Expeditionsprogramm Nr. 57

FS „POLARSTERN“

ANTARKTIS XVIII / 1 und 2

2000

ALFRED-WEGENER-INSTITUT
FÜR POLAR- UND MEERESFORSCHUNG
BREMERHAVEN

Juli 2000

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FS "POLARSTERN"
ANTARKTIS XVIII/1 und 2
2000

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ANT XVIII/2 - Prof. Dr. Victor Smetacek

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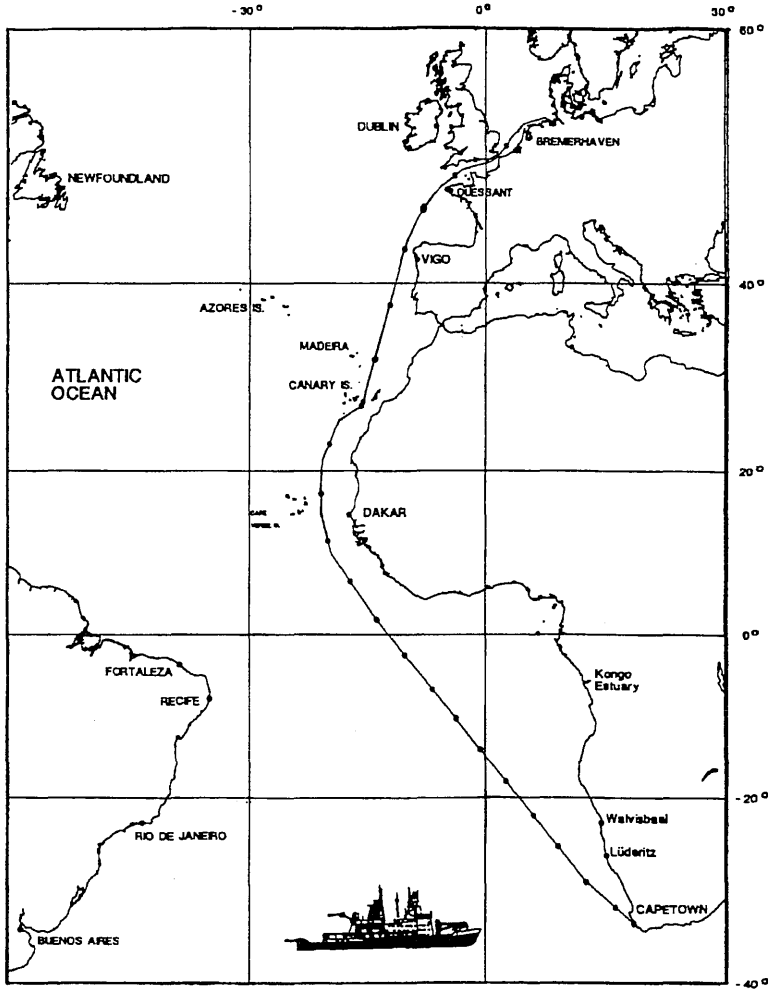

Abb.1: Geplante Route auf ANT XVIII/1 FS "Polarstern"
Fig. 1: Planned Route on ANT XVIII/1, RV "Polarstern"

FAHRTABSCHNITT ANTARKTIS XVIII/1
BREMERHAVEN - KAPSTADT
(29.09. - 23.10.2000)

1. EINLEITUNG = FAHRTLEITER

Dr. Saad El Naggar

Zusammenfassung

Der erste Fahrtabschnitt der 18. Reise der "Polarstern" in die Antarktis wird zur Erprobung von wissenschaftlichen Geräten und zur Durchführung von atmosphärischen Messungen genutzt.

Die Reise wird am 29.09.2000 in Bremerhaven beginnen und am 23.10.2000 in Kapstadt enden. Die "Polarstern" wird auf kürzestem Wege nach Kapstadt geführt (Abb. 1) und die Transferzeit wird ca. 24 Tage betragen. Zur Erprobung der Winden und der Maschinensteuerung werden mehrere Stationen in der Biskaya für ca. 48 Stunden benötigt. Eine andere 4-stündige Station zur Aufnahme einer Verankerung in der nähe von Cape Blanc (21°17 N; 20°43 W) ist geplant. Die wissenschaftlichen atmosphärischen, meereschemischen und luftchemischen Messungen werden bei voller Fahrt des Schiffes durchgeführt.

Ein Teil der Testmannschaft (AWI, INTER, RFL, ROCHEM, MTU, STNH, WERUM) wird am 9.10.2000 in Gran Canaria (Las Palmas) ausgeschifft.

Im Rahmen der Generalreparatur der " Polarstern" wurde die gesamte Windensteuerung durch die Firma STN-Atlas-Elektronik, Hamburg, erneuert. Die Maschinensteurung wurde durch die Firma Motoren und Turbinen Union (MTU), Friedrichshafen, komplett modernisiert. Beide Maßnahmen werden auf See zwischen Bremerhaven und Las Palmas im realen Betrieb getestet und abgenommen.

Das alte Datenerfassungs- und Anzeigesystem der "Polarstern" (PODEV) wurde durch ein auf Echtzeit basierendes System (PODAS) durch die Firma WERUM ersetzt. Implementierung, Test, Abnahme und Inbetriebnahme des neuen Systems wird auf diesem Fahrtabschnitt bis Kapstadt durchgeführt. Dabei werden alle Sensoren angeschlossen, getestet und abgenommen. In diesem Rahmen wurden die alten VMS-Rechner (Digital Equipment) durch auf UNIX-basierende Rechner und Server (SUN Micro System) ausgetauscht. Mehr als 30 Anwender- und Anzeigerechner (COMPAQ, Windows 2000) werden neu installiert und getestet.

Die UV-B-Gruppe des AWI wird während der Reise eine UV-B-Meßkampagne durchführen, die die spektrale UV-Verteilungen (UV-B&UV-A) in Abhängigkeit von den Breitengraden ermitteln soll. Hierfür werden kontinuierliche Spektralmessungen mit dem AWI-Spektrometer durchgeführt. Gleichzeitig werden Dosismessungen mit vom AWI entwickelten Personen-UV-B-Dosimetern (ELUV-14) stattfinden.

Begleitend zu den UV-B-Messungen werden täglich ECC-Ozonsonden zur Sondierung der Atmosphäre und zur Ermittlung der Ozonverteilungen gestartet.
Eine Wissenschaftlergruppe der University of East Anglia, UK, führt verschiedene luft- und meereschemische Messungen durch. CO2-Konzentrationen in Luft und Wasser werden kontinuierlich registriert und analysiert. Aerosole werden mit Saugpumpen und Filter sowie durch Regenwasser gesammelt und auf Eisengehalt untersucht. Biogen halogene Kohlenstoffe werden ebenfalls kontinuierlich gemessen und analysiert.
Der Sonderfachbereich SFB 2612 der Universität Bremen (Geowissenschaften) untersucht durch Langzeitverankerung in der nähe von Cape Blanc (21°17 N; 20°43 W) den Partikelfluss der Sahara. Eine Verankerung wird dort geborgen und durch eine neue ersetzt.
Die Arbeitsgruppe Luftchemie am Institut für Umweltphysik, Uni Heidelberg, möchte dieses Jahr DOAS-Streulichtmessungen (differentielle optische Absorptions-Spektroskopie), bei denen atmosphärische Spurenstoffe anhand ihrer Lichtabsorption detektiert werden, bis Kapstadt durchführen.
Die Spurenmetallgruppe von NIOZ wird den Eisengehalt des Obflächenwassers während der Anreise bestimmen. Hierfür wird das Seewasser mit einer Spezialeinrichtung angesaugt und analysiert. Ein Vergleich der Meßmethoden wird durchgeführt.

1. INTRODUCTION = CHIEF SCIENTIST
Dr. Saad El Naggar

Summary of cruise ANT XVIII/1
The first leg of the 18th Antarctic cruise of RV "Polarstern" will start in Bremerhaven on 29.09.2000 and will be completed in Cape Town on 23.10.2000. During this cruise different scientific instrumentations will be tested and an atmospheric marine program will be carried out. The ship will sail on the shortest way to Cape Town (Fig. 1). The transfer time will be about 24 days including 2 days for station works between Bremerahaven and Las Palmas for testing the winchs and the new machine control system. An other station of about 4 hours will be nearby Cape Blanc to recover one mooring at approx. 21°17 N; 20°43 W and redeploy it at the same position. A part of the testing crew (AWI, INTER, RFL, ROCHEM, MTU, STNH, WERUM) will disembark on 09.10.2000 in Gran Canaria (Las Palmas).
During the third step of the Midlife Conversion (MC) of "Polarstern" between 29.8.2000 - 29.09.2000 in Bremerhaven, the main machine control system was replaced by the company "Motoren und Turbinen Union, (MTU)", Friedrichshafen. The winch's power supply and control system was also replaced by the company "STN-Atlas-Elektronik", Hamburg and Bremerhaven. Sea trials of the mentioned systems will be carried out during this cruise.
The old data acquisation and display system of "Polarstern" (PODEV) was replaced by a new (PODAS) on a real-time based data management system (RTDBMS). The company

WERUM, Lüneburg has been developed this software package and will do the sea trial during the cruise.
The on VMS-based computers (Digital Equipment) were replaced by SUN-Server (UNIX-based). More than 30 Compaq computers (Windows 2000) are installed for data display and acquisation. Installation and tests of the hardware will be carried out.
The UV-B-group of AWI will measure the UV-B-distributions (spectral and doses measurements) as a function of latitude. The AWI-spectrometer (UV-B & UV-A) and the electronic UV-B-personal dosimeter (ELUV-14) will be used. Calibration of instruments will be done. In addition, ozone profile sounding will be carried out to compare it with the UV-B-measurements.
A scientfic group from University of East Anglia, UK, will carry out different on-line measurements during the cruise:
- Aerosol and rain samples will be collected using Graseby-Anderson high-volume samplers and collection funnels to determine the deposition of iron to Atlantic surface waters.
- Biogenic production of volatile organo-halogen and organo-nitrogen compounds in seawater will be measured and analysed.
- Quantifying the air-sea exchange of carbon dioxide will be the third programme of this group during this cruise.
The geoscience department of the University of Bremen, SFB 261, is monitoring the Sahara dust deposition to the Atlantic waters by using a mooring system located nearby Cape Blanc (21°17 N; 20° 43 W). The mooring will be recovered and a new one will be deployed at the same location.
The institute of environmental Physics of the university of Heidelberg will carry out Differential Optical Absorption Spectroscopy (DOAS) measurements during the cruise to determine the distributions of different chemical tracers in the atmosphere.
The trace metal group from NIOZ will make continuous underway measurements of dissolved iron using a towed fish and trace metal clean pumping system. Intercalibration of measuring systems will be carried out.

