimethylsulphoniopropionate in an algal bloom in the North Sea. Environmental Microbiology 3, 304-311.

15. MICROPHYTO- AND PROTOZOOPLANKTON

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Objectives

The phytoplankton group will study the response of the phytoplankton assemblage to iron addition over a period of roughly 45 days during the Indo-German large-scale iron fertilization experiment LOHAFEX scheduled for austral summer 2009 (January – March) in the SW Atlantic north of South Georgia. In order to interpret the wax and wane of individual species populations over the course of the iron induced bloom it will be critical to understand the mechanisms that trigger growth and mortality phases of the dominant species since the former will determine species dominance and the latter the transfer to higher trophic levels and/or the subsequent fate along the deep water column. Different methods will be applied in order to address the above objectives and are detailed in the following sections.

Work at sea

15.1 ROUTINE COUNTING OF THE MICROPHYTO- AND PROTOZOOPLANKTON ASSEMBLAGE

For the quantitative assessment of the plankton assemblage water samples will be taken at 7 discrete depths between 10 and 150 m at in- and out-patch CTD stations using Niskin bottles. Both Formalin and Lugol fixed water samples of 200 ml will be sampled for diatoms, coccolithophores, choanoflagellates and thecate dinoflagellates in case of the former and for Phaeocystis, ciliates, naked dinoflagellates, silicoflagellates and other flagellates in case of the latter. One 2 l sample representative of the mixed layer (20 m depth) will be concentrated over 10 µm gauze and counted directly on board to keep track of the bloom. For large protozoa (mainly sarcodines) and small metazoa (mainly copepod nauplii and copepodites) larger volumes (at least 24 l) will be concentrated to a volume of about 50 ml by pouring the water gently through 20 µm gauze which will require one extra CTD cast. Large volume samples will also be sampled from the deep water column (150 m – sea floor) and concentrated over 10 µm gauze throughout the experiment to follow the sinking of individual species population.

15.2 VITAL STAINING OF THE PLANKTON ASSEMBLAGE DIRECTLY ON BOARD

Routine counting will be supplemented with the application of different staining techniques to follow the physiological status of individual phytoplankton species. Incubation experiments with the PDMPO stain that stains newly polymerised silica will be performed to estimate *in-situ* growth rates. Application of the viability stain FDA will provide information on the number of live cells within a population whereas the use of SYTOX Green will only label those cells that have lost their membrane integrity (dead cells). Thus the combination of both stains will provide an estimate of the number of dead and live cells within a population. Furthermore a fluorescent dye specifically binding to apoptotic cells will be applied to infer whether

programmed cell death is involved in the demise of individual species populations. Specific lipid stains will be used to infer the physiological status of phytoplankton species and DNA and RNA stains (SYBR Green I and II) in order to visualize particular cell compartments (nucleus, ribosomes). Furthermore compound specific dyes for polysaccharides and proteins (Alcian Blue and Coomassie Brilliant Blue respectively) will be applied to visualize the mucous matrix of sinking aggregates and infer their chemical composition.

15.3 ISOLATION AND CULTURING OF DOMINANT DIATOM SPECIES

Another major aim is to establish cultures of dominant diatom species during the experim isolation and total preparations of diatom material for both light and electron microscopy. The unialgal cultures will be used for later morphological, phylogenetic, life history and experimental studies in the home laboratory.

15.4 SAMPLING FOR MOLECULAR STUDIES

Both DNA and RNA samples of the natural plankton assemblage will be taken on board for biodiversity/metagenomic and gene expression/metatranscriptomic analysis respectively. Large volume samples for DNA will be filtered and then stored away at –80°C for later analysis. Samples for RNA will be immediately processed on board, including filtration, extraction and isolation. We are particularly interested in the expression of genes related to cell cycle regulation (e.g. PCNA, Cyclins) to determine *in-situ* growth rates and genes involved in the programmed cell death pathway (e.g. metacaspases). Quantitative real time RT-PCR analysis will later allow precisely determining the mRNA expression levels of the genes of interest and linking their expression with the pattern observed by microscopy.

15.5 LINKS TO OTHER GROUPS

- Zooplankton grazing experiments will be conducted in cooperation with Humberto Gonzalez and Maria Grazia Mazzochi.
- Dilution experiments to determine microzooplankton grazing will be conducted together with the group of Mangesh Gauns.
- Subsamples of the phytodetritus fluff layer on surface sediments provided by Oliver Sachs and Michael Schlüter will be sampled for species composition.
- Sampling of neutrally buoyant sediment traps will be performed in close cooperation with Patrick Martin and Kevin Saw.
- Klaus Valentin, Uwe John (AWI), Chris Bowler (ENS, Paris) will be involved in molecular studies.

16. MESO- AND MACROZOOPLANKTON

Grazia Mazzocchi Maurizio Ribera D'Alcalà (SZN), Humberto E. González (UACH-COPAS), K. Karuppasamy (NIO) and Pieter Vandrommes (UPMC-CNRS)
Collaborators not on board: Sigrid Schiel (AWI), Ann Bucklin (UCONN) and Lars Stemmann (UPMC-CNRS)

Objectives

The general objective is to evaluate the structural and functional responses of primary consumers to the spatial and temporal variations of food quantity and quality, and the impact of zooplankton activity on the carbon flux during the evolution of the phytoplankton bloom induced by iron fertilization.

In particular, three aspects will be investigated onboard with sampling and experimental activities, by following a species-level approach: 1) species distribution and abundance in space and time, 2) feeding performances (grazing rates and selectivity) of dominant species, 3) copepod egg production and viability in dominant species. These investigations will be closely linked to the *in-situ* video recording of particle distribution by the Underwater Video Profiler 5 (UVP5). Moreover, target zooplankton species will be selected for DNA barcoding in association with Census of Marine Zooplankton (CmarZ).

Work at sea

16.1 DISTRIBUTION

Species composition, abundances, biomass, and vertical distribution patterns of dominant zooplankton species and their developmental stages will be analysed from Multinet, Rectangular Midwater Trawl, Bongo and WP2 samples. Day and night catches will be performed outside and within the fertilized patch, from onset till demise of the bloom. The taxonomic identification and specimen counts will be done at species level as far as possible. Supplementary tows will be performed on occasions to collect healthy organisms for experiments and for later analyses of the specific carbon and nitrogen content.

16.2 GRAZING

The functional responses of dominant copepod species, euphausiids (*Euphausia superba*) and salps (*Salpa thompsoni*) will be investigated in terms of feeding behaviour and performances in relation to food quantity and quality. Copepods will be gently collected with WP2 net (200 μm) and krill with Bongo-net (300 μm) and target species will be sorted for conducting incubation experiments (24 hours) in natural particle assemblages. The feeding rates (clearance and ingestion) and selectivity of zooplankton species on phytoplankton species, the faecal pellet production and the grazing impact on phytoplankton concentration and composition will be estimated outside and inside the patch and during the bloom evolution.

The grazing experiments will be linked to the observations conducted by the (UVP5) for the *in-situ* distribution of particles (>60μm) and qualitative zooplankton-particle interactions.

16.3 COPEPOD EGG PRODUCTION AND VIABILITY

The functional responses of the same dominant copepod species utilized for the grazing experiments will be investigated in terms of reproductive performances and recruitment. The egg production and viability will be estimated outside and inside the patch and during critical phases of the bloom evolution. Moreover, the hatched nauplii NI will be frozen to be later stained with TUNEL kit and observed under the epifluorescent microscope to record the presence of apoptotic cells. This procedure will allow us to obtain information on the health conditions of nauplii and their further development for population recruitment both inside and outside the patch.

16.4 POM EXPORT (BIOLOGICAL PUMP EFFICIENCY) DUE TO FAECAL MATERIAL FLUX AND MACROZOOPLANKTON STANDING STOCK

Classification and enumeration of the faecal material from the neutrally buoyant, free-floating sediment trap samples should give a background to estimate the impact of the zooplankton on both the carbon flux and the possible fate of the phytoplankton bloom.

Collection of faecal pellets from the water column will be conducted using a Multi-net (55 µm mesh size) at five water column strata: 0-50; 50-150; 150-300; 300-500 and 500-1,000 m depth.

The UVP5 will be used to monitor the spatial and temporal distribution of large particles and macrozooplankton (to a maximum depth of 3,000 m depth) during the cruise. The data on particle size spectra will be used to assess the success of aggregation following the bloom and to monitor the subsequent export of particles to the deep ocean. The data on macrozooplankton will be used to estimate their effect on particle transformation while those from sediment traps and nets will allow us to assess the contribution of aggregates of phytoplankton origin and zooplankton faeces to the total stock of large particles.

17. SINKING CARBON FLUX (PELAGRA: A NEUTRALLY-BUOYANT SEDIMENT TRAP)

Patrick Martin and Kevin Saw (NOCS)

Objectives

Although it has been a key aim of iron fertilization experiments to date to measure whether the fertilization leads to removal of additional carbon from the upper ocean, as well as to its sequestration below the winter mixed layer, this measurement has so far proved elusive. This is due in part to insufficient cruise-duration, as well as to methodological problems with the use of sediment traps.

On LOHAFEX, we intend to use neutrally-buoyant sediment traps of the PELAGRA design to measure particle flux throughout the experiment. These traps very significantly reduce the problem of zooplankton 'swimmers' entering the sample cups, as well as virtually eliminating hydrodynamic biases due to their Lagrangian mode of operation. Hence we hope to provide accurate quantitative and qualitative information on the particle flux within the traps' depth range (200 - 900 m). The traps have been deployed successfully on previous cruises, but we are hoping to eliminate gaps in the flux record by staggering the deployments in such a fashion as to achieve continuous sampling of particle flux at two different depths. Given the duration of the cruise, we will thus be able to provide a convincing estimate of the particle flux resulting from the fertilized bloom, as well as to calculate its attenuation with depth. Moreover, aliquots of PELAGRA samples will be given to other scientists on board to conduct a suite of analyses on the composition of the sinking material that can be related to concomitant measurements in the upper ocean.

Work at sea

Trap dimensions are 2 m height and approximately 1 m diameter, with a weight of 122 kg when fully equipped. They have a 1 m-tall titanium lifting-frame mounted on top, to which a strobe-light and a signal flag are attached to facilitate recovery. The traps are deployed by hooking the lifting-frame to a crane, lifting them over the side of the deck and as far clear of the ship as possible, and lowering them into the water. Similarly, the traps are retrieved by hooking the lifting-frame and then lifting the traps on board with a crane. Once they have dropped their ballast, they are buoyant enough for the lifting frame to protrude completely above the water. Upon surfacing at the end of a deployment, the traps transmit their position via the ARGOS satellite network, and notification e-mails with updated positions are sent to us regularly. Moreover, a Gonio receiver indicates the relative bearing of the traps' radio signal once they are within about 4 km of the ship. Due to the signal flag and the strobe light, the traps can be spotted both by day and by night. Each trap will be deployed for 3- 5 days.