2. ABNAHME UND ERPROBUNG DER NEUEN INSTALLATIONEN

(AWI, INTER, RFL, ROCHEM, STNH, MTU)

Während der dritten Phase der Generalreparatur des FS „POLARSTERN" vom 29.08.2000 – 29.09.2000 wurden folgende Umbaumaßnahmen realisiert:

Austausch des VAX-VMS-Rechners gegen 3 Sun-Enterprise 250-Server.
Austausch der alten Anzeigerechner gegen neue COMPAQ-DESKPRO ENS 6600 (30 Stück).

Austausch des alten Datenerfassungssystems PODEV gegen eine neue auf UNIX- und Real-Time-Datenbank basierende Software (PODAS).
Abrüstung der wissenschaftlichen Navigationsanlage ANP 2000. Als Ersatz dafür wird die Navigationsanlage NACOS –55-3 nach Anpassung der Sensorik eingesetzt.
Abrüstung des Differential GPS-(DGPS)-Systems von RACAL SURVEY. Die Genauigkeit des GPS-Systems wurde durch die US-Regierung seit dem 01.05.2000 nicht mehr künstlich herabgesetzt und liegt nun bei ca. 18 m. Selective Availability (SA) ist abgeschaltet.
Abrüstung des GPS-Rechners (VAX 4000).
Modernisierung der Hauptmaschinensteuerung.
Modernisierung der Versorgung und Steuerung der Winden.
Auf dem Teilabschnitt Bremerhaven – Las Palmas werden die installierten Systeme im realen Betrieb getestet und abgenommen.
Die Integration der neuen Erfassungssoftware PODAS wird bis Kapstadt ergänzt und abgenommen.
Zur Abnahme von Maschinen- und Windensteuerungen sind Stationen von ca. 48 Stunden geplant.

2. SEA TRIAL OF THE NEW INSTALLATIONS CARRIED OUT DURING THE THIRD PHASE OF MIDLIFE CONVERSION OF RV „POLRASTERN"

(AWI, INTER, RFL, ROCHEM, STNH, MTU)

RV "POLARSTERN" was at the Lloyd Werft shipyard, Bremerhaven, from 29.08.2000 – 29.09.2000, where the third phase of the Midlife Conversion (MLC) was carried out.
Following main installations were made:

Replacement of all VAX-VMS-computers by three SUN-Enterprise-250-Servers.
Replacement of all info terminals by COMPAQ-DESKPRO ENS 6600 computers with TFT-display (30 pieces).
The old data acquisition system PODEV is replaced by the new PODAS, based on Real Time Data Based Management System (RTDBMS).
The scientific navigation unit "ANP 2000" was dismantled. The new navigation system (NACOS-55-3) was modified to replace the "ANP 2000".
Differential GPS (DGPS) of RACAL SURVEY was operationally stopped, due to the fact that the GPS system has now an accuracy of 18 m without DGPS. Selective availability (SA) was disabled since 01.05.2000.
GPS-workstation was removed and replaced by different GPS-receivers and integrated navigation system (MINS).
The main machine control system was replaced by a new one based on the newest technology.

Supply and control system of the winch was dismantled and replaced by a state of the art system.
Between Bremerhaven and Las Palmas all newly installed equipments and systems will be tested. The planned test time will be about 48 hours.

3. FORSCHUNGSPROGRAMME / SCIENTIFIC PROGRAMME

Ozonverteilung, UV-Strahlung und UV-B Dosimetrie
(AWI/UV-B-Gruppe)

Die solare UV-B-Strahlung hat bedingt durch den Ozonabbau zugenommen. Die Auswirkung dieser Strahlenbelastung auf die Biosphäre ist heute ein Schwerpunkt vieler wissenschaftlicher Programme. Ziele des Forschungsvorhabens sind:
- Messung der meridionalen Ozonverteilung (Stratosphäre & Troposphäre).
- Messung der meridionalen spektralen UV-B- und UV-A-Strahlungsverteilung.
- Bestimmung der globalen UV-B-Dosis auf dem meridionalen Abschnitt zwischen Bremerhaven und Kapstadt unter Verwendung des Polysulphondosimeters und des elektronischen UV-B-Dosimeters ELUV-14.
-Bestimmung der maximalen Tagesdosis in Abhängigkeit von der Sonnenhöhe und Ozonkonzentration. Für die Risikoabschätzung werden Vergleichsdaten benötigt. Diese sollen auf meridionalen Abschnitten zu verschiedenen Jahreszeiten ermittelt werden. Dadurch gewinnt man die maximal zu erwartende Dosis auf Meeresniveau und deren Variationen.

Das Arbeitsprogramm umfaßt:
- Bestimmung der Ozonkonzentrationen mit Radiosonden.
- Exponieren der verschiedenen Dosimeter zur Bestimmung der globalen Tagesdosis.
- Spektrale Messung der solaren UV-Strahlung mit Hilfe eines UV-A & UV-B Spektralradiometers.

3.1 Ozone Distributions, UV-Irradiances And UV-B-Dosimetry
(AWI/UV-B-Gruppe)

Due to the ozone depletion during the last years, increased UV-B-solar radiation was observed. A personal dosimetry program has been started at Alfred-Wegener-Insitute to quantify the impacts of the UV-B-radiation on human beings in Antarctica and Arctica. This program includes the use of polysulphone dosimeter and an electronic dosimeter (ELUV-14). The ELUV-14 dosimeter was specially developed for this purpose.

During the cruise ANT XVIII/1 of RV "Polarstern" the global UV-B doses distributions will be measured as a function of latitudes. We expect to measure the maximum available UV-B exposures at sea level. These data are needed to calculate the risk factor of UV-B exposure on the ice shelf. Spectral UV-irradiances (UV-B&UV-A) will be continuously measured by the AWI-UV-Spectrometer.
Objectives of these campagne are:
- Determination of the golbal UV-B doses as a funktion of latitude, sun elevation and ozone by using different dosimeters (Eluv-14, Biosense, Polysulphone, Biometer).
- Finding out the maximum daily doses at sea level.
- Measuring the spectral UV-B- and UV-A-distributions by AWI-spectrometer.
- Measuring the ozone column densities and profiles by using ECC-Ozone sondes.

3.2 Das neue Datenerfassungssystem der "Polarstern" PODAS

(AWI/ Informationszentrum, AWI/ Logistik, RFL, WERUM)

Die automatische Datenerfassung erfolgt im Observatoriumsbetrieb auf "Polarstern" über Sensoren, die über Analog-Digital-Wandler und Datalogger und dem bordeigenen Netzwerk an einen zentralen Server angeschlossen sind.
Im dritten Abschnitt der Generalreparatur von FS "Polarstern" wurde die seit 1992 in Einsatz befindliche PODEV Software durch eine kommerzielle, konfigurierbare Datenverwaltungssoftware für die Meßdatenerfassung (Realtime- oder Echtzeit-Datenbankmanagementsysteme) ersetzt.
Vorteile des neuen Polarstern Data Systems (PODAS) sind:
- Erheblich verringerte Programmieraufwand, da die Software in weiten Bereich nicht mehr erstellt sondern nur noch konfiguriert werden muß.
- Die größere Sicherheit, da bei einer Störung alle Daten bis zum letzten vollständig übermittelten Meßwert konsistent erhalten bleiben.
- Die bessere Verfügbarkeit, da Daten, die in eine Echtzeitdatenbank geschrieben werden, sofort nach dem Eintrag sichtbar sind.
- Die bessere Qualitätskontrolle der Experimente und die bessere Weiterbearbeitung im AWI, da die Meßdaten bereits im Datenbankformat vorliegen und eine Konvertierung in das hauseigene Datenbank Format (SYBASE) schnell und einfach möglich ist.
- Die Sicherheit bei der Datenerfassung, die Qualität der aufgezeichneten Daten und die spätere Verfügbarkeit wird durch den Einsatz solcher Systeme erheblich verbessert.

Auf der Fahrt ANT XVIII/1 der "Polarstern" wird PODAS-System in den operativen Einsatz gehen. An Bord werden die notwendigen Anpassungen und Abstimmungen, die nur im operativen Betrieb vorgenommen werden können, programmiert und die endgültige Abnahme durchgeführt.

3.2 The new data acquisation system of "Polarstern"; PODAS

(AWI/ Informationszentrum, AWI/ Logistik, RFL, WERUM)

Automatic data acquisition on the RV "Polarstern" is carried out on sensors connected to data loggers which are driven by PCs or workstations sending their data over the local area network (LAN) to a central server.
A new data acquisition and control software PODAS based on a real-time data management system (RTDBMS) will replace the old PODEV system on board. RTDBMS are 'commercial systems of the shelf (COTS)' fulfilling most of the requirements of complex data acquisition.
Advantages of the operation of RTDBMS are:
- less programming efforts, because the software has only to be configured for specific problems
- more security due to transaction processing
- better quality control through on-line viewing capabilities
- easier processing in the laboratories due to comfortable data conversion into a relational database management system.

On ANT XVIII/1 the PODAS System will become operational. Adaptions which could only be performed on board, will be programmed and the system handed over for continuos operation.

3.3 Langzeitliche Partikelflussuntersuchungen im Auftriebssystem vor Cape Blanc (Mauretanien)

(UB/ SFB 261)

Seit 1988 werden Partikelflussstudien im Gebiet vor Kap Blanc (Mauretanien) durchgeführt, die in den SFB 261 (FB Geowissenschaften Univ. Bremen, AWI) eingebunden sind. Die Station wurde bisher überwiegend mit dem Forschungschiff METEOR bedient. Es ist vorgesehen, die Untersuchungen über möglichst viele Jahre hin fortzusetzen, da sich aus anderen Langzeituntersuchungen im oligotrophen Ozean (z.B. von der Bermuda oder Hawaii Time-Series-Station) erhebliche interannuelle Variationen im Partikelfluß ergeben haben, die auf langzeitlich schwankende Oberflächenwassermassenbedingungen zurückzuführen sind. Unsere mesotrophe Station befindet sich im Randbereich des saisonal wandernden Kap Blanc Filamentes, welches z.T. mehrere 100 km in den offenen Ostatlantik hineinreicht. Bisherige Auswertungen zeigen deutliche interannuelle Schwankungen der Stoffflüsse, die evtl. mit großräumigen Klimavariationen (z.B. NAO) zusammenhängen. Am Probenmaterial dieser „Langzeit-Station" evaluieren und vergleichen wir außerdem verschiedene Proxies (vor allem für die Wassertemperatur, Nährstoffgehalte und Produktion), um so eine zuverlässigere Interpretation von Sedimentkerndaten zu

ermöglichen. Die Station ist ferner geeignet, den Einfluss des äolisch eingetragenen Saharastaubes auf die Partikelsedimentation und den Export von organischem Kohlenstoff in den tiefen Ozean zu untersuchen. Auf ANT XVIII/1 ist geplant ein Verankerungsystem mit zwei Sinkstofffallen und einem Strömungsmesser bei ca. 21°17 N; 20°43 W aufzunehmen und an etwa gleicher Position wieder auszusetzen.

3.3 Long-term particle flux studies in the upwelling system off Cape Blanc (Mauretania)

(UB/SFB 261)

Since 1988, long-term particle flux studies have been performed in the Cape Blanc region, (Mauretania) within the scope of the Special Research project (SFB 261, Dept. of Geosciences, AWI). This site was mainly supplied with the research vessel METEOR. It is planned to continue these investigations over many years. Other long-term studies from open ocean sites (Bermuda and Hawaian Time Series) have proven a distinct long-term variability of particle fluxes, related to changing surface water conditions. Our mesotrophic site is located at the edge of the seasonally moving Cape Blanc filament, which travels several 100 km offshore into the open eastern Atlantic. Our results show strong interannual variation of particle fluxes probably corresponding to larger scale climatic fluctuations such as the NAO. We further use this material to evaluate and compare a variety of proxies (e.g. for SST, nutrients and production) necessary for a reliable interpretation of sediment core data. This site is also suitable to study the influence of saharan dust on particle sedimentation and the export of organic carbon to the deep ocean. On this POLARSTERN cruise we plan to recover one mooring at approx. 21°17 N; 20°43 W and redeploy it at the same position.

3.4 DOAS-Streulichtmessungen an Bord der Polarstern

(UH)

Mit Hilfe der Differentiellen Optischen Absorptions-Spektroskopie (DOAS) können simultan viele Spurenstoffe in der Atmosphäre gemessen werden. Dabei dienen besonders schmalbandige (< 5nm) Absorptionsstrukturen, die charakteristisch für das jeweilige Molekül sind, zur Identifizierung und Quantifizierung der einzelnen Spurenstoffe. Als Lichtquelle dient neben künstlichen Quellen vor allem die Sonne, sowohl bei Direktlichtmessungen gegen die Sonne als auch bei Messung des Himmelsstreulichts (im Zenit oder unter bestimmtem Winkel zum Zenit).

Bei der Polarsternfahrt, bei der der Atlantik von Nord nach Süd überquert wird, bietet sich während der Überfahrt von Bremerhaven (53°N) nach Kapstadt/Südafrika (33°S) die

Gelegenheit, die Breitenverteilung vieler wichtiger und interessanter Spurenstoffe (NO2, Ozon, BrO, ...) zu untersuchen.
Bei früheren Polarsternfahrten (Oktober/November 1990 bzw. Oktober/November 1993) waren bereits Breitenverteilungen von NO2 und Ozon von Mitgliedern unseres Instituts gemessen worden [Kreher et al. 1995, Senne et al. 1996]. Bei dieser Fahrt soll insbesondere die Frage von troposphärischen BrO-Vorkommen untersucht werden. In der Stratosphäre hat BrO maßgeblichen Anteil am Ozonabbau. Kürzliche Veröffentlichungen legen auch troposphärische BrO-Vorkommen nahe, die den troposphärischen Ozonhaushalt beeinflussen, stützen sich aber auf indirekte Methoden. Direkte Messungen von BrO während der Polarsternfahrt sollen diese Lücke schließen. Als Messgerät dient ein Streulicht-DOAS-System mit entsprechender Einkoppeloptik, einem am Institut gebauten Spektrographen sowie der dazugehörigen Elektronik. Durch Off-Axis-Streulicht-Messungen wird die Troposphäre gegenüber der Stratosphäre stärker gewichtet, so daß Messungen von troposphärischem BrO möglich sind.

Publikationen:
K. Kreher, M. Fiedler, T. Gomer, J. Stutz, und U. Platt, The latitudinal distribution (50°N-50°S) of NO2 and O3 in October/November 1990, Geophys. Res. Lett., Vol. 20, No. 10, P 1217-1220, 1995
T. Senne, J. Stutz und U. Platt, Measurement of latitudinal distribution of NO2 column density and layer height in Oct./Nov. 1993, Geophys. Res. Lett., Vol. 23, No. 8, P. 805-808, 1996

3.5 Testinstallation eines Magnetometersystems auf FS Polarstern

(AWI/Geophysik, AWI/Potsdam)

Erste Testmessungen im Mai/Juni 2000 auf FS Polarstern haben gezeigt, daß Messungen des Erdmagnetfeldes mit einem fest installierten Sensor überraschend gute Ergebnisse geliefert hat. Allerdings wurden die Daten durch asynchrone Übertragung des Zeitstempels mit der entsprechenden Lageinformation für das Schiff, künstlich verrauscht. Diese Fehler sollen mit der Neuinstallation der Datenerfassung auf FS Polarstern behoben werden.
Ziel der erneuten Testmessungen ist es, die Datenerfassungssoftware für das Magnetometer an die neuen Formate und Rechnerbedingungen anzupassen. Voraussichtlich stehen bei Rückfragen Repräsentanten verschiedenen Firmen direkt bei der Überfahrt zur Verfügung, um evtl. auftretende Probleme schnell zu lösen. Der Test beinhaltet mehrere Drehkreise während der Überfahrt, um den Kompensationsalgorithmus zu überprüfen. Nach erfolgreichem Test soll endgültig über eine entsprechende Installation entschieden werden.

3.5 Test installation of a magnetometer system on board of FS Polarstern

(AWI/Geophysik, AWI/Potsdam)

First test measurements during May/June 2000 on RV "Polarstern" showed, that recordings of the Earth's magnetic field from a fixed mounted sensor are surprisingly of excellent quality. However, during the leg problems with the computer system and the distributed time and navigation information were encountered. This produced extra noise on the data. This problems should be solved with the installation of the new computer system for the data distribution onboard Polarstern.

Objective of the new test measurements is to adapt the data acquisition software of the magnetometer to the new formats and computer system. During the leg representatives of several companies will be onboard to help solving problems with the new computer installation. This guarantees a fast solution of problems which might occur. The test includes several turns during the transit towards the south to check the compensation algorithm. After a successful test a final decision for a fixed-mounted magnetometer will be made.

3.6 Deposition of iron to Atlantic surface waters

(UEA)

Transport of airbourne dust from the continents provides a route by which iron can enter remote surface ocean waters. This transport may be of particular importance in HNLC areas where iron appears to be the limiting nutrient for phytoplankton growth. Dust transport is episodic and many aspects of iron deposition are currently uncertain – what fraction of dust is deposited in rainfall; how much of the iron is actually soluble; what is the redox speciation of the iron; what processes control iron solubility?

During ANT XVIII/1 aerosol samples will be collected using Graseby-Anderson high-volume samplers. Samples collected during the transect past West Africa will be of particular interest, as the Sahara is a major source of dust to the atmosphere. In the event of rain, collection funnels will also be deployed. Aerosol and rain samples will be analysed for iron concentration and redox speciation. The extent of organic complexation of iron in rainwater will also be determined, if sample volumes allow. Dust collected during the cruise will be used in process-oriented laboratory studies at UEA.