18. SEDIMENT GEOCHEMISTRY

Oliver Sachs and Michael Schlüter (AWI)

Objectives

The AWI geochemistry group will study and compare organic carbon (C_{org}) fluxes at the seafloor below and adjacent to the LOHAFEX experimental site. Our contribution is to be seen as the link between the water column investigations and the sea floor: The sea floor as

the final recipient of deep carbon export stands between pelagic production and particle sedimentation on the one hand and the utilization of carbon resources by the benthic fauna on the other side. Therefore we expect to get new insights about the build up, fate and the process of sedimentation in the deep sea of an artificially induced diatom bloom. From the out patch stations we expect the first insights of the seasonal variation and episodic variabilities of benthic C_{org} fluxes in the SW Atlantic Ocean. From the geochemical point of view we will expand the still small data base of high quality benthic flux measurements in the Southern Ocean. This enables us to improve budget considerations in respect to organic carbon influx to the seafloor as well as the chance to improve transfer functions to correct existing laboratory measurements.

Early diagenetic processes in surface sediments are closely linked to the sedimentation of particulate organic matter. This allows the quantification of organic carbon influx into the sediment surface. For this purpose a free-fall Lander system equipped with an *in-situ* microprofiler will be deployed. Furthermore, the measurement of geochemical microgradients provides a tool to quantify the amount of C_{org} which was artificially produced and transferred to the seafloor.

Most of the organic carbon arriving at meso- and oligotrophic sediments is remineralized right below the sediment-water interface, consuming dissolved oxygen as a primary electron acceptor. In addition, oxygen functions as a final electron acceptor for anaerobic pathways. Thus, the measurement of the pore-water oxygen distribution provides a suitable tool for the determination of C_{org} fluxes. Besides the quantification of oxic respiration rates by *in-situ* chambers or laboratory core incubation, O_2 microelectrodes have proven to be an appropriate tool to determine diffusive oxygen fluxes via the measurement of the porewater O_2 depth distribution in very high resolution. In order to avoid sampling and pressure artefacts during core retrieval it is highly desirable to measure O_2 microprofiles *in-situ*, i.e. at the sea floor (e. g. Glud et al., 1994; Sauter et al., 2001).

Only a limited data set, mostly measured *ex-situ*, exists for high latitudes beyond 60° N or S. During ANT-XXI/4 we had the opportunity to measure *in-situ* fluxes two weeks after the end of the European Iron Fertilization Experiment (EIFEX) and at the Polar Front (Sachs, 2008). Up to now, only little is known about the total amount of organic carbon remineralized and fixed within surface sediments of the Southern Ocean.

During LOHAFEX the main focus will therefore be on the *in-situ* measurement of O_2, pH, H_2S and porosity microprofiles and a complementing sediment sampling programme from the beginning till the end of the experiment. In addition pore water analysis will provide information about the turnover of biogenic silica and the release of nutrients.

Work at sea

In this study *in-situ* microprofile measurements will be performed by means of an autonomously working microprofiler able to drive microsensors for O_2, pH, and H_2S as well as a resistivity probe into the sediment with a minimal vertical resolution of up to 0.1 mm. The profiler can either be mounted into a free falling lander system co-equipped e.g. with a deep-sea still or video camera, an acoustic Doppler velocimeter and / or a water sampler.

In-situ measurements will be complemented by *ex-situ* measurements of microprofiles sediment, pore water and bottom water sampling for the determination of other geochemical parameters like TOC, C/N ratio and nutrient profiles. Sediment sampling will be performed by a conventional multicorer.

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ANT-XXV/4

21 March 2009 - 9 April 2009

Punta Arenas - Punta Arenas

Chief scientist
Christine Provost

CONTENTS

1. ÜBERBLICK UND FAHRTVERLAUF

Christine Provost, (LOCEAN, Paris)

Polarstern wird am 21. März 2009 von Punta Arenas auslaufen. Nachdem sie die Drake-Passage zweimal überquert haben wird, wird sie am 9. April 2009 wieder nach Punta Arenas zurückkehren. Die geplante Route ist in Abb.1 dargestellt. Nach dem Verlassen der Magellan-Straße, wird *Polarstern* Kurs nach Südosten in die nördliche Drake-Passage nehmen. Dann wird sie dem Messprofil #104 des Satelliten Jason folgen, bis am Kontinentalabhang der Antarktis eine Wassertiefe von 200 m erreicht sein wird. Anschließend wird der Kurs nach King George Island führen, wo in der Admiralty Bay Fischfallen ausgelegt und wieder aufgenommen werden. Während dieser Zeit werden Versorgungsarbeiten bei der Jubany-Station und dem angeschlossenen Dallmann-Labor erfolgen. Danach geht es zurück durch Drake-Passage nach Norden entlang des Jason-Messprofils #28. Der südliche Teil des Messprofils #28 führt genau entlang der Shackleton-Bruchzone, die bis 1500 m unter den Meeresspiegel aufragt.

Entlang Messprofil #104 werden 5 Strömungsmesser-Verankerungen aufgenommen, die 2008 während ANT-XXIV/3 ausgelegt wurden. Zusätzlich werden CTD/LADCP-Messungen an etwa 50 hydrographischen Stationen ausgeführt, bei denen auch Wasserproben in 22 Tiefenhorizonten genommen werden, um die Konzentrationen der gelösten Nährstoffe, von Sauerstoff, Spurenstoffen (Helium-Isotope, Neon, Freone), der Parameter des CO_2-Systems, und des Phytoplanktongehalts in der Wassersäule zu bestimmen.

Etwa 50 CTD/LADCP-Stationen werden auf dem Rückweg entlang Jason-Messprofil #28 ausgeführt. Auf dem Weg nach Süden und zurück nach Norden werden Stationen zur Bestimmung der Mikrostruktur in der Wassersäule erfolgen.

Die endgültige Zahl der hydrographischen und Mikrostruktur-Stationen wird entsprechend dem Fortgang der Arbeiten angepasst werden. Zeitverluste auf Grund unerwarteter Ereignisse oder langsameren Fortschritts der Arbeiten als erwartet, müssen durch Kürzung der Stationszeit ausgeglichen werden.

In der Admiralty Bay werden mit verankerten Fallen lebende Fische gefangen, die nach Bremerhaven gebracht werden sollen, um dort zu physiologischen Untersuchungen der Temperaturabhängigkeit biologischer Prozesse gehältert zu werden.

Der Fahrtabschnitt ist ein Beitrag zu POGO, der Partnership for Observation of the Global Oceans, http://www.ocean-partners.org/aboutPOGO.html.

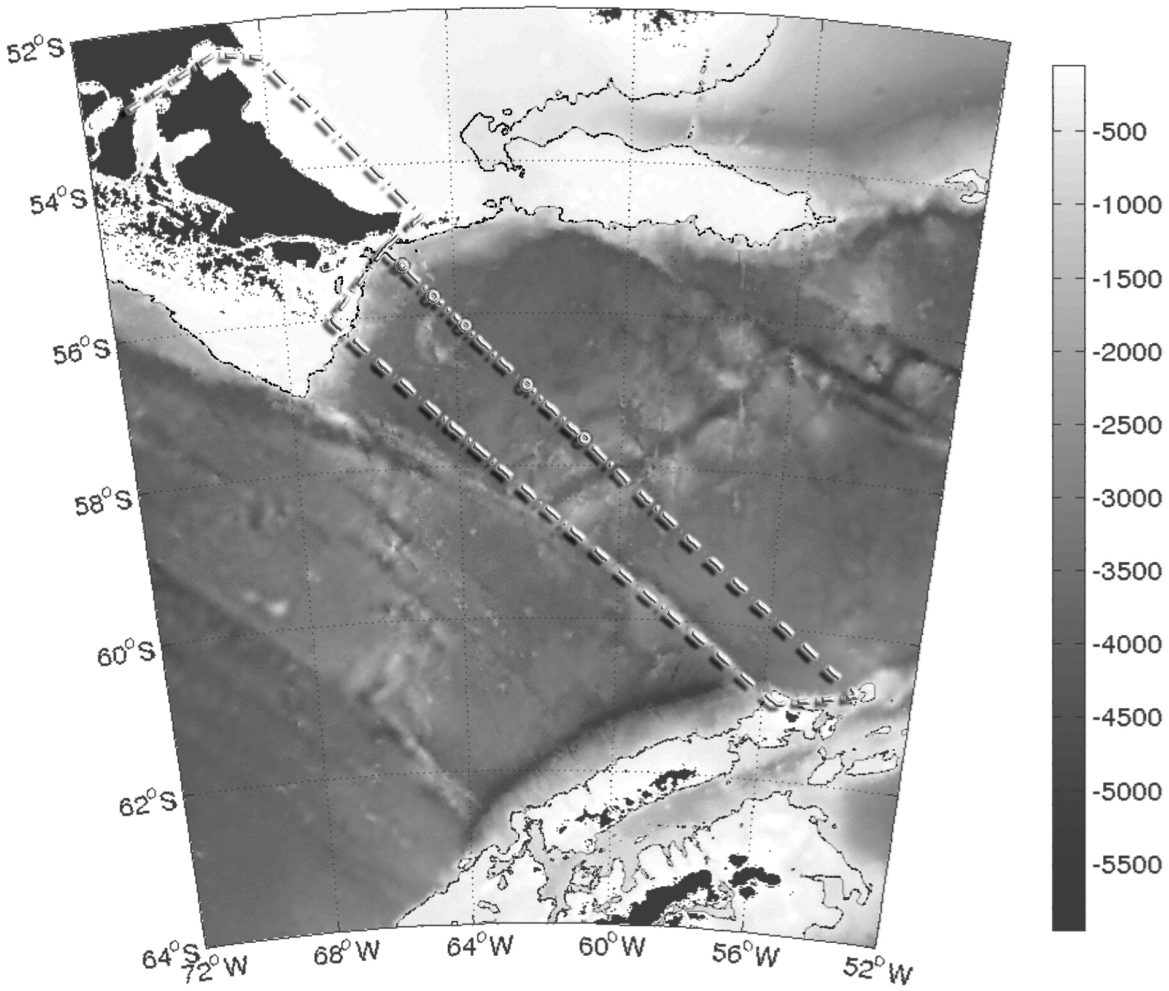

Abb. 1: Geplante Fahrtroute der Drake Passage während ANT-XXV/5. Die Punkte geben die Lage der Verankerungspositionen an.
Fig. 1: Planned route for Drake cruise ANT-XXV/4. Dots are mooring locations.

ITINERARY AND SUMMARY

The research vessel *Polarstern* will leave Punta Arenas on 21 March and return to Punta Arenas on 9 April 2008 after two crossings of the Drake Passage. The planned route is shown on Fig.1. After leaving the Magellan Channel, *Polarstern* will head southeast towards the north of Drake Passage. Then she will follow ground track #104 of Jason satellite until a depth of 200 m is reached on the continental slope of Antarctica. Afterwards she will head west towards King George Island for a stop at Jubany for logistics purposes and fish trap deployment and recovery in Admiralty Bay (KGI). Then she will cross back Drake Passage northward along Jason ground track #28. The southern part of track 28 rides exactly over the Shackleton fraction zone the crest of which is only 1,500 m below sea surface.

Along ground track 104, the 5 current meter moorings (M1 to M5) deployed in 2008 during ANT-XXIV/3 will be retrieved and CTD/LADCP measurements will be carried out on approximately 50 hydrographic stations with water samples taken at 22 different depths to determine the concentration of dissolved nutrients, oxygen, tracers (helium isotopes, neon, freons), CO_2 parameters, abundance in phytoplankton in the water column.

About 50 CTD/LADCP stations will be carried out on the way back along Jason ground track # 28. A few microprofiling stations will be performed on the way south and on the way north.

The final number of hydrological and microstructure stations will be adjusted to the progress of work. Time losses due to unexpected events or slower progress than expected will be buffered by a reduction of station time.

In Admiralty Bay alive fish will be caught with traps to be brought to Bremerhaven in oder to carry out physiological investigations to understan the temperature dependance of biological processes.

This leg is a contribution to POGO, der Partnership for Observation of the Global Oceans, http://www.ocean-partners.org/aboutPOGO.html.

2. MONITORING THE ACC TRANSPORT AT DRAKE PASSAGE

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Scientific background

The Southern Ocean is especially sensitive to climate change, responding to winds that have increased over the past 50 years and warming significantly more than the global ocean over the past 50 years. The Antarctic Circumpolar Current (ACC), the world's largest current, is the pulse of the Southern Ocean and a key element of the global climate system. The Drake Passage (DP) chokepoint is not only well suited geographically (ACC constricted to its narrowest extent, 700 km), but observations and model suggest that dynamical balances which control the ACC transport are particularly effective through the DP.

While the ACC is the major inter-ocean link, our understanding of the variability of the ACC and the impact of such variability on the climate system is rudimentary. The ISOS (International Southern Ocean Studies) experiment of the 1970s provided an estimate of the mean transport and variability of the ACC at the DP. More recently, hydrographic sections and repeated observations from ship of opportunity (XBT and S-ADCP) have filled in details of the kinematics of the ACC (Satellite altimeters have provided an unprecedented view of the eddy variability of the Southern Ocean). High resolution numerical models have illuminated the dynamics of the current, its importance for climate and proposed scenarios for its response to changing winds. Recently, high mixing rates in the ACC have retained much attention as they are key to the oceanic overturning circulation. Nevertheless, major gaps remain in our understanding of the ACC and its role with respect to climate variability.

The magnitude and time variability of the total volume transport of the ACC through the DP is a key climatic index. Yet the total transport is poorly documented. The only *in-situ* current meter mooring array deployment (ISOS programme) goes back to the 1970s, before the era of satellite altimetry.

Objectives

Monitoring the magnitude and variability of the ACC through Drake Passage

The heart of the project is an experiment with *in-situ* measurements for 4 years (it started in February 2006), which is coupled with the satellite altimetric observations (TOPEX/POSEIDON and Jason). This project should serve to give us access to intraseasonal, seasonal and inter-annual variations of the volume transport at DP since 1992 (16 years).

Furthermore, by comparing the transport time series obtained from the ISOS programme in the 1970's (4 consecutive years + 1 year) we may be able to estimate the evolution over 30 years.

During ANT-XXIII/3 (January-February 2006) an array of 10 current meter moorings across Drake Passage was deployed below track 104 of altimetric satellite Jason-1. During expedition ANT-XXIV/3 8 of the 10 moorings were retrieved (April 2008) and 5 new moorings were deployed to pursue the time series series in the northern Drake Passage (Fig.1) where the flow is the strongest and where low frequency modes of variability in sea surface height have been identified.

Thus, one of the objectives of ANT-XXV/3 is to retrieve the 5 moorings deployed in 2008.

Validation of the altimetric signal

A proper use of the altimetric data requires a better understanding of the altimetric signal in these high latitudes. Therefore an important technical objective is a precise validation of the altimetric signal. In particular, the rough sea state and atmospheric conditions require a precise examination of the corrections to be applied for the ocean response to the atmospheric pressure and the sea state effects on the altimetric measurements.

The upward-looking ADCPs on moorings M1 and M3 will provide valuable data for validation.

High frequencies and transients

The current meter data will permit to investigate the dynamic role that eddies play in the ACC. Although one of the major goals of DRAKE is to calibrate and verify satellite sea surface height with *in-situ* observations, the data also fill a lack of subsurface observations that are needed to address recent hypotheses about the dynamics of the ACC.

Three questions will be addressed with these data: (1) what are the spatial modes and frequency distribution of variability of temperature, salinity, velocity, and eddy heat fluxes, (2) how do eddy heat fluxes relate to wind forcing, and (3) are there statistically significant changes in eddy properties since 1980? Thus, in addition to a basic description of spatial and temporal structure of the velocity fields, mooring-derived eddy heat fluxes over the 3 years will also be analyzed in a similar manner. Wind forcing has increased in the past decade and mid-level waters have warmed slightly, yet the role of eddies in mediating this response below the surface is poorly understood. The eddy response to wind forcing is assumed to be linear but needs to be tested directly in Drake Passage. Determining the spatial distribution and forcing mechanisms of eddy fluxes and internal waves is critical to understanding the response of the Southern Ocean to long-term changes in wind-forcing.

Water masses
The Drake Passage is the entry point for the water masses from the Pacific into the Atlantic Ocean. In Drake Passage water masses undergo substantial modifications.

The realisation of a « closed box » with the two tracks of hydrographic stations will allow making budgets and « inversions ». Our objectives concerning water masses are the following:

- Identify precisely water masses, their sources and paths,
- estimate the ”age” of the water masses (age = elapsed time since they last saw the surface),
- study mixing by multiparameter analysis and small scale structure examination (both from LADCP and from CTD) and inversions,
- estimate anthropic carbon in intermediate waters,
- study climate change in water masses using historical data.

Mixing
Observations in the southern ocean suggest that mixing is intense and widespread, even well above rough topography. These high mixing rates have retained much attention as they are key to the oceanic overturning circulation. Particularly high mixing rates have been estimated in the Drake PassageHowever mixing rates remain poorly constrained primarily because few direct observations exist in the region. Therefore beyond getting indirect information from the CTD, the LADCP and moorings, we also want to get direct micro-structure measurements that can explicitly resolve small scale diapycnal mixing.

Work at sea

Mooring recovery
We plan to recover the 5 moorings M1 through M5 deployed in 2008 (Fig.1).

Hydrological stations
To complement the mooring array, we shall perform two high resolution CTD/LADCP station sections : one section below track 104, the other below track 28, thus defining a closed box (Fig.1). The distance between adjacent stations will be less than 20 km with a closer spacing in the frontal regions and on the continental slopes. The hydrographic stations will gather water samples at different levels for tracers.

Microstructure profiler stations
A few profiles (only upper 500 m) with a microstructure profiler will be gathered at selected stations.

En route measurements
Temperature, salinity and ocean currents will be measured with the thermosalinographs and acoustic Doppler profiler from the moving vessel. During the whole cruise, the ship-borne gravimeter KSS-31 and GPS will be operated (see part II).

Expected results
The data to be gathered will provide
- new information on the velocity field in the northern Drake Passage where the flow is the strongest. More than three years of data will then be available allowing precise quantification of time scales, vertical structure, transients, mean flow, seasonal and inter-annual variability (from current meters and full depth LADCP).
- A better understanding of the altimetric signal in the Drake Passage.
- A precise quantification of the mass and volume transport through DRAKE on the mean and variability, a precise distribution of the flow between the three fronts making up the ACC.
- A precise estimation of the exchanges between the PF and SAF in the Yaghan Basin (Northern DP).
- Two new sections through DP with full depth high resolution hydrography with tracers, thus information on variability in water mass characteristics, paths. The two sections form a narrow closed box allowing budgets and inversions.
- New estimates of mixing, new information on mixing processes particularly around the barrier of the Shackleton fracture zone.

The present project is an integral part of the IPY activity CASO Climate of Antarctica and the Southern Ocean, The Ocean Circulation Cluster.

3. SEA LEVEL AND GRAVITY FIELD MEASUREMENTS BY GPS AND MARINE GRAVIMETRY

Richard Biancale (CNES), Stavros Melachroinos (LEGOS)

Scientific background
The altimetric data need to be complemented and carefully validated. Due to the intense currents and the complex bathymetry, the global mean sea surface (MSS) built from altimetry data does not adequately represent the small scale geoid fluctuations and quasi stationary sea topography (QSST) undulations in Drake Passage. GPS and gravimetric surveys will be performed along the JASON tracks 28 and 104 to provide independent sea level and gravity anomalies data to validate altimetric data and to build a precise local geoid in the region.

Objectives
- The GPS and gravity measurements along the track have four main objectives:
- To test and implement new processing algorithms for high precision positioning: to validate with respect to altimetry data such a kinematic high frequency GPS technique for

measuring sea state and the sea surface height (SSH) in absolute and relative positioning mode in a well-defined reference frame (ITRF05) over baselines of a few hundred kilometres in an especially rough area;
- to give recommendations based on this innovative technique for offshore Cal/Val activities with observations on the ground tracks of the tandem altimeter satellite mission of JASON-1 and JASON-2. The radiometer of the altimeters does not suffer from any footprint related errors since observations are far away from the coasts;
- to combine GPS-derived sea level data with altimetric and gravimetric observations to compute gravity anomaly profiles and an improved marine geoid along JASON 1 and 2 ground tracks and to determine the mean sea surface profile of the geostrophic current;
- to compare profiles of the 2006 DRAKE campaign in respect to the sea surface and gravity anomaly, investigate possible differences and temporal variability.

Working at sea

3 GPS receivers will be installed on board *Polarstern* and one on a special buoy system. This configuration will be used for the sea level and sea-state determinations.

ITRF-IGS frame Ties : The GPS data will be analysed in a post-processing semi-kinematic mode using stable GPS reference stations of the International Global navigation satellite systems service (IGS). The Rio Grande and Belgrano multi-technique stations will permit a geodetic connection between GPS and nearby Doris stations (both systems being used for the precise orbit determination of the Jason satellite).

At the harbour (before departure) : 2 GPS sessions on a floating buoy will be performed for the determination of *Polarstern* floating line with respect to the GPS antennas on board. Moreover, optical measurements on board will help us define the reference frame of the boat (b-frame) centered at one of the 3 GPS antennas and the inertial measurement unit (MINS).

During hydrographic stations : GPS buoy sessions will be carried out at every hydrological station for the exact determination of the sea-state and the ship's floating line.

GPS - TG ties: eventually, GPS buoyancy sessions will be used again in order to connect the TG systems and their sea level indications at Puntas Arenas to our GPS reference frame.

Expected results

JASON-1 and JASON-2 altimetry will be compared to *in-situ* GPS observations. Problems like ambiguity resolutions and multi–GNSS constellation combinations over long baselines for the determination of high precision coordinates in GPS kinematic mode and at high dynamics state, which remain a challenging part of geodesy, will be studied and resolved.

The knowledge and experience gained during this project will be used for extending the kinematic GPS survey to other regions, like coastal areas.

A better mean sea estimate and improved altimetry data treatment in the DP.
Composite profile maps from merged altimetric data sets and operational models (MERCATOR) will be evaluated with respect to our observations. This will contribute to the geostrophic current field and absolute transport estimation in the DP.