3.7 Biogenic production of volatile organo-halogen and organo-nitrogen compounds in seawater (UEA)

Low molecular weight halogenated hydrocarbons (halocarbons) have been shown to be produced by various species of macroalgae and phytoplankton. These gases, when transported across the sea surface into the atmosphere, play a potentially important role in tropospheric photo-oxidant chemistry and as precursors of reactive species that can destroy ozone. Oceanic fluxes of many halocarbons, eg iodocarbons, have large uncertainties associated with them. Alkyl nitrates ($RONO_2$) are an important NO_y reservoir species which play a role in a variety of atmospheric processes such as tropospheric and stratospheric ozone production and destruction. Atmospheric measurements in remote oceanic regions led to suggestions that the tropical ocean is a significant source of alkyl nitrates (Atlas et al, 1993; Blake et al, 1999 & refs therein).

I will be measuring surface seawater concentrations of several biogenic halocarbons, e.g. methyl iodide, chloroiodomethane, bromoform, diiodomethane, bromodichloromethane, dichlorobromomethane and also methyl and ethyl nitrate by purge-and-trap GC-ECD. Air samples will also be measured on board to coincide with seawater samples and samples for phytoplankton pigments will be collected, to

3.8 Air-sea exchange of carbon dioxide in the eastern Atlantic Ocean (UEA)

The fugacity of carbon dioxide (fCO_2) and dissolved inorganic carbon (DIC) content in surface water will be continuously monitored, as well as fCO2 in marine air, between Bremerhaven and Capetown. The DIC measurements will be made with a coulometer kindly made available by the Netherlands Institute for Sea Research (NIOZ).
These surface water CO_2 data will represent a valuable sequel to measurements in October/November 1993 (ANT XI/1) and in May/June 1994 (ANT XI/5) along a similar transect (Bakker, 1998; Bakker et al., 1999a, 1999b). Comparison of the data in October-November 1993 with the 2000 data will show whether surface water fCO_2 in the eastern Atlantic Ocean has increased by 1.4 µatm yr^{-1} in response to the increase of the atmospheric CO_2 level, as observed in other oceanic regions. The annual increase of surface water fCO_2 in various oceanic regimes remains one of the main uncertainties in estimates of the net global oceanic CO_2 uptake (Takahashi et al., 1995, 1997, 1999).

Collocation of the CO_2 data with satellite observations of ocean colour (SEAWIFS) and sea surface water temperature (AVHRR) will allow situating the surface water fCO_2 and DIC measurements in a wider context of oceanic circulation and biological activity. The product

of the fCO_2 difference across the sea surface and the gas transfer velocity, which is taken as a function of wind speed, will provide an estimate of the CO_2 air-sea flux along the ship's cruise track.

Little is known about the interannual variability of CO_2 air-sea exchange in the equatorial and South Atlantic Ocean. Variability in the strength of coastal and equatorial upwelling is likely to affect the CO_2 air-sea flux in the equatorial (Bakker et al., 2000) and eastern Atlantic Ocean. It remains an open question whether a low salinity area with fCO_2 below the atmospheric value between 0° and 10°N, east of 25°W (Lefèvre et al., 1998; Bakker et al., 1999a, 1999b), is a permanent or temporary feature. Combination of surface water fCO_2 measurements collected during ANT XVIII/1 with existing data will contribute to a better quantification of CO_2 air-sea exchange and its annual and seasonal variability in the eastern Atlantic Ocean.

3.9 Continuous measuremnts of dissolved iron and system intercalibration

(NIOZ, UoP, UEA)

During the anreise, the trace metal group from NIOZ will make continuous underway measurements for dissolved iron using a towed fish and trace metal clean pumping system. This will allow surface samples to be taken along the cruise track from Bremerhaven to Cape Town. Several other trace metal groups from around the world will also be on board performing similar measurements, but using different equipment to that at NIOZ, as part of the first stage of an intercalibration for iron at open ocean concentrations. At the present time there are several different methods for the determination of iron at sub nano-molar levels ($< 1 \times 10^{-9}$ mol/L), but no comparison between these methods has been made until now. The chemistry of iron in seawater is very complex, and the different analytical methods used for measuring iron may not all be measuring the same concentrations for chemical reasons. For this reason it is important that the various methods are used on the same fresh samples so that we can fully understand the differences between the methods and what that tells us about the chemistry. This work is of extreme importance, as iron has been shown to be a major limiting factor for primary productivity in many open ocean regions, noticeably the Southern Ocean. Further to this work, in a low iron region, south of the Equator, a large volume sample (1 m^3) for total dissolved iron will be obtained, stored, sub-sampled and later distributed to other laboratories (approximately 20) from around the world, who are participating in the iron intercomparison.
This large volume sample will form the first step in the production of a certified reference material for low iron ($<0.3 \times 10^{-9}$ mol/L) waters. This work takes place under the auspices of a joint IUPAC/SCOR program (working group 109) and is funded in part by the EU project IRONAGES (A collaboration between 12 partners, coordinated by NIOZ, partners include AWI and the University of Plymouth.

4. BETEILIGTE INSTITUTIONEN/ PARTICIPATING INSTITUTIONS ANT XVIII/1

Adresse/Address		Teilnehmer/Participants
AWI	Alfred-Wegener-Institut für Polar- und Meeresforschung Postfach 12 01 61 27515 Bremerhaven, Germany	9
DWD	Deutscher Wetterdienst Seewetteramt Bernhard-Nocht-Straße 20359 Hamburg, Germany	2
INTER	Interschalt Oberbrooksweg 42 22869 Schenefeld /Hamburg	1
IRI/ Delft	Interfacultair Reactor Instituut Technische Universiteit Delft Melkweg 15 2629 JB Delft, The Netherlands	2
MTU	Motoren und Turbinen Union Werk 3 88040 Friedrichshafen, Germany	3
NIOZ	Netherlands Institute for Sea Research Postbus 59, 1790 AB Den Burg – Texel, The Netherlands	5
RFL	Reederei F. Laeisz, Bremerhaven Barkhausen-Str.37 27568 Bremerhaven,	3
ROCHEM	Rochem UF-Systeme GmbH Stadthausbrücke 1-2, Fleethof D–20355 Hamburg, Germany	1

STNH	STN-Atlas-Elektronik GmbH Behringer-Str. 120 22763 Hamburg, Germany	4
UB	Universität Bremen Fachbereich Geowissenschaften, SFB 261 Klagenfurter Strasse 28359 Bremen, Germany	2
UBO	Université de Bretagne Occidentale (University of Brest, UMR CNRS 6539) Institut Universitaire Europeen de la mer Place Nicolas Copernic 29 280 PLOUZANE, FRANCE	2
UEA	University of East Anglia School of Environmental Sciences Norwich NR4 7TJ, United Kingdom	3
UH	Universität Heidelberg Institut für Umweltphysik Im Neuenheimer Feld 229 69120 Heidelberg, Germany	1
UoP	University of Plymouth Dept. of Environmental Sciences Plymouth PL4 8AA, United Kingdom	2
WERUM	Werum GmbH Erbstorfer LandStr. 14 21337 Lüneburg	4

5. FAHRTTEILNEHMER /PARTICIPANTS ANT XVIII/1

Name/Name	Institut/Institute	Nationalität/Nationality
Bluszcz, Taddäus	AWI/Chemie	D
El Naggar, Dr. Saad (Chief Scientist)	AWI/Logistik	D
Gerchow, Peter	AWI/Infozentrum	D
Hofmann, Michael	AWI/Logistik	D
Krause, Dr. Reinhard	AWI/Logistik (Las Palmas)	D
Reinke, Dr. Manfred	AWI/ Infozentrum	D
Kopsch, Conrad	AWI/Potsdam	D
NN	AWI/Geophysik	D
NN	AWI/UV-Gruppe	D
Knuth, Edmund	DWD	D
Köhler, Herbert	DWD	D
Drauschke, Peter	INTER	D
Thomas, Dr. Hans-Jürgen	MTU (Las Palmas)	D
Längin, Hans-Dieter	MTU (Las Palmas)	D
Müller, Markos	MTU (Las Palmas)	D
Boye, Marie	NIOZ I + II	F
Croot, Dr. Peter	NIOZ I + II	NZL
Gerringa, Dr. Loes	NIOZ	NL
Laan, Patrick	NIOZ I + II	NL
Rijkenberg, Micha	NIOZ I + II	NL
Fischer, Astrid	NIOZ/(IRI, Delft) I + II	NL
Kroon, Koos	NIOZ/(IRI, Delft) I + II	NL
Wagner, Eberhard	RFL (Las Palmas)	D
Manthei, Wolfgang	RFL (Las Palmas)	D
Hofmann, Dr. Jörg	RFL	D
Neuhäuser, Uwe	ROCHEM (Las Palmas)	D
Bade, Dirk	STNH (Las Palmas)	D
Heckel, Christian	STNH (Las Palmas)	D
Wolke, Günther	STNH (Las Palmas)	D
NN	STNH (Las Palmas)	D
Schäfer, Raphael	UB	D
Segl, Dr. Monika	UB	D
Blain, DR. Stephane	UBO	F
Sarthou, DR. Geraldine	UBO	F
Baker, Dr. Alex	UEA	UK

Bakker, Dr. Dorothee	UEA	NL
Chuck, Adele	UEA	UK
Leser, Hans	UH	D
Achterberg, DR. Eric	UoP	UK
Bowie, Dr. Andy	UoP	UK
Schmidt, Horst	WERUM (Las Palmas?)	D
Sommer, Christian	WERUM (Las Palmas)	D
Viergutz, Thomas	WERUM	D
Zenker, Uwe	WERUM	D

6. SHIP'S CREW / SCHIFFSBESATZUNG ANT XVIII/1

Master	Keil, Jürgen	
1. Offc.	Grundmann, Uwe	
2. Offc.	Spielke, Steffen	
Ch.Eng.	Schulz, Volker	
Ch.Eng.	Pluder, Andreas	(Las Palmas)
Doctor	NN	
2. Offc.	Fallei, Holger	
R. Offc.	Hecht, Andreas	
1. Eng.	Delff, Wolfgang	
2. Eng.	Ziemann, Olaf	(Las Palmas)
2. Eng.	Folta, Henryk	
2. Eng.	Simon, Wofgang	
Electron.	Piskorzynski, Andreas	
Electron.	Roschinsky, Jörg	(Las Palmas)
Electron.	Fröb, Martin	
Electron.	Greitemann-Hackel, Andreas	(Las Palmas)
Electron.	Baier, Ulrich	
Electron.	Muhle, Helmut	Las Palmas)
Electron.	Bretfeld, Holger	
Electron.	Dimmler, Werner	
Electr.	Holtz, Hartmut	
Electr.	Muhle, Heiko	(Las Palmas)
Boatsw.	Loidl, Reiner	
Carpenter	Neisner, Winfried	
A.B.	Bäcker, Andreas	
A.B.	Schmidt, Uwe	

A.B.	Winkler, Michael
A.B.	Moser, Siegfried
A.B.	Bindernagel, Knuth
A.B.	Bastigkeit, Kai
Storekeep.	Beth, Detlef
Mot-man	Arias Iglesias, Bnr.
Mot-man	Schubert, Holger
Mot-man	Fritz, Günter
Mot-man	Krösche, Eckard
Mot-man	Dinse, Horst
Cook	Fischer,
Cooksmate	Tupy, Mario
Cooksmate	Martens, Michael
1. Stwdess	Dinse, Petra
Stwdss/Nurse	NN
2. Stwdess	Streit, Christina
2. Stwdess	Schmidt, Maria
2. Stwdess	Deuß, Stefanie
2. Stwdess	Tu, Jlan Min
2. Stwdess	Wu, Chi Lung
Laundrym.	Yu, Chung Leung
Trainee	Buchner, Bernd

FAHRTABSCHNITT ANT XVIII/2 KAPSTADT – KAPSTADT

(25.10.00 – 03.12.00)

1. EINLEITUNG

V. Smetacek (AWI)

Theoretischer Hintergrund:

Es hat sich herausgestellt, dass Plankton des offenen Ozeans Eisen limitiert ist, und dass Eiseneintrag über Staub oder die Sedimente des Kontinentalschelfs die Wachstumsraten bestimmter Phytoplanktonarten beschleunigt. Bis jetzt wurden drei Eisenexperimente durchgeführt (zwei im äquatorialen Pazifik „IRONEX I und II" und eins im pazifischen Sektor des Südlichen Ozeans „SOIREE"), wobei ein Wasserkörper mit Eisen gedüngt und der Einfluss auf das Phytoplankton untersucht wurde. In allen drei Experimenten konnten gesteigerte Wachstumsraten und Aufbau von Phytoplankton Biomasse beobachtet werden, einhergehend mit einer Abnahme der umgebenden CO_2 Konzentration. Diese Experimente wurden von kleinen Forschungsschiffen ausgeführt, daher war nur eine eingeschränkte Anzahl von Messungen möglich. Der Einfluss von Eisenzugabe auf das pelagische Ökosystem als Ganzes und auf verschiedene biogeochemische Kreisläufe mit Ausnahme von Kohlenstoff und Stickstoff wurde bisher noch nicht umfassend studiert.

Das Ziel der Polarsternausfahrt EISENEX I ist eine Periode von Eiseneintrag in das Oberflächenwasser des offenen Ozeans im Bereich der Polarfront bei 50°S zu simulieren, um die Wirkung auf die pelagische Lebensgemeinschaft und die biogeochemischen Prozesse, die durch gesteigertes Wachstum der unterschiedlichen Komponenten des pelagischen Ökosystems gesteuert sind, abschätzen zu können. Um dies zu erreichen wird ein Flecken Oberflächenwasser (50-100 km^2) mit Eisensulfat-Lösung gedüngt und die in diesem Wasserflecken ablaufenden Prozesse verfolgt und mit den Prozessen, die in dem gleichen Wasserkörper bei normalen Eisenkonzentrationen ablaufen (außerhalb des gedüngten Wasserflecken), verglichen. Die Eisensulfat-Lösung enthält SF_6 als „Tracer". Die Eisendüngung wird mehrmals während der Ausfahrt durchgeführt, entweder in demselben Wasserkörper oder in einer geeigneteren Gegend.

Wir erwarten, dass durch die Düngung die Phytoplanktonbiomasse ansteigen wird, gefolgt von einer CO_2 Abnahme und einer Anregung anderer Komponenten, insbesondere der Bakterien und der Protozoen. Der Biomasseanstieg wird hauptsächlich auf große Diatomeen zurückzuführen sein. Ihr Aufbau von Biomasse kann auf die höheren Wachstumsraten dieser Arten gegenüber anderen Arten zurückzuführen sein oder durch Mortalitätsraten anderer Arten, die parallel zur zunehmenden Wachstumsrate steigen, in erster Linie durch den Fraßdruck von Protozoen.

Fahrtplan:
Die ökologischen Bedingungen, die uns vor Ort erwarten werden, können nur erahnt werden. Diatomeenblüten wurden Mitte Oktober 1992 in der Polarfrontzone (PFZ) beobachtet, die gegen Ende der Fahrt (ANT X/6) Mitte November hohe Biomasse erreicht hatten. Eisenkonzentrationen waren zu dieser Zeit besonders hoch und Eisberge waren sehr häufig. Die idealen Bedingungen für EISENEX I, um den Einfluss von Eisendüngung auf die Frühjahrsgemeinschaft zu untersuchen, wäre ein Wasserkörper niedriger Eisenkonzentration mit einer homogene Planktonpopulation bei geringer Biomasse, der mindestens dreimal so groß wie der gedüngte Wasserflecken ist.

Auswahl des Untersuchungsortes:
Einen großräumigen Überblick der Region entlang des 20°E Meridians erfolgt durch die ScanFish Untersuchung, die an der subantarktischen Front (SAF) beginnt und über die antarktische Polar Front (APF) bei 50°S bis in den Bereich des antarktischen Zirkumpolarstroms (ACC) bei etwa 52°S verläuft. Neben der ScanFish Untersuchung werden hochauflösende Eisenmessungen, Bestimmung der Planktonabundanz und Artenzusammensetzung im Oberflächenwasser durchgeführt. Diese kontinuierliche Untersuchungen des Oberflächenwassers in 10 km Intervallen (40 Minuten) beinhalten Messungen der folgenden Parameter: Eisen, Nährsalze, Chlorophyll (extrahiert), Planktonzusammensetzung und relative Abundanz durch schnelle mikroskopische Auswertung. Dieser Transekt wird ca. zwei Tage beanspruchen.

Das Gebiet näherer Untersuchung wird auf der Basis der Hydrography (Entfernung von Diskontinuitäten) und anderer Ergebnisse ausgewählt. Ein Raster von ca. 50 x 50 km, das vier Nord – Süd Transekte beinhaltet, wird durch das Schleppen des ScanFish in dem erfolgsversprechendsten Gebiet erstellt. Abhängig von den direkten Untersuchungen und den Ergebnissen der kontinuierlichen Untersuchungen des Oberflächenwassers wird das Raster nach Norden oder Süden verschoben bis ein geeigneter Wasserkörper gefunden ist. Dieses sollte innerhalb von ein bis zwei Tagen erfolgen, spätestens bis zum 31. Oktober.

Drei Stationstypen werden durchgeführt:
Lange Station: drei bis vier CTD Durchläufe (wenn Wasser für Experimente benötigt wird) mit Go–Flo Flaschen (an einem Kevlardraht befestigt) und ein Multinetz sowie Bongo- und RMT-Netze bei Nacht. Anderes Gerät wie z.B. eine Strömungssonde wird verwendet.
Mittlere Station: zwei bis drei CTD Durchläufe mit Go-Flo und Multinetz.
Kurze Station: Ein kurzer CTD Durchlauf.

Nach der Identifikation des gedüngten Wasserkörpers wird eine lange Station (LS0) in dessen Mitte durchgeführt gefolgt vom Ausbringen einer Argos/Radio Boje. Die

Eisendüngung wird in einem spiralförmigen (langrangischen) Verfahren durchgeführt. Die genaue Fahrtroute wird anhand des vom schiffseigenen ADCP aufgezeichneten Strömungsfeldes bestimmt. Während der Düngung wird das Oberflächenwasser überwacht, um den Nullwert des gelösten Eisens in diesem Gebiet zu bestimmen. Falls es zu einer starken Heterogenität in der Wassersäule kommen sollte, sollte die Düngung gestoppt und ein neues Untersuchungsgebiet ausgewählt werden.

Nach der Düngung wird eine lange Station als Reverenzkontrolle (Kontrolle, LSK1) außerhalb des Eisenflecks durchgeführt. Es folgt eine weitere lange Station (LSFe1) im Zentrum des durch die Argos/Radio Boje markierten Fleckens. Die Fahrtzeit zwischen der Kontrollstation und dem Eisenflecken wird am Anfang des Experiments ca. ein bis zwei Stunden betragen und sich mit der Ausbreitung des Eisenfleckens verlängern. Wir werden wahrscheinlich immer mehr Zeit zur Suche des Eisenfleckens im Verlauf des Experiments aufbringen müssen, besonders dann, wenn die Argos/Radio Boje nicht mehr zum Auffinden des Eisenfleckens verwendet werden kann. Der größte Anteil der biologischen Untersuchungen wird während der langen Stationen durchgeführt. Kurze Stationen werden in regelmäßigen Abständen durchgeführt um den Fleck ausfindig zu machen und dienen dazu die Vergleichbarkeit der LS-Kontrollen zu überprüfen. Deren Häufigkeit wird sich in den Tagen nach der Düngung erhöhen.