4. DISSOLVED NUTRIENTS AND DISSOLVED OXYGEN MEASUREMENTS

Véronique Garçon, Danièle Thouron, Nicolas Jugnet (LEGOS), Françoise Henry (ULCO), Cécile Mioni (UCSC), Silvia Romero (SHN)

Objectives

The Drake Passage is an important entry point for several water masses from the Pacific into the Atlantic Ocean. They are carried around the Antarctic continent with the Antarctic Circumpolar Current (ACC) and thus, can enter the South Atlantic and Weddell Sea. It is crucial to quantify the importance of the cold water route of the return flow of the thermohaline circulation but also its variability. Indeed, the last detailed CTD survey across Drake passage was from the WOCE A21 cruise on board RV *Meteor* in 1990. A water mass analysis performed with hydrographic and nutrients data from the ANT-XXIII/3 cruise has revealed a passage of the South East Pacific Deep Waters (SPDW) across the Shackleton Fracture Zone on either side of the West Scotia Ridge above the 3,000 m isobath. The designed transect will allow to cross twice the West Scotia Ridge in Drake Passage along Jason tracks 104 (same transect than during ANT-XXIII/3 and ANT-XXIV/3) and 28 (above the Shackleton Fracture Zone).

Work at sea

We will sample for nitrates, phosphates and silicates determinations at each CTD station along the southward and northward transects through Drake Passage. The CTD network will be such to resolve the fine scale structure (every 20 km) and on the vertical 22 depths will be sampled from the Niskin bottles. The samples will be analyzed on board with an Autoanalyzer Technicon by the LEGOS team. For dissolved oxygen, discrete bottle samples will be collected at each CTD station at a few depths for ensuring a proper calibration of the Sea Bird oxygen sensor. Dissolved oxygen will be determined according to the Winkler method using potentiometric titration. Replicates will be collected at each CTD station.

Expected results

The distribution of the dissolved nutrients mentioned will give information on water masses origin and pathways, variability in water masses characteristics in the cold water route of the thermohaline circulation. This work is an integral part of the IPY activity CASO Climate of Antarctica and the Southern Ocean, the Ocean Circulation Cluster.

5. TRACER MEASUREMENTS: CHLOROFLUOROCARBONS (CFCS) AND NOBLE GASES (3HE, 4HE, NE)

Madlen Gebler and Olliver Huhn (IUP)

Objectives

Newly formed Weddell Sea Bottom and Deep Water (WSBW, WSDW), generated in the western and southwestern Weddell Sea, partly escape the Weddell Basin through gaps in the South Scotia Ridge system towards the north. Traces of this leakage were observed further to the west, on the southern slope of the Drake Passage. High Chlorofluorocarbon (CFC) and slightly enhanced noble gas (He and Ne) values indicate a (rapid) flow from out of

the Weddell Basin around the northern tip of the Antarctic Peninsula to the west through Drake Passage. Even further to the west slightly enhanced CFC values were reported from sections in the 90s of the last century, possibly originating from Weddell Sea ouflow.

During this expedition, the volume and time scale of this Weddell Sea outflow to the west, its fate and further mixing while overflowing or surrounding the Shackleton Fracture Zone shall be investigated by detailed measurements of CFCs and noble gases up- and downstream the Shackleton Fracture Zone. These measurements shall be compared to previous observations from the northwestern Weddell Sea slope and the South Scotia Ridge area, its most likely source.

CFCs are anthropogenic trace gases and enter the ocean by gas exchange with the atmosphere. The evolution of these transient tracers in the ocean interior is determined by their temporal increase in the atmosphere (since the middle of the last century) and the formation (and mixing processes) of intermediate, deep and bottom water, in which they are carried. Observation of these tracers allow determination of internal transit times (i.e., transit time distributions, TTDs) and formation rates of water masses (tracer inventories).

Ocean surface water is mostly in equilibrium with atmospheric helium (^{3}He, ^{4}He, and also the constant atmospheric ^{3}He/^{4}He ratio) and neon (Ne). Neon has no internal oceanic sources while primordial helium enters the ocean from spreading regions of submarine ridge systems (mainly in the Pacific, i.e., mantle helium with a far higher ^{3}He/^{4}He ratio) and from the earth crust (lower ^{3}He/^{4}He). Additionally, helium and neon enter the inner ocean from glacial ice, in which these stable atmospheric gases are trapped in bubbles and which are dissolved completely by melting the ice from below under enhanced hydrostatic pressure. Thus, noble gases allow distinguishing – and quantifying – various contributing source water masses of the water in which they are observed.

Work at sea

Water samples for CFCs (~300) will be stored in glass ampoules and be sealed off after a CFC free headspace of pure nitrogen has been applied. The CFC samples will be analysed later at the IUP-Bremen by purge and trap sample pre-treatment followed by gas chromatographic (GC) separation on a capillary column and electron capture detection (ECD). The helium and neon samples (100) will be stored in clamped off copper tubes. They will be analysed with the IUP-Bremen noble gas mass spectrometer (combined quadrupole and sector field mass spectrometer), after the gases were extracted from the sea water samples and separated from other gaseous components by several cooling traps.

6. PHYTOPLANKTON MEASUREMENTS

Luc Beaufort (CNRS/CEREGE), Alejandro Bianchi (SHN)

Objectives

The ocean is getting acidified in response to atmospheric CO_2 increase. The impact of such an acidification on primary producers is usually investigated through laboratory experiments or coupled physical/biogeochemical modelling. What is the *in-situ* state of the ocean with respect to pH conditions and distribution of the various phytoplanktonic groups? This knowledge is a prerequisite for both carrying out proper models outputs validation, and establishing the present state.

In the Polar frontal Region of Drake Passage we are interested in two major phytoplanktonic functional types: diatoms (siliceous phytoplankton) and coccolithophorids (calcareous phytoplankton). Our main objective is to investigate the relationship between the variations of acidification level (pH and alkalinity) and the distribution of these two groups.

Work at sea
We will sample across the Polar Front from the Niskin bottles along the two transects and then perform filtrations for further determination of pigments composition by HPLC (on land) and for further species identification and quantification of diatoms and coccolithophorids biomass by microscopy (on land). 500 samples will be collected for HPLC determination and 750 for microscopy speciation (diatoms and coccolithophorids).

Expected results
The distribution of the two phytoplanktonic groups in the Polar Frontal region will be described. By comparing the pH and alkalinity conditions of the surface water masses, it will be possible to derive a relationship linking chemistry of seawater and the phytoplanktonic speciation.

7. DISSOLVED CARBON DIOXIDE MEASUREMENTS

Christian Brunet (LOCEAN), Carlos Balestrini, Marcela Charo, Ana Paula Osiroff (SHN)

Objectives
Monitoring the pCO_2 variations in surface waters and determining the DIC content of the water column will be performed at mesoscale along both transects. This will allow the assessment of the source/sink role of CO_2 of this region, and the crucial role of the Polar Front bio-geo-chemical barrier. This will be compared with the distribution of phytoplanktonic groups on either side of the Polar Front. Data will also enable us to compute an anticipated increase of anthropogenic carbon, particularly in the AAIW.

Work at sea

Autonomous underway pCO_2 in surface waters
The pCO_2 system will collect data of pCO_2 in surface waters as well as marine air. The collected data will contribute to the global data set for assessment of CO_2 exchange between ocean and atmosphere.

Alkalinity and DIC along vertical profiles
Samples will be collected from CTD stations of both northern and southern transects along vertical profiles in glass bottles for analyses of alkalinity and total dissolved inorganic carbon Analyses will be performed on board to obtain a refined resolution, and samples will be taken back to LOCEAN for analyses by SNAPOCO2 (Service National des parameters océaniques du CO_2) and then checking calibration. The Alk/DIC dataset will be reported to the international ocean CO_2 databases.

8. CONTINENTAL BACKGROUND IN OCEANIC AIR MASSES

Aurélie Collomb, Rodolphe Paris (LISA)

Scientific background

In Drake Passage, continental air masses are mixed with pure oceanic air masses, and are evolving through the circumpolar atmospheric circulation. The most probable origin of continental air is Australia and Patagonia. Dust is deposited into the ocean surface and trace gases are oxidized and exchanged with the ocean. The long term evolution of continental air over the ocean is only poorly known, even if the oceanic surface is more than 80 % of the South Hemisphere. Dust deposition can bring micro-nutrients to the marine biota as trace metals and metalloids. The atmospheric dust content and deposition rate is quite unknown in Austral regions; recent field experiments have shown large differences between estimated and measured dust or deposition. The Southern Ocean is poorly characterized in terms of organic compounds and trace gases. Numerous laboratory experiments have shown that marine biology such as phytoplankton can emit volatile organic compounds (VOCs), but few shipborne measurements have been performed to determine potential source or sink of selected species. Especially in austral regions, recent campaigns (MANCHOT in Indian austral ocean in 2004; OOMPH between Cape town and Punta Arenas in 2007) have shown the impact of oceanic emission on global atmospheric chemistry.

Objectives

- Observing the relation between dust, trace gases and aging of the air masses,
- contributing to the evaluation of the dust deposition over the remote Austral oceanic regions,
- improving the knowledge of the atmospheric composition over remote oceanic areas, the trace gases emission from oceanic sources (especially from phytoplankton species) and the influence of the continental emissions.

Work at sea

- Sampling aerosol and rainwater,
- sampling gases,
- analysing reactive gases.

Expected results

- Dust content in air, dust flux to the ocean, solubility of trace metals and metalloid, biogeochemical impact of atmospheric deposition,
- chemistry of aged continental air masses,
- interactions between continental and oceanic VOC and relative impact on the atmospheric chemistry.

9. INPUT OF SE PACIFIC WATERS TO THE PATAGONIAN CONTINENTAL SHELF

Alberto Piola (SHN), Oscar Pizarro (Universidad de Concepcion)

Scientific objectives
To better determine the relative contributions of SE Pacific waters to the Patagonia continental shelf.

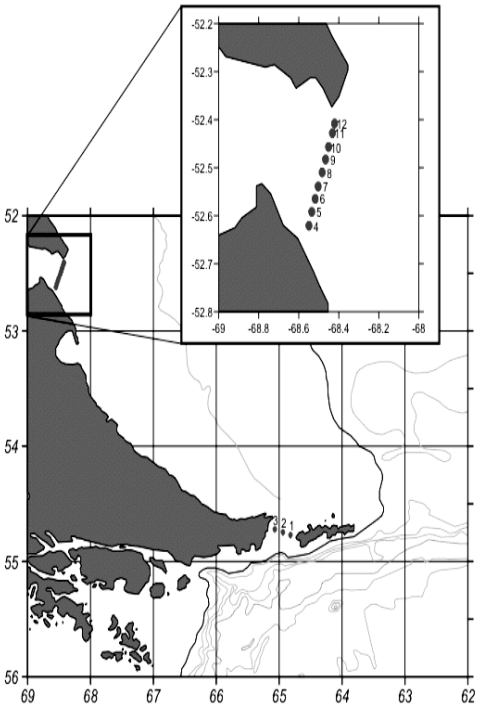

Fig. 2: Map of the planned CTD section and stations in Argentine waters

Work at sea
(sea Fig. 2 above)
- A CTD section (around 10 stations) across the eastern mouth of the Magellan Straits, in Argentine waters,
- a couple of CTD stations in the Le Maire Straits, also in Argentine waters.