Es ist schwierig vorauszusagen wie sich das Experiment entwickeln wird, da es stark vom Wetter und der Hydrography des Untersuchungsgebietes abhängt. Wir sollten ungefähr jeden fünften Tag mit rauhem Wetter und dazwischen liegenden ruhigen Phasen rechnen, obwohl wir auch schon längere Perioden besseren Wetters im November 1992 (ANT X/6) in der Umgebung der antarktischen Polarfront erlebt haben. Möglicherweise wird derselbe Fleck nach einigen Tagen ein weiteres Mal gedüngt oder es wird ein neues Gebiet ausgesucht. Der oben beschriebene Vorgang wird während der gesamten Fahrt wiederholt.

Die höchstmögliche Anzahl langer Stationen während dieser Fahrt, eine LSFe und LSC für jeden Tag vorrausgesetzt, beträgt 56. Aller Wahrscheinlichkeit nach wird es weniger geben (aufgrund schlechten Wetters, Fleckensuche, erneute Düngung etc.), vielleicht nur die Hälfte der angestrebten Stationen. Natürlich finden noch weitere kurze und mittlere Stationen, sowie Oberflächenwasserbeprobung statt.

1. INTRODUCTION

V. Smetacek (AWI)

Rationale

It has been shown that open ocean plankton is by and large iron-impoverished and that input of iron via dust outfall or from continental sediments enhances growth rates of certain species of phytoplankton. So far 3 experiments (2 in the Equatorial Pacific, IRONEX I, II, and one in the Pacific sector of the Southern Ocean, SOIREE) have been carried out where a patch of water has been fertilised by adding iron solution and the effect on the phytoplankton studied. In all 3 experiments enhancement of growth rates and build-up of phytoplankton biomass have been observed, accompanied by decrease in the ambient CO_2 concentrations. These experiments were carried out from small ships, hence only a restricted number of measurements were possible. The impact of iron addition on the pelagic system as a whole and on various biogeochemical fluxes other than carbon and nitrogen has not yet been studied comprehensively.

The aim of FS Polarstern cruise EISENEX I is to simulate an episode of iron input to open-ocean surface water in the vicinity of the Polar Front at 50°S in order to assess its impact on pelagic community structure and biogeochemical processes driven by enhanced growth of various components of the pelagic ecosystem. To this end a patch of surface water of 50 – 100 km^2 will be fertilised with iron sulphate solution containing SF_6 as tracer and the resultant processes followed within it and compared with those occurring in the same water mass at ambient iron concentrations (outside the patch). Iron fertilisation will be carried out several times during the cruise, either in the same patch or in other more suitable areas. We expect that the biomass of phytoplankton will increase following fertilisation accompanied by removal of CO_2 and stimulation of other components, in particular bacteria and protozoa. Most of the biomass increase will be due to large diatoms. Their biomass build up can be due to greater enhancement of the growth rate of these species relative to the others or to mortality rates of the other species increasing with their growth rate, primarily due to protozoan grazers.

Cruise plan

The ecological situation awaiting us in our study site can only be guessed at. Diatom blooms have been observed in the Polar Frontal Zone (PFZ) in mid-October 1992 that attained high biomass by mid-November at the end of the cruise (ANT X/6). Iron concentrations at the time were exceptionally high and ice bergs were abundant. The ideal situation for EISENEX I studying the impact of iron fertilisation on the spring community would be a water mass with low ambient iron supporting a homogeneous plankton population at low biomass at least three times as large as the size of the patch.

Site selection

A large-scale overview of the region probably along the 20° E meridian will be provided by a ScanFish survey which will begin at the Sub-Antarctic Front (SAF) and run across the Antarctic Polar Front (APF) at about 50° S well into the southern Antarctic Circumpolar Current (ACC) (about 52° S). The Scanfish survey will be accompanied by high-resolution monitoring of iron concentration, ~~and~~ plankton abundance and species composition in the surface water. This continuous monitoring of surface water (CMSW) will involve measurements of the following parameters at about 10 km (40 min) intervals: iron, nutrients, chlorophyll (extracted), plankton composition and relative abundance by rapid microscopical assessment. This transect will take about 2 days.

The area for closer examination will be selected on the basis of hydrography (distance from discontinuities) and other results. A grid of about 50 x 50 km comprising 4 north-south tansects will be mapped by towing ScanFish in the area holding most promise. Depending on online observations and results of CMSW the location of the grid will be shifted north or south till an adequate water mass has been identified. This should be completed in about 1 or 2 days, i.e. by 31st Oct, latest.

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. Other equipment such as the turbulence sonde will also be deployed.

Medium station: 2 – 3 CTD casts with Go-Flo + Multinet.

Short station: 1 CTD dip.

After identification of the patch to be fertilised, 1 Long Station (LS0) will be carried out in its middle followed by deployment of an Argos/Radio buoy. Fertilisation will be carried out in a spiralling Langrangian mode. The exact cruise track will be determined according to the current field recorded by the ships ADCP. During fertilisation surface water will be monitored to determine the areal zero value of dissolved iron. If we encounter strong heterogeneity then fertisation should be stopped and a new site selected.

After fertilisation is completed a Long Station (control, LSC 1) will be occupied upstream of the patch as zero control, followed by the next Long Station (LSFe 1) which will be carried out in the centre of the patch marked by the Argos/Radio buoy. Steaming time between the control station and the patch will be about 1 – 2 hours in the beginning of the experiment but will take longer as the patch distorts and disperses. We will probably have to spend more time searching for the patch as the experiment progresses, particularly if the Argos buoy fails to track it.

Most of the biological work will be carried out at the Long Stations. Short stations on a regular grid will be used to locate the patch and assess the suitability of the LS control sites; their frequency will increase in the days following fertilisation.
It is diffciult to predict how the experiment will develop as this will depend on weather and hydrography of the study area. We should expect rough weather about every 5 days with relatively calm spells inbetween, although we have experienced longer periods of favourable weather during November (ANT X/6) in the vicinity of the APF. Possibly the same patch will be fertilised again after a few days or a new site selected. The procedure described above will then be repeated throughout the cruise.
The maximum number of long stations possible on this cruise, assuming one LSFe and one LSC every day, is 56. In all probability there will be less (bad weather, patch searching, renewed fertilisation etc.): perhaps only half the above figure. Of course. there will be short stations and mesostations (inbetween) and surface water sampling as well.

2. WETTER

F.-U. Dentler, H. Sonnabend (DWD)

BORDWETTERWARTE

Operationelles Programm

Die Bordwetterwarte ist mit einem Meteorologen und einem Wetterfunktechniker des Deutschen Wetterdienstes besetzt.

Aufgaben:

1. Beratungen

Meteorologische Beratung von Fahrt- und Schiffsleitung, der vom Schiff aus startenden Hubschauberpiloten sowie der wissenschaftlichen Gruppen und Fahrtteilnehmer. Auf Anforderung und nach Absprache auch Vorhersagen und Berichte für andere Forschungsgruppen (auch im Rahmen internationaler Zusammenarbeit) im Fahrtgebiet.

2. Meteorologische Beobachtungen und Messungen

Kontinuierliche Wetterbeobachtung mit täglich sechs bis acht Wetterbeobachtungen zu den synoptischen Terminen und deren Weitergabe im WMO-Code (World Meteorological Organization) in das internationale Datennetz GTS (Global Telecommunication System) der WMO.

Weitgehend automatische Durchführung von Radiosondenaufstiegen zur Bestimmung der vertikalen Profile von Temperatur, Feuchte und Wind bis zu etwa 32 km Höhe. Die ausgewerteten Daten werden in WMO-Code umgesetzt und über Satellit in das GTS eingesteuert.

Aufnahme, Auswertung und Archivierung von Bildern meteorologischer Satelliten.

2. WHEATHER

F.-U. Dentler, H. Sonnabend (DWD)

SHIP'S METEOROLOGICAL STATION

Operational Programme

The ships meteorological station is staffed with a meteorologist and a meteorological radiooperator of the Deutscher Wetterdienst (Hamburg).

Duties

1. Weather consultation

Issueing daily weather forecasts for scientific and nautical management, helicopter pilots starting from the ship, and for scientific groups. On request weather forecasts are issued to other research groups (especially in the frame of international cooperation) in the operating area of „Polarstern".

2. Meteorological observations and measurements

Weather observation including six to eight synoptic weather observations daily. Coding and feeding these into the GTS (Global Telecommunication System) of the WMO (World Meteorological Organization) via satellite or radio.

Largely automated rawinsonde soundings of the atmosphere up to about 32 km height. The processed and coded data are inserted onto the GTS of the WMO via satellite.

Recording, processing, and storing of pictures from meteorological satellites.

3. SEAWIFS – DATA

B. Davenport (Univ. Bremen)

The major research interest on the cruise will be to support the iron fertilisation experiment by providing near real-time SeaWiFS imagery of any subsequent planktonic blooms. The SeaWiFS HRPT data as collected on Polarstern provides approximately 1 km resolution chlorophyll imagery. The application of remote sensing for such an experiment has the potential to provide large-scale and daily coverage.

In addition SeaWiFS data will be collected as far as possible throughout the cruise for the purposes of comparing the SeaWiFS chlorophyll algorithm with in situ fluorescence measurements. This is particularly important for NASA/GSFC to check the quality of the algorithm for regions for which there is little in situ chlorophyll data.

4. PHYSICAL CONDITIONS OF PRIMARY PRODUCTION AND BIOGEOCHEMICAL FLUXES DURING EISENEX, THE FIRST IRON FERTILISATION EXPERIMENT IN THE ATLANTIC SECTOR OF THE SOUTHERN OCEAN

V. Strass, B. Cisewski (AWI), H. Leach (Univ.Liverpool), S. Gonzalez (NIOZ), Z. Duarte (FURG), F. Trumm, J. Post (Hydromod)

The Antarctic Circumpolar Ocean is considered as an ocean region of potential influence on global climate. This view in part is based on the observation of excess macro-nutrients which, after being upwelled in the Antarctic divergence, are not completely utilised by phyto-plankton primary production fuelling the biologically- mediated carbon draw-down but instead are subducted again at fronts within the Circumpolar Current. Possible reasons of the limitation of primary production include insufficient availability of light for the phytoplankton growing in the mixed layer when the mixing is deep due to wind stirring and convection, the lack of trace nutrients such as iron, and zooplankton grazing.
The physical measurements to be made in parallel with the iron fertilisation experiment during Polarstern cruise ANT-XVIII/2 are aimed at three objectives.

Objective 1: To identify a suitable site where to conduct the iron fertilisation experiment. That site has to satisfy two conditions. On the one hand, it has to be dynamically rather quite, i.e. far enough away from vigorous frontal jets or edges of eddies to avoid the injected dissolved iron dispersing too rapidly. On the other hand, ideally, it should be close enough to the Antarctic Polar Front where the silica-rich Antarctic Surface Water subducts.
The measurements aiming at Objective 1 will be made by use of an instrument package combining a towed undulator (Scanfish) and the vessel-mounted acoustic Doppler current profiler (VM-ADCP). The Scanfish+ADCP package allows the mesoscale density and velocity fields being mapped simultaneously with other physical and biological variables down to 200 - 300 m depth at high horizontal resolution in quasi-synoptic manner. The Scanfish undulates vertically through the water column while being towed behind the ship moving at 6 - 7 knots; it will carry sensors for the measurement of temperature, conductivity, and pressure (depth, salinity and density as derived variables), and for core biological variables such as the chlorophyll concentration. The vessel mounted ADCP of Polarstern enables the measurement of the current profile in the depth range of the top few hundred metres. In addition, the ADCP can be used as a detector for zooplankton abundance by evaluating the echo amplitude.

Objective 2: To monitor the displacement and spreading of the fertilised water body under the action of advection and diffusion.
For that purpose, different measuring techniques will be used in combination. A surface buoy, equipped with GPS receiver and ARGOS transmitter and drogued at 10 – 15 m depth,

will be deployed within the fertilised patch of water to track its motion. The buoy will also carry a downward looking self-contained acoustic Doppler current profiler (SC-ADCP) to obtain a Lagrangian time series of the current shear, and the zooplankton vertical migration pattern, within the upper 600 metres.
Casts of a CTD (Conductivity Temperature Depth) sonde, attached to a rosette water sampler holding 24 bottles of 12 l volume each, will be made for hydrographic profiling from the surface to intermediate depths. Samples from the bottles will be used to measure the concentration of SF_6, the tracer released together with the iron solution in order to mark the fertilised water. By performing repeated CTD surveys in the area at fine horizontal resolution of a few kilometres it will be possible to map the three-dimensional distribution of the SF_6 and thus to monitor the development of the fertilised patch in time. To achieve synoptic mapping of the mesoscale structures it is essential that these surveys are conducted as fast as possible, i.e. without being interrupted by other work. The CTD rosette sampler will also be the major tool for supplying the various scientific disciplines on board with water samples.
A tethered free-falling microstructure probe equipped with two shear sensors (one for shear measurement, the other as a reference to flag noise caused by unexpected device vibrations and external disturbances), two temperature sensors (a fast for microstructure and a slow one for high precision measurements) and one pressure sensor will be used for profiling small-scale turbulent motions down to 200 m depth. From these data the vertical distributions of turbulence parameters like the Ozmidov-, Kolmogorov- and Thorpe-scales will be estimated.

Objective 3: To provide a detailed description of the physical environment of the phytoplankton and zooplankton at the experimental site.
This will be achieved by a combined analysis of the various measurements described above. The description of the physical environment will consist of the three dimensional distributions of temperature, salinity, density, currents and turbulence parameters as well as of the horizontal distribution of integral or bulk characteristics like the mixed layer depth, including a discrimination between just homogeneously mixed and actively mixing turbulent layers, and their variation in time. Further, by combining vertical profiles of the turbulent kinetic energy derived from the ADCP current measurements with the vertical distribution of the dissipation rate determined from the free-falling shear probe data, vertical eddy diffusivity profiles can be estimated. Comparison with the temporal change of the three-dimensional SF_6 distribution will add to our understanding of the physical processes acting to spread tracers.

5. AN IRON GRIP ON THE SOUTHERN OCEAN ECOSYSTEM

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The Southern Ocean constitutes a pathway between the deep ocean and the atmosphere and plays an important role in global budgets of heat and many biogeochemical elements. Phytoplankton growth is low in large parts of the Southern Ocean, despite high concentrations of major nutrients. Iron limitation has been put forward as an explanation for the low algal growth. During the Southern Ocean Iron Release Experiment (SOIREE) the response of the ecosystem to iron addition and the resulting chemical changes were studied for 13 days in September 1999. It was shown that low iron concentrations indeed limit algal growth in certain parts of the Southern Ocean. The subsequent evolution of the bloom and the fate of the organically fixed carbon remain uncertain.
In the CARUSO iron enrichment experiment we will endeavour to study the algal response and the related biogeochemical changes over an extended period of roughly 25 days. The comparison of the biogeochemical changes in springtime CARUSO and summertime SOIREE will give a first indication of the variability of iron related effects in the Southern Ocean system. The combined addition of the tracers sulphur hexafluoride (SF_6) and helium-3 (^3He) will provide a unique open ocean dual tracer experiment in a high wind speed region. It will also allow to study the potential reduction of air-sea gas transfer by an algal bloom via the production of natural surfactants. Vertical diffusivity across the pycnocline will be determined in several high resolution grid studies. Glacial to interglacial changes of Patagonian dust deposition, rich in iron, preceded increases of the southern hemisphere air temperature, as well as changes in the atmospheric content of CO_2 and non-sea salt sulphate. The latter changes occurred before the melting of land ice in the northern hemisphere (Broecker and Henderson, 1998). This suggests that the Southern Ocean and its iron supply were important factors in promoting these climatic changes (Watson et al., 2000). The CARUSO experiment will enlarge our understanding of the role of the Southern Ocean in the atmospheric budgets of carbon and dimethylsulphide (DMS) in past and present climates.

6. Logistics of the CARUSO Iron Enrichment Experiment

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The site for the CARUSO iron enrichment should be representative for large areas of the Southern Ocean. Criteria for site selection will be based on experience gained in previous *in situ* experiments. Important criteria are: a low ambient iron content, a low phytoplankton

biomass, moderate to high levels of macro-nutrients and a homogeneous mixed layer shallower than 75 m. Further the area should have low spatial biogeochemical variability and a low to moderate storm frequency. The release should be done away from fronts, where jets could cause fragmentation and subduction of the patch. Using oceanographic and meteorological data from previous cruises and real-time satellite information, a suitable area will be identified before sailing.

On arrival in the area the hydrographic and biogeochemical characteristics will be determined using a towed body, surface water mapping and CTD-casts. This pre-site survey will assess whether the area is indeed suitable, as well as establish the background conditions prior to the experiment. The release will start with the deployment of one or more central buoys, which will give a lagrangian frame for the experiment. Subsequently iron sulphate, sulphur hexafluoride (SF_6) and helium-3 (^3He) will be released at roughly 15 m depth to form a coherent patch of about ~7 km x ~7 km with ca. 2 nM dissolved iron (Fe) in the mixed layer.

Daily mapping of SF_6 and dissolved Fe will assess the shape and spread of the patch and its Fe-content. Several surface water parameters, eg. the fugacity of CO_2 (fCO_2), dissolved inorganic carbon (DIC), pH, nutrients, particulate DMSP, DMS and halocarbons, will be sampled in parallel by the CARUSO scientific party. Regular CTD-casts, nets and Go-flows at stations inside and outside the patch will allow assessment of the effect of the release on a suite of biogeochemical parameters in the mixed layer and collection of water for deck incubations. Vertical diffusivity across the pycnocline will be determined from SF_6 measurements taken during grid studies. If iron levels fall below a critical level, additional iron will be added to maintain the patch, eg. after 3, 5, 7 days. As a failure contingency we will hold enough iron sulphate and a buoy in reserve to allow restarting the experiment.

7. SULPHUR HEXAFLUORIDE STUDIES DURING CARUSO

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Sulphur hexafluoride (SF_6) plays several roles in the experiment. Firstly, as a tracer, it will enable a large suite of biogeochemical analyses to be made in the same water body. Secondly, SF_6 concentrations will be used to determine physio-chemical properties. The combined SF_6 and ^3He measurements will provide a dual tracer experiment, in which rates of air-sea gas transfer can be determined (see section on gas exchange). Vertical profiles of SF_6 will allow determination of its diffusivity across the pycnocline, which is important to calculate the budget of nutrients, trace gases etc. in the mixed layer. The results obtained during SOIREE have indicated surprisingly low vertical diffusivity across the pycnocline (Law et al., 2000). In order to confirm this finding high resolution studies with a grid of about 18 CTD-stations across the patch will be conducted.

8. GAS EXCHANGE COMPONENT OF CARUSO IRON ENRICHMENT EXPERIMENT

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A major uncertainty in studies of biogeochemical cycles lies in estimating the flux of volatile compounds between the atmosphere and the oceans. The rate of exchange (k) of a poorly soluble gas across the air-water interface is often parameterised with wind speed (U_{10}). However, the two most commonly employed relationships between k and U_{10} (1,2) give differences of 40% to 85% in the calculated air-sea fluxes of CO_2, DMS and other climatically relevant gases. Additionally, neither of the relationships was based on measurements of k at sea but on a combination of lake and laboratory studies (1) and on a modelled fit to the oceanic uptake of bomb-derived radiocarbon (2). The magnitude of the oceanic uptake of CO_2 is extremely sensitive to parameterisations of k, e.g. a new parameterisation (3) increases the global annual uptake of CO_2 from 1.4 to 2.2 Gt C yr^{-1}, almost entirely due to enhanced transfer at high U_{10} in the Southern Ocean. The size of the oceanic source of gases such as DMS and the uptake of CH_3Br will be similarly sensitive.
The dual tracer technique is based on the deliberate release of small quantities of two inert tracers, 3-helium (^3He) and sulphur hexafluoride (SF_6), into the sea (4).
Results from the N. Sea (5), Florida Shelf (6), and Georges Bank (7) show a clear increase of k with U_{10} and generally fall between published relationships (5). However, no values of k are available for very high winds (above 15 m s^{-1}) where there is great uncertainty in gas exchange rates. Enhanced transfer might be expected in the open ocean in response to production of breaking waves and bubbles by a more fully developed wave field.
Furthermore, regions of high marine productivity might be expected to reduce k due to the presence of surfactant films which have long been know to reduce k in wind/wave tanks (e.g. 8). Recently, laboratory results using seawater samples, collected on a transect from the USA to Bermuda, in a wind-wave tank have shown that the decrease in k correlates well with bulk-water chlorophyll and dissolved organic carbon (DOC) (9).
These observations imply that parameterisations of k based on U_{10} are unlikely to satisfactorily represent a considerable proportion of the global ocean where there is significant biological activity. However, the effect of surfactants on k has never been tested *in-situ* in an oceanic environment. One component of an *in-situ* iron enrichment study in the Pacific Ocean (10) was a dual tracer release. In this study we showed that estimates of k in the open ocean were similar in magnitude to those from coastal and shelf seas at low U_{10} (11). Additionally, there was no significant impact of the algal bloom on k even though chlorophyll levels increased ten fold. However, as no surfactant measurements were made, we do not know if this was because there is no surfactant effect, or that there was insuffi-

cient time for biologically produced surfactants to enter the water or that surfactant material was recycled (e.g. by bacteria). We therefore propose to piggyback a dual tracer experiment onto an already funded study in the Southern Ocean to make *in-situ* measurements of *k* during the development of an algal bloom induced by iron enrichment specifically to test whether natural surfactants from algae play an important role in inhibiting gas exchange in the oceans. We will also determine *k* in an area critical to oceanic CO_2 uptake.

Specific Objectives of this proposal
To test *in-situ* whether algal blooms reduce transfer rates via the production of natural surfactants. To obtain measurements of air-sea transfer rates at high wind speeds in the Southern Ocean.
Methodology, approach and plan of research.
The iron enrichment study is based around the addition of dissolved iron sulphate to approx 72 km^2 of the Southern Ocean in a High Nutrient Low Chlorophyll area where marine productivity is believed to be limited by the availability of iron. The technology and methodology by which these open ocean manipulation experiments can be carried out by co-deploying SF_6 as a purposeful tracer have been pioneered by groups at PML and UEA (PDN has already led 6 such releases in the Pacific Ocean, N. Atlantic and N. Sea). A successful iron enrichment study (including staff from PML and UEA) has already been carried out in the Southern Ocean as part of the SOIREE project. An increase in phyto-plankton activity was observable within 4 days of the release of iron and a large algal bloom developed over the following 8 days (12).

We plan to co-deploy a small quantity of ^3He with the SF_6 tracer and iron sulphate. The deployment techniques have been fully described elsewhere (13). Gas exchange rates can then be calculated from the change in the ratio of these two compounds over time (^3He diffuses more rapidly across the air-water interface) and subsequently correlated with environmental variables (4,5). Discrete water samples (10–12 depths) will be routinely collected from the centre of the patch (as identified by underway SF_6 surveying) for vertical profiling of SF_6 and analysed within a few hours on-board ship using previously published techniques (14). ^3He will be analysed on return to the lab by the group of Prof. W. Roether (PI on CARUSO) and surfactant activity will be determined at UEA by polarographic techniques (15). Other measurements (DOC, chlorophyll) are already funded via the CARUSO project. The experiment has a total of 24 days allocated to post-enrichment measurements allowing ample time for an algal bloom to develop and surfactant material to be released into the water column.

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9. EVOLUTION OF THE FUGACITY OF CO_2 IN SURFACE WATER DURING CARUSO

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In the CARUSO iron enrichment experiment we will study the response of the ecosystem and the resulting changes of the fugacity of CO_2 (fCO_2) in surface water and CO_2 air-sea exchange over a ~25 day period. Comparison of the size and the rate of fCO_2 changes in SOIREE and CARUSO will give an indication of the variability of iron related changes in the Southern Ocean carbon cycle. During CARUSO we will monitor fCO_2 in surface water and marine air, as well as determine vertical profiles of fCO_2 by sampling the regular CTD casts inside and outside the patch. Interpolation of the high-frequency surface water fCO_2 data will demonstrate the spread and shape of the patch for a parameter directly affected by algal carbon uptake. Combination of fCO_2 with dissolved inorganic carbon (DIC) (H. Thomas and H. de Baar) and pH (R. Bellerby) will allow study of changes in the marine carbonate system and assessment of the net decrease of DIC in the patch. Correction of the net DIC decrease for vertical diffusion, air-sea exchange and lateral dispersion will provide an estimate for the total drawdown of DIC, which we will compare with algal carbon uptake, grazing rates and plankton carbon stocks in a carbon budget.

10. STUDIES OF ORGANOHALOGENS AND ORGANONITRATES

A. Chuck, University of East Anglia, UK

Low molecular weight halogenated hydrocarbons (halocarbons) have been shown to be produced by various species of macroalgae and phytoplankton. These gases, when transported across the sea surface into the atmosphere, play a potentially important role in tropospheric photo-oxidant chemistry and as precursors of reactive species that can destroy ozone.

Alkyl nitrates ($RONO_2$) are an important NO_y reservoir species which play a role in a variety of atmospheric processes such as tropospheric and stratospheric ozone production and destruction. Measurements taken in seawater along a transect in the Atlantic Ocean, and also a small number of measurements taken at a coastal site off Tasmania show that the ocean can be supersaturated with methyl and ethyl nitrate and suggest a possible oceanic source.

It is vital to know which compounds, and in what amounts they are produced by marine biota and their fluxes into the atmosphere. Changes in the delivery of nutrients, for example Fe, has the ability to affect species composition and hence the fluxes of these environmentally important gases. We already have a small amount of evidence to show that these compounds are sensitive to iron levels. Surface measurements and depth profiles will be carried out for methyl iodide, chloroiodomethane, bromoform, methyl nitrate and ethyl nitrate.

11. DIMETHYLSULPHONIOPROPIONATE (DMSP) AND DIMETHYL SUPHIDE (DMS

S. Turner, University of East Anglia, UK.

DMS is a biogenic trace gas which, after emission from surface seawater to the air, is oxidised and forms sulphate aerosol. Changes in atmospheric particle density have important consequences for atmospheric albedo, through direct scattering of solar radiation and cloud formation and whitening, particularly in regions remote from anthropogenic sources. Model studies suggest that albedo of the Antarctic region is particularly susceptible to changes in aerosol concentration and that a three-fold increase in DMS emissions could lead to a Southern hemispheric cooling of about 2ºC. Further, palaeochemical data from Antarctic ice cores suggest that DMS emissions may have been considerably higher during glacial periods than in warm interglacials.

DMS is produced from the decomposition of DMSP, a constituent of phytoplankton cells and different algal groups produce variable amounts: diatoms generally produce little DMSP, whereas prymnesiophytes are strong producers.

Studies of *in situ* iron augmentation in high-nitrate-low-chlorophyll oceanic regions of the equatorial Pacific (IronEx I and II) and Antarctic (SOIREE) have shown that DMSP-

producing phytoplankton respond rapidly to iron addition, with an approximate three-fold increase in DMSP, over a few days. However, the net production and fluxes of DMS to the atmosphere were variable. This may indicate that there were differences in the responses of bacterial and microzooplankton communities, which are mainly responsible for the production and internal cycling of DMS. In order to better inform models of past and future climate change, it is important to assess the variability of net DMS production. During the CARUSO expedition, concentrations of DMSP (particulate) and DMS will be determined for different depths in the water column, both at the centre of the iron enriched patch and outside. Surface water concentrations will be measured during mapping of the patch to enable assessment of spatial variability and budgeting. Size-fractionated DMSP samples will indicate which phytoplankton groups are responsible for genesis of DMS. All DMS and most DMSP samples will be analysed on board using gas chromatography. Full interpretation of the data will require biological information from colleagues.

12. IODENE PRODUCTION DURING CARUSO

A. Baker and S. Turner, University of East Anglia

The principal chemical species of iodine in surface seawater are iodate (IO_3^-) and iodide (I^-). Reduction of iodate, the thermodynamically favoured form, to iodide