10. ROLE OF TEMPERATURE, CO_2 AND OXYGEN IN EVOLUTION: INTEGRATIVE ECOPHYSIOLOGICAL STUDIES STUDIES ON FISH AND CEPHALOPODS

Magnus Lucassen, Heidrun Weindish (AWI)

Objectives

Ecological physiologists have historically been interested in the effect of abiotic factors, such as temperature, hypoxia and salinity, on the physiology of animals, and how these factors influence physiological performance and species distribution patterns in nature. In general, these studies have had two approaches – to examine how the changes in the abiotic factors alter or disrupt physiological processes, and to study how animals adjust their physiological processes to adaptively respond to fluctuations in environmental conditions. Molecular approaches are more and more implemented for an understanding of the genetic basis.

Temperature has a large impact on all biological processes and is therefore especially important in marine ecosystems. Animal organisms, due to their inherently high levels of organisational complexity, specialize on environmental temperature much more than unicellular bacteria and algae. Accordingly, thermal tolerance windows differ between ectothermal animal species depending on latitude or seasonal temperature acclimatisation and are therefore related to geographical distribution. Trade-offs and constraints in thermal adaptation become visible when ectotherms specialized on various temperature regimes and their tissues are compared. The hypothesis of oxygen limited thermal tolerance provides a conceptual framework for the investigation of how ectotherms compensate for changing ambient temperatures. Accordingly, thermal limitation becomes effective firstly at high hierarchical levels of organisation, the intact organism, and then at lower levels, cellular and molecular functions. Inadequate oxygen supply is likely the first indicator of cold intolerance in both water and air breathers, however, compensatory mechanisms are assumed to set in before such limits are reached. These limits exert their effects on the growth rate of individual specimens and the abundance of a population thereby shaping the biogeography of a species. Nevertheless, thermal limitations are based on molecular functions and the integration of single molecules into functional and regulatory networks. Similarly, studying the temperature adaptation of organisms in a changing environment therefore needs to consider the functional integration of single molecules into higher organisational levels.

Evolutionary adaptation to various climates is addressed in our department “Marine Animal Physiology” in comparative studies carried out with populations of the same species in climatic gradients or with congeneric species living in different climatic zones. For example, member species of the fish family Zoarcidae (eelpouts) inhabit temperate, subpolar and polar waters and represent a model system for the study of evolutionary adaptation versus seasonal acclimatisation to temperature. Therefore, a reasonable number of publications of our department have been emerged from studies on Antarctic eelpout (*Pachycara brachycephalum*) and common eelpout (*Zoarces viviparus*) (cf. AWI epic). Furthermore, our previous studies have demonstrated the high conservation level of functional genes in different eelpouts from boreal and Antarctic waters, corroborating that these species are excellent models in comparative functional genomics studies. On the other hand Notothenioidei represent the most important and most specialized fish group in the Southern ocean, occupying all available habitats, but seem to be more sensitive to climate change. These species have been used in a number of studies for elucidation of general principles.

The main focus of the work during the *Polarstern* cruise ANT-XXV/4 will therefore be the collecting of live animals, which is the absolute prerequisite for the continuous work of our department at the AWI. By means of baited bottom traps we aim to catch mainly eelpouts (*P. brachycephalum*), at the Antarctic Peninsula near King George Island (Admiralty Bay). In a parallel expedition of our department to Jubany station during February/March 2009 further cold-adapted animals (fishes, mainly Notothenioidei, and Cephalopods) will become available for further experimentations on live animals in Bremerhaven. Thus, we aim to transport live animals from both expeditions by use of our aquarium container onboard of *Polarstern*.

Work at sea

During the cruise about four baited releaser traps (Posidonia compatible) will be deployed close to King George Island in depths of 400 to 800 metres. The best catches have been obtained during several previous expeditions in Admiralty Bay. After deployment the traps should stay for at least 24 hours at the sea bottom. The release of the traps will be followed by means of the Posidonia system onboard *Polarstern*. Between deployment and recovery of the traps about 18 hours of time is available for transport of live animals and frozen samples (-80° C) from Jubany station to *Polarstern* and other work.

All animals will be kept in the aquarium container (AWI 024) at 0°C water temperature and are going to be transferred alive to Bremerhaven (ANT-XXV/5). Depending on the number of specimens some fish will be acclimated to higher temperature for several days/weeks (to be continued during ANT-XXV/5) and tissue samples will be taken and flash frozen in liquid nitrogen for further molecular genetic and physiological analyses.

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Sonnabend	Hartmut	DWD	Technician
Sudre	Joel	LEGOS, CNRS	Engineer, physical oceanography
Thouron	Daniele	LEGOS, CNRS	Engineer, biogeochemical oceanography
Windisch	Heidrun	AWI	Scientist, biology

13. SCHIFFSBESATZUNG / SHIP'S CREW

No.	Name	Rank
1.	Pahl, Uwe	Master
2.	Grundmann, Uwe	1.Offc.
3.	Krohn, Günter	Ch.Eng.
4.	Bratz, Herbert	2.Offc.
5.	Hering, Igor	2.Offc.
6.	Janik, Michael	3.Offc.
7.	Erich, Matthias	Doctor
8.	Koch, Georg	R.Offc.
9.	Kotnik, Herbert	2.Eng.
10.	Schnürch, Helmut	2.Eng.
11.	Westphal, Henning	2.Eng.
12.	Holtz, Hartmut	Elec.Tech.
13.	Rehe, Lars	Electron.
14.	Dimmler, Werner	Electron.
15.	Fröb, Martin	Electron.
16.	Feiertag, Thomas	Electron.
17.	Clasen, Burkhard	Boatsw.
18.	Neisner,Winfried	Carpenter
19.	Kreis, Reinhard	A.B.
20.	NN	A.B.
21.	Burzan, G.-Ekkehard	A.B.
22.	Schröder, Norbert	A.B.
23.	Moser, Siegfried	A.B.
24.	Pousada Martinez, S.	A.B.
25.	Hartwig-L., Andreas	A.B.
26.	Kretzschmar, Uwe	A.B.
27.	Beth, Detlef	Storekeep.
28.	Kliem, Peter	Mot-man
29.	Fritz, Günter	Mot-man
30.	Krösche, Eckard	Mot-man
31.	Dinse, Horst	Mot-man
32.	Watzel, Bernhard	Mot-man
33.	Fischer, Matthias	Cook
34.	Tupy,Mario	Cooksmate
35.	Völske, Thomas	Cooksmate
36.	Dinse, Petra	1.Stwdess
37.	Hennig, Christina	Stwdss/KS
38.	Streit, Christina	2.Steward
39.	Hischke, Peggy	2.Stwdess
40.	Wartenberg, Irina	2.Stwdess
41.	Hu, Guo Yong	2.Steward
42.	Sun,Yong Sheng	2.Steward
43.	NN	Laundrym.
44.	NN	Appr.
45.	NN	Appr.

ANT-XXV/5

11 April 2009 - 24 May 2009

Punta Arenas - Bremerhaven

Chief Scientists

Walter Zenk (Punta Arenas - Las Palmas)

Saad El Naggar (Las Palmas - Bremerhaven)

CONTENTS

1. ÜBERBLICK UND FAHRTVERLAUF

Walter Zenk (IFM-GEOMAR)

Am 11 April 2009 wird das Forschungsschiff *Polarstern* die Rückreise von Punta Arenas nach Bremerhaven antreten. Die Fahrt wird zur kontinuierlichen Untersuchung atmosphärischer und ozeanischer Eigenschaften sowie der Energie- und Stoffflüsse zwischen Ozean und Atmosphäre genutzt. Folgende Projekte werden durchgeführt:

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

Fernerkundung der Aerosol-Zusammensetzung (in der Atmosphärensäule)
Die Hauptziele sind die Charakterisierung des Aerosols in der Atmosphärensäule, der Konsistenztest mit begleitenden breitbandigen Strahlungsflüssen sowie die Erfassung der zeitlichen Entwicklung von Aerosoleigenschaften, um Aerosol-Wolken-Wechselwirkungen und meridionale Gradienten des troposphärischen Aerosols zu erforschen.

Schiffsgetragene ADCP-Messungen des äquatorialen Strömungssystems
Schiffsgetragene ADCP-Messungen mit *Polarstern* erhöhen die Verfügbarkeit von Strömungsabschnitten und erlauben so das Studium von intra-saisonaler bis saisonaler Variabilität des Transports der Hauptströmungszweige. Darüber hinaus werden die als Referenzdaten für Verankerungsbeobachtungen am Äquator bei 23°W genutzt**.**

Transport lebender Tiere
Lebende Fische aus der Antarktis werden zu molekular-genetischen und physiologischen Untersuchungen nach Bremerhaven transportiert.

Langfristige Veränderungen der Wassertemperaturen in der Tiefsee im Vema-Kanal
Es ist geplant die seit 1972 durchgeführten Temperaturmessungen im Vema-Kanal mit einer weiteren CTD-Station fortzusetzen.

Parasound-Training und POSIDONIA-Tests
In Las Palmas werden zusätzliche Fahrtteilnehmer an Bord kommen, um an einen Kurs zur Erlernung des selbständigen Betriebs des Parasound System P-70 zu erlernen und das POSIDONIA System zu testen.

Am 24 Mai 2009 wird *Polarstern* in Bremerhaven einlaufen.

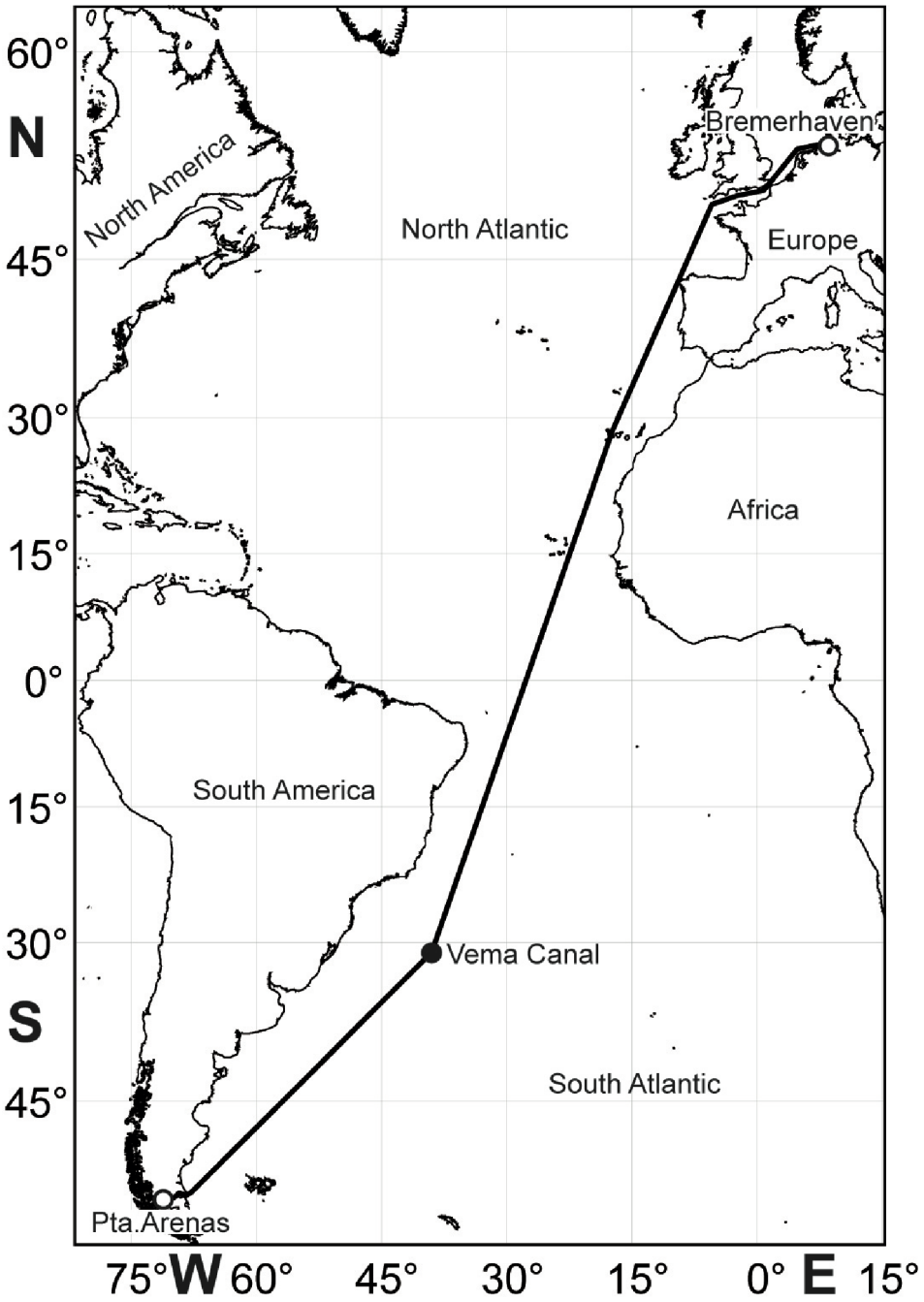

Abb. 1: Fahrtroute ANT-XXV/5
Fig. 1: Cruise track on ANT-XXV/5

ITINERARY AND SUMMARY

On 11 April 2009 *Polarstern* will start its return from Punta Arenas to Bremerhaven. 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 following projects will be carried out:

Autonomous measurement platforms for energy and material exchange between ocean and atmosphere (OCEANET)
In order to provide a solid basis for the observational monitoring of energy and material exchange between ocean and atmosphere it is planned to develop an autonomous observation system for operational use onboard of 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), the GKSS research centre (ferry box, remote sensing of marine biology with ENVISAT/MERIS) and AWI Bremerhaven (CO_2-system, marine infrastructure of *Polarstern*).

Remote sensing of (atmospheric column) aerosol composition
The main goals are to characterize aerosol column properties, check their consistency with associated measurements of broadband radiative fluxes, and to monitor temporal evolution of aerosol properties in order to explore aerosol-cloud interactions and to establish meridional gradients of tropospheric aerosols.

Shipboard ADCP-measurements of equatorial current system
Shipboard ADCP measurements with *Polarstern* will enhance the availability of current sections and thus allow in the future to address the intraseasonal to seasonal variability of the transports of the main current branches. Furthermore, they will be used as a reference data set for the moored observation at the equator at 23°W.

Transport alive animals
Alive fish will be transported to Bremerhaven for further molecular genetic and physiological analyses.

Long-term changes of abyssal temperatures in Vema Channel
It is planned to extend the time series of abyssal temperatures beginning 1972 by an additional CTD station at the Vema Channel.

Parasound training and POSIDONIA tests
In Las Palmas further participants will come on board for a training course for self-efficient operation of the new hull-mount Parasound system P-70 and tests of the POSIDONIA system.

On 24 May 2009 *Polarstern* will return to Bremerhaven.

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

Timo Hanschmann, Michael Schlund, Yann Zoll (IFM-GEOMAR), Henner Sandmann (MedKlim)
Not on board: A. Macke (IFM-GEOMAR)

Objectives

a) Radiation & 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 a handheld sun photometer calibrated and maintained by NASA. The data will enter the Marine Aerosol Network. If available, stand-alone sun-photometer (CIMEL) will be operated under calm sea conditions. In the long run, based on the experiences of this and later Atlantic transects an autonomous measurement container is planned for operational atmospheric monitoring onboard commercial ships. Aerosol measurements

b) Fluctuation of subsurface radiation

Physical, biological and chemical processes in the surface near ocean react in a non-linear manner on the intensity of the available radiation.

A radiation measurement platform developed at IFM-GEOMAR will be deployed to obtain the temporal and spatial fluctuation of the spectral downwelling radiation at various depth. The device will be operated from a zodiac outside the light and wave shadow of *Polarstern*.

c) 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 content in ocean and atmosphere at a lower data rate performed by marine chemist (see section 3) flux parameterizations can be derived.

Work at sea

Upon departure from Punta Arenas the following instruments will be installed onboard *Polarstern* for continuous measurements:

1) Multichannel microwave radiometer HATRPO. The instruments requires occasional calibrations with liquid nitrogen as well as tipp-calibrations under calm sea and homogeneous atmospheric conditions.
2) Ceilometer including tilt measurement device for cloud bottom height measurements.
3) Whole sky imager for cloud structure measurements.
4) Handheld sun photometer (Microtops) for aerosol and cloud optical thickness.
5) Inclinometer for sea surface tilt measurements.
6) Sonic anemometer USA-1 to measure the wind components and temperature.
7) LiCor to measure water vapour and CO_2.
8) M-100 absorption hygrometer to measure water vapour.

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.
Most instruments require only little maintenance.

Expected results

1) 2d 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 longwave radiation.
3) Vertical structure of temperature and humidity as well as its variability for validation of IASI products.
   x) Aerosol optical thickness for clear-sky conditions.
4) All results under mid-latitude, tropical and subtropical climate conditions.
5) Sea surface roughness (tilt angle distribution).
6) Turbulent fluxes of momentum, sensible, and latent heat.
7) Flux of CO_2 between ocean and atmosphere.
8) Flux parameterizations for measured fluxes. (It is expected that this will require more data than those which will be gained during this planned cruise)

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

B. Fiedler, I. Piller (IFM-GEOMAR)
Not on board: A. Körtzinger, T. Steinhoff (IFM-GEOMAR), M. Hoppema (AWI Bremerhaven), H. Zemmelink (NIOZ)

Objectives

This project is part of the WGL-PAKT-Initiative OCEANET which aims to combine the existing expertise of IFM-GEOMAR, GKSS and AWI to further develop, test and install on R/V Polarstern autonomous instrumentation for measurement of exchange of energy and matter between the atmosphere and the surface ocean. The long term goal of this initiative is to provide operational approaches for unattended operation on “Voluntary Observing Ships”.

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. A deconvolution of these driving forces requires both a rather comprehensive observational approach as well as high spatial and temporal coverage. These requirements can only be met with multi-parameter observational approaches that can be operated in unattended mode on platforms such as merchant vessels.

During the first OCEANET cruise in April/May 2008 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, pH, oxygen, total gas tension, nutrients), and biological parameters (chlorophyll a, photosynthetic parameters) and small inter-comparison for measurements of CO_2 partial pressure and oxygen took place. The main focus of this cruise will be field tests for newly developed CO_2 partial pressure sensors and a broader inter-comparison of different sensors to point out the differences of the sensors and their pro and cons. It is a great chance to study heir behavior in different biogeochemical regions.

In addition to the pCO_2 measurements we will also conduct DMS measurements in the surface seawaters and the atmosphere of the East Atlantic Ocean by comparing two different methods: Gas Chromatography and Atmospheric Pressure Chemical Ionization Mass Spectrometry. The atmosphere/ocean flux of DMS should be estimated as oceanic DMS is supposed to have the capacity to regulate local or regional climate through its effect on cloud condensation nuclei concentrations.

Work at sea

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

- Autonomous continuous measurements of CO_2 partial pressure in surface waters with different instruments (AWI, NIOZ, IFM-GEOMAR)
- Autonomous continuous measurements of fluorescence, dissolved oxygen and total gas tension in surface waters (IFM-GEOMAR)
- Discrete water samples for dissolved inorganic carbon and alkalinity will be taken every 6 hours (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.

In addition the comparison of instruments for the measurements of CO_2 partial pressure along the transect will show the pro and cons of the different methods and have the potential to guide further developments.

4. REMOTE SENSING OF (ATMOSPHERIC COLUMN) AEROSOL COMPOSITION

Timo Hanschmann, Michael Schlund, Yann Zoll (IFM-GEOMAR), Henner Sandmann (MedKlim)
Not on board: A. Macke (IFM-GEOMAR)

Objectives

Atmospheric aerosol introduces one the largest uncertainties in our understanding of anthropogenic climate change. Aerosol originates from different sources, has a lifetime of a few days and spans several orders of magnitude in size. Thus, an appropriate regional and seasonal representation in (global) modelling is a challenge.

To capture characteristic aerosol properties and its variability, remote sensing tools are employed. Remote sensing from space provides aerosol data, however, mainly in a qualitative way (due to uncertain background noise and retrieval assumptions). Quality data are usually provided by (long-term) ground remote sensing networks, such as AERONET, where sky-radiance data allow estimates on all relevant aerosol optical properties (amount, absorption, size and shape). Since all AERONET sites are landlocked, the statistics on aerosol data over oceans is relatively sparse. Samples of sun-photometry measurements during the voyage will add to the over-ocean data-base for aerosol optical depth (AOD), size and absorption (via radiance-field inversion techniques) and provide insights on the meridional distribution in April.
(CIMEL sunphotometer and downward solar broadband fluxes)

Aerosol, moreover, interacts with other drivers of anthropogenic change, in particular aerosol interacts with clouds. This is important, since clouds are the main modulators of the Earth's climate. High temporal observations of aerosol prior and past the passing clouds allow the examination of aerosol-cloud interactions.
(microtops handheld sun-photometer)

Work at sea

Upon departure from Punta Arenas the following instruments will be installed onboard *Polarstern* for intermittent and continued measurements (note, continued CIMEL measurements can provide data on cloud properties):

1) Oversee automatic CIMEL sun-photometer measurements,
2) conduct supplementary Microtops handheld sun-photometer sampling,

3) perform real-time closure studies for consistency of aerosol properties and associated broadband (solar) fluxes.

Expected results

1) Improved record on aerosol optical properties over oceans as function of latitude,
2) new insights through correlation with associated atmospheric properties (e.g. wind, cloud micro- and macrophysics)

5. SHIPBOARD ADCP-MEASUREMENTS OF EQUATORIAL CURRENT SYSTEM

Timo Hanschmann, Michael Schlund, Yann Zoll (IFM-GEOMAR), Henner Sandmann (MedKlim)
Not on board: P. Brandt (IFM-GEOMAR)

Objectives

While for the near-surface flows seasonal cycles could be determined from drifter currents and altimetry, reliable transports and seasonal cycle analyses of the subsurface flows from the interior tropical Atlantic that could serve as a calibration base for model simulations have not become available. Recently, however, time series from moored ADCPs were obtained within the context of the Pilot Research Moored Array in the Tropical Atlantic (PIRATA) (Brandt et al. 2006). The mooring activity was continued in the frame of the project BMBF *Nordatlantik*. Within this project a current meter mooring array was deployed at 23°W for the first time in August 2006. While the moored instruments will yield multi-year current observations at fixed positions, ship sections are needed to resolve the complicated structure of the equatorial current system.

Shipboard current observations were used to obtain mean transports of the primary equatorial current branches, particularly the Equatorial Undercurrent (EUC) at 35°W and 26°W (Brandt et al. 2006). However, up to now the available ship sections have not been conclusive concerning the seasonal cycle of EUC transports (Hormann and Brandt, 2007). Shipboard ADCP measurements with *Polarstern* will enhance the availability of current sections and thus allow in the future to address the intraseasonal to seasonal variability of the transports of the main current branches. Furthermore, they will be used as a reference data set for the moored observation at the equator at 23°W.

Work at sea

Polarstern is equipped with a shipboard 150 kHz Ocean Surveyor ADCP. Velocity data were acquired during *Polarstern* cruises ANT-XXII in June 2005 (Brandt et al. 2006) and ANT-XXIII/10 in April 2007. The velocity data obtained after processing were of good quality. Depth range is 200 to 250 m for the whole cruise. Thanks to frequent purposeful deviations from a straight cruise track, the transducer misalignment - which is an essential factor in data processing - could be determined quite well. Those purposeful deviations prove most suitable if the time intervals between course changes are 10 minutes at least and course changes are 10 degrees at least. During the second cruise in April 2007, heading data were available from the Laser-navigation-platform. This heading resulted in slightly lower data quality compared to the previous cruise in June 2005, when the heading from the ASHTECH array was used. It is thus recommended to store heading information from both the Laser-navigation-platform and the ASHTECH array together with the ADCP data. The ADCP

should run as long as possible, i.e. outside the 200 nm zone. Frequent purposeful deviations from the course should be performed twice a day in the region 10°S to 20°N.

References

Brandt, P., F. A. Schott, C. Provost, A. Kartavtseff, V. Hormann, B., Bourlès, and J. Fischer, Circulation in the central equatorial Atlantic: Mean and intraseasonal to seasonal variability, Geophys. Res. Lett., 33, L07609, doi:10.1029/2005GL025498, 2006.

Hormann, V., and P. Brandt, Atlantic Equatorial Undercurrent and associated cold tongue variability, J. Geophys. Res., 112, C06017, doi:10.1029/2006JC003931, 2007.

6. ELEMENTAL MERCURY SEA-AIR FLUX

Joachim Kuss and Martin Kunze (IOW)
Not on board: Bernd Schneider and Detlef Schulz-Bull (IOW)

Objectives

The objective of the study is to determine the elemental mercury (Hg^0) sea-air flux in various geochemical provinces of the Atlantic Ocean. The transect will be the second transect and is done as a seasonal intercomparison to the transect ANT-XXV/1, in the frame of a project funded by the German Science Foundation (DFG). The spatial variability of the Hg^0 flux will be investigated in relation to prevailing biological conditions and physical forcing factors like wind and solar radiation. In addition, during the transect ANT-XXV/5 suspended particulate material will be collected from surface waters for the analysis of persistent organic pollutants (POPs).

Mercury mobilized by anthropogenic activity is introduced into the sea by wet and dry deposition and by river drainage. But the sea could also become a significant source because of Hg^0 sea-air gas exchange. Transformation of ionic mercury to volatile Hg^0 is possibly caused by direct photon-induced reactions and/or by biotic processes in surface waters. The spatial and seasonal variability of the Hg^0 emission has been shown for the Baltic Sea in 2006 (Kuss and Schneider, 2007) and will be investigated in the Atlantic Ocean by the two cruises of *Polarstern*. POPs are released from anthropogenic sources and are subjected to long-range transport in the atmosphere and via ocean currents. The following questions are attempted to be answered during the study:

- How do the atmospheric and oceanic circulations and thus the biogeochemical regimes determine the dissolved Hg^0 and particle associated POPs concentrations in surface waters?
- Is the Hg^0 concentration in surface water related to biological processes?
- Do enhanced Hg^0 concentrations occur mainly in regions with a predominance of primary production or of heterotrophic respiration?
- Is the elemental mercury (Hg^0) emission of the Atlantic Ocean variable in space and time?
- Is the release of Hg^0 controlled by latitudinal-dependent solar radiation?

Work at sea

The Hg^0 concentration in Atlantic surface water will be determined by a new method that rely on measurements of air that is equilibrated with surface water concerning Hg^0 (Kuss and

Schneider, 2007). During the transect seawater is pumped continuously by a clean-seawater supply system and dispersed into the headspace of a 20 L gas bottle by a shower head and drained afterwards. Two water supply systems will be compared during the cruise. Either water is analyzed that will be pumped from below the ships hull by a “snorkel” or from a “fish sampler” (streamlined body that keeps the intake of the tubing at a few metres depth) that will be towed alongside. After about 1 hour the headspace air is in equilibrium with the surface water and Hg^0_{equ} will be subsequently measured by cold-vapour atomic fluorescence spectroscopy. Alternately Hg^0_{atm} will be measured in the marine atmosphere. The Hg^0 sea-air flux is then calculated by using $F=k*(Hg^0_{equ}-Hg^0_{atm})/H$; with the gas exchange transfer velocity k dependent on wind speed, and Henry’s law constant H.

Continuously supplied seawater will be filtered via large glass fibre filters for several hours up to one day for later analysis of particle associated persistent organic pollutants (POPs), Water samples will be regularly taken and subjected to a filtration procedure for the determination of dissolved and particulate organic carbon (DOC/POC), chlorophyll a, and phaeopigments. Filters and filtrates will be stored deep-frozen until analyses that will be done after the campaign in the laboratories of the IOW. From continuously pumped seawater also the partial pressure of CO_2 will be measured by an Equilibrator coupled to a non-dispersive infrared spectrometer.

Kuss, J. and Schneider, B., 2007. Variability of the gaseous elemental mercury sea-air flux of the Baltic Sea. Environmental Science and Technology, 41(23): 8018–8023.

7. ROLE OF TEMPERATURE, CO_2 AND OXYGEN IN EVOLUTION: INTEGRATIVE ECOPHYSIOLOGICAL STUDIES ON FISH AND CEPHALOPODS

Heidrun Windisch, Nils Koschnick (AWI)
Not on board: Rainer Knust, Magnus Lucassen, Felix Mark, Hans-Otto Pörtner (AWI)

Objectives

Temperature has a large impact on all biological processes and is therefore especially important in marine ecosystems. Animal organisms, due to their inherently high levels of organisational complexity, specialize on environmental temperature much more than unicellular bacteria and algae. Accordingly, thermal tolerance windows differ between ectothermal animal species depending on latitude or seasonal temperature acclimatisation and are therefore related to geographical distribution. Tradeoffs and constraints in thermal adaptation become visible when ectotherms specialized on various temperature regimes and their tissues are compared. The hypothesis of oxygen limited thermal tolerance provides a conceptual framework for the investigation of how ectotherms compensate for changing ambient temperatures. Accordingly, thermal limitation becomes effective firstly at high hierarchical levels of organisation, the intact organism, and then at lower levels, cellular and molecular functions. Inadequate oxygen supply likely is the first indicator of cold intolerance in both water and air breathers, however, compensatory mechanisms likely set in before such limits are reached. These limits exert their effects on the growth rate of individual specimens and the abundance of a population thereby shaping the biogeography of a species. Nevertheless, thermal limitations are based on molecular functions and the

integration of single molecules into functional and regulatory networks. Similarly, studying the temperature adaptation of organisms in a changing environment therefore needs to consider the functional integration of single molecules into higher organisational levels.

Evolutionary adaptation to various climates is addressed in our department “Marine Animal Physiology” in comparative studies carried out with populations of the same species in climatic gradients or with congeneric species living in different climatic zones. For example, member species of the fish family Zoarcidae (eelpouts) inhabit temperate, subpolar and polar waters and represent a model system for the study of evolutionary adaptation versus seasonal acclimatisation to temperature. Therefore, a reasonable number of publications of our department have been emerged from studies on Antarctic eelpout (*Pachycara brachycephalum*) and common eelpout (*Zoarces viviparus*). Furthermore, our previous studies have demonstrated the high conservation level of functional genes in different eelpouts from boreal and Antarctic waters, corroborating that these species are excellent models in comparative functional genomics studies. On the other hand Notothenioidei represent the most important and most specialized fish group in the Southern ocean, occupying all available habitats, but seem to be more sensitive to climate change. These species have been used in a number of studies for elucidation of general principles.

The main focus of the work during the *Polarstern* cruise ANT-XXV/5 will be the transporting of live animals, collected during ANT-XXV/4 (fishes) and on a parallel expedition to the Dallmann laboratory on King-George-Island (fishes and cephalopods), for the continuous work of our department at the AWI and for two DFG-funded projects (Lucassen: LU1463/1-1; Mark: MA4271/1-1).

Work at sea

During the cruise we aim to transport live animals from two expeditions by use of our aquarium container onboard of *Polarstern*. Further cooled laboratory containers will serve as backup system. Thus, no station time will be required during this cruise. Depending on the number of specimens some fish will be acclimated to higher temperature for several days/weeks, and tissue samples will be taken and flash frozen in liquid nitrogen for further molecular genetic and physiological analyses onboard *Polarstern* or at the home institute.

8. MAX-DOAS MEASUREMENTS OF ATMOSPHERE TRACE GASES FOR SCIAMACHY-VALIDATION

Jens Tschritter (IUP)
Not on board: U. Platt (IUP)

Objectives

An important aspect of environmental sciences is the knowledge on trace gases and their concentration and distribution in the atmosphere. Tropospheric gases like NO_2, H_2O, HCHO, IO, BrO, O_4 and SO_2 are especially interesting due to their direct impact on humans. Stratospheric gases like O_3, NO_2, BrO, OClO and H_2O may influence the earth’s radiation budget. Measurements of these species can be performed for instance by satellites, as by the instrument SCIAMACHY onboard ENVISAT launched into a polar orbit in March 2002. Figure 2 shows the mean distribution of tropospheric NO_2 between January 2003 and June 2004. To validate satellite-provided data, however, ground-based control-measurements

done at locations beneath the satellite's orbit are necessary. In case of SCIAMACHY, measurements onboard *Polarstern* seem best suited for that purpose, because on the way to and from the Antarctica, the ship follows a polar course corresponding to ENVISAT's orbit.

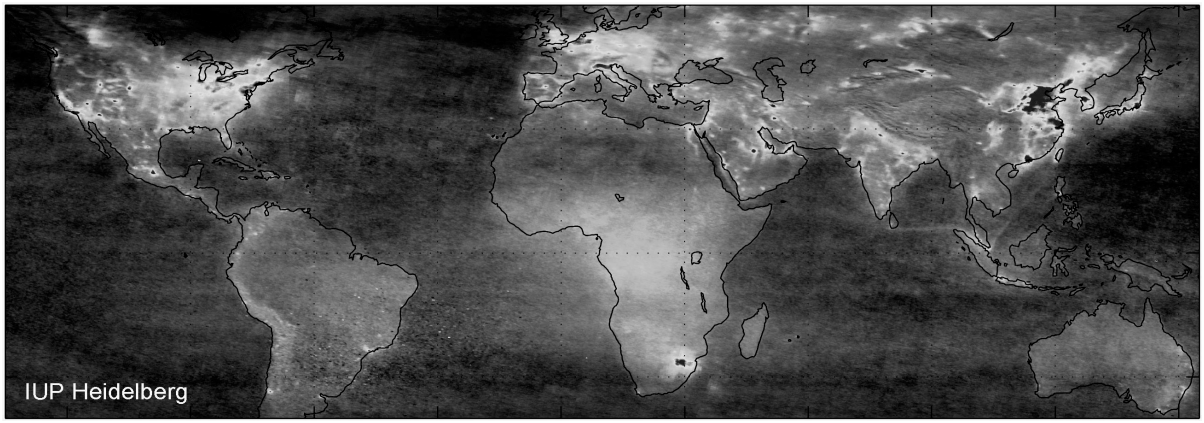

Fig. 2: Mean distribution of tropospheric NO_2 between January 2003 and June 2004 measured by the satellite instrument SCIAMACHY

Work at sea

The method used by the satellite's instrument is the proven Differential Optical Absorption Spectroscopy (DOAS). For this principle, the fact is used that solar light passing through the atmosphere is not only strayed but also absorbed by gas molecules and will thereby yield absorption lines within the gained spectra which are characteristic for each gas compound. From these lines, identity and amount of atmospheric trace gases can be obtained. For ground-based measurements, it is even possible to derive height profiles of the trace gases: light coming in vertical is dominated mainly by absorption of stratospheric gases because. Light coming in more horizontal contains more and more absorption of tropospheric gases due to the longer way of the sunlight through this sphere. This is the so-called Multi-Axis (MAX)-DOAS principle.

The validation instrument onboard *Polarstern* also applies the (MAX-)DOAS measurement principle of the satellites apparatus, of course. Thereby a moveable telescope which is able to point sequentially to the different vertical directions is mounted on a cardanic system to reduce the effect of the ship's movements (see Fig. 3). In its housing it contains not only a stepper motor for movement, but also protective shutters and HgNe- and Halogen calibration lamps. The incoming light is conducted to a cooled miniature Czerny-Turner spectrograph/CCD-detector unit (OceanOptics USB2000) by seven-fold glass fibres. The wavelength range of about 290 to 430 nm allows the retrieval of NO_2, BrO, SO_2, HCHO and others. Last, the gained spectra are stored in PC hard disk for the DOAS analysis. The instrument is working mostly automatically.

Expected results

For instance, measurements performed during the cruise ANT-XIX of *Polarstern* from Bremerhaven to Cape Town using a precursor of the nowadays instrumentation (same instruments, but another configuration of telescope units) feature the concentration of BrO and NO_2: The maxima were reached when the ship passed the English Channel with 3.1 ± 1.1 parts per trillion for BrO and 0.36 ± 0.13 parts per billion for NO_2. This was to be expected from the high air pollution in Europe. Furthermore an anti-correlation of BrO and NO_2 could be observed indicating a reservoir substance formed by the two gases (Diploma

thesis J. Boßmeyer). On further cruises the ship-based DOAS instrumentation should gather data to investigate such events including other trace gases in combination with satellite results. Besides these measurements done mainly for validation purposes, gathering data in Antarctic seas is important for further atmospheric and also climate research.

Ship-based DOAS measurements have been carried out before in the years 1990, 1993 and from 2001 through 2007 with good success from the Heidelberg Institute of Environmental Physics.

Fig. 3: The on-deck instrumentation of the MAX-DOAS instrument. The telescope unit is mounted on a cardanic system whereby the brush is used for braking the movement influenced by the ship's movement.

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9. LONG-TERM CHANGES OF ABYSSAL TEMPERATURES IN VEMA CHANNEL

W. Zenk (IFM-GEOMAR)

Objectives

Major quantities of Antarctic Bottom Water of the South Atlantic spread towards the equator as a deep western boundary current in the Argentine Basin. This process is supposed to play a paramount role in the global thermohaline circulation. On its flow from Antarctic sources to lower latitudes the densest water encounters the Rio Grande Ridge at about 31° S. This topographic constrain acts as a natural barrier for abyssal waters heading for the Brazil Basin farther to the north. The zonal alignment of the rise is disrupted by a narrow gap called Vema Channel. Actually the Vema Channel features a conduit for advected bottom water. Physical measurements at the Vema sill are therefore predestined for long-term observations of property and transport changes of Antarctic Bottom Water. Records of over thirty years in the near-bottom layers in the Vema Channel depict a clear temperature increase beginning in the early 1990s. This positive trend has been repeatedly documented in observations from local CTD stations gathered in international cooperation.

Work at sea

During ANT-XXV/5 it is planned to extend the time series by an additional CTD station at the Vema Channel.

Expected results

The time series of lowest potential temperatures collected from critical locations at the mouth of the Vema Channel since 1972 will be extended. Since 1991 data points have been collected exactly at the same area of the Vema sill, i.e. the location where the coldest core of Antarctic Bottom Water hugs against the eastern wall of the channel. We expect to document if the trend is ongoing or if a new concept has to be developed.

10. PARASOUND: SYSTEM TESTING AND TRAINING UNDER EXPEDITION CONDITIONS

Gerhard Kuhn, Frank Lamy, Jens Matthiessen, Frank Niessen, (AWI), 4 x NN
(all 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, Maria S. Merian* and *Sonne* in 2009-2011. The aim or the system test is to check the Parasound data for correct ship-motion compensation in order to make improvements possible if needed.

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. No stations are required. The area at sea along the routine course track from Las Palmas roadstead to the eastern British Channel is

particularly suitable for Parasound system training because the range of sea-floor topography, sediment penetration and water depth allows to use all possible modes of operation. The work includes 24-hour operation during which participants are running the system under expedition conditions.

11. SEA TRIAL AND TESTS OF THE NEW UPGRADED UNDER WATER NAVIGATION SYSTEM POSIDONIA

Saad El Naggar (AWI), Frederic Bellier (IXSEA), NN (IXSEA)
(all at Las Palmas, Canary Islands for about 6 hours in the roads)

Objectives

The underwater navigation system POSIDONIA was upgraded during the shipyard stay of Polarstern in Bremerhaven. Newly designed hard and software were installed and tested in the harbour of Bremerhaven. New acoustic array and window were fix-installed nearby the moon pool in addition to the mobile acoustic array. A complete new electronic cabinet was installed, modified and tested.

The final sea trial and calibration carried out during the cruise on the way to Las Palmas during ANT-XXV/1 showed serious deficiencies. *In-situ* test of the damaged antenna will be carried out at Las Palmas in roads to find out, the kind and raison of damage occurred to the antenna..

Work at sea

The group will come on board in Las Palmas and carry out tests in roads for about 6 hours and disembark again.

12. FAHRTTEILNEHMER / PARTICIPANTS

Name	Vorname/ First Name	Institut/ Institute	Beruf/ Profession
Bellier	Frederic	IXSEA	Engineer
El Naggar	Saad	AWI	Chief scientist, physicist
Fiedler	Björn	IFM-GEOMAR	Chemist
Hanschmann	Timo	IFM-GEOMAR	Student, meteorology
Koschnick	Nils	AWI	Technician
Kuhn	Gerhard	AWI	Geologist
Kunze	Martin	IOW	
Kuss	Joachim	IOW	
Lamy	Frank	AWI	Geoscientist
Matthiessen	Jens	AWI	Geologist
Niessen	Frank	AWI	Geologist
Piller	Inga	IFM-GEOMAR	Student, chemistry
NN		AWI	
NN		AWI	
NN		AWI	
NN		AWI	
Sandmann	Henner	MedKlim	Physicist
Schlund	Michael	IFM-GEOMAR	Student, meteorology
Sonnabend	Hartmut	DWD	Technician
Tschritter	Jens	IUP	Physicist
Windisch	Heidrun	AWI	Biologist
Zenk	Walter	IFM-GEOMAR	Chief scientist, oceanographer
Zoll	Yann	IFM-GEOMAR	Meteorologist

13. BETEILIGTE INSTITUTE / PARTICIPATING INSTITUTES

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MedKlim	Institut für Medizinische Klimatologie an der Universität Kiel Hermann-Rodewald-Strasse 5 24118 Kiel Germany

14. SCHIFFSBESATZUNG / SHIP'S CREW

No.	Name	Rank
1.	Schwarze, Stefan	Master
2.	Spielke, Steffen	1.Offc.
3.	Farysch, Bernd	Ch. Eng.
4.	Peine Lutz	2. Offc.
5.	Fallei, Holger	2. Offc.
6.	Ettlin, Margrith	2.Offc.
7.	Uhlig, Holger	Doctor
8.	Hecht, Andreas	R.Offc.
9.	Minzlaff, Hans-Ulrich	2.Eng.
10.	Sümnicht, Stefan	2.Eng.
11.	Schaefer, Marc	3.Eng.
12.	Scholz, Manfred	Elec.Tech.
13.	Nasis, Ilias	Electron.
14.	Verhoeven, Roger	Electron.
15.	Muhle, Helmut	Electron.
16.	Himmel,Frank	Electron
17.	Loidl, Reiner	Boatsw.
18.	Reise, Lutz	Carpenter
19.	Guse, Hartmut	A.B.
20.	NN	A.B.
21.	Winkler, Michael	A.B.
22.	Vehlow, Ringo	A.B.
23.	Hagemann, Manfred	A.B.
24.	Schmidt, Uwe	A.B.
25.	Bäcker, Andreas	A.B.
26.	Wende, Uwe	A.B.
27.	Preußner, Jörg	Storek.
28.	NN	Mot-man
29.	Voy, Bernd	Mot-man
30.	Elsner, Klaus	Mot-man
31.	Hartmann,Ernst-Uwe	Mot-man
32.	Pinske, Lutz	Mot-man
33.	Müller-Homburg, Ralf-Dieter	Cook
34.	Silinski, Frank	Cooksmate
35.	Martens, Michael	Cooksmate
36.	Jürgens, Monika	1.Stwdess
37.	Hölger, Irene	Stwdss/KS
38.	Czyborra, Bärbel	2.Stwdess
39.	Silinski, Carmen	2.Stwdess
40.	Gaude, Hans-Jürgen	2.Steward
41.	Möller, Wolfgang	2.Steward
42.	Huang, Wu-Mei	2.Steward
43.	Yu, Kwok Yuen	Laundrym.
44.	NN	Appr.
45.	NN	Appr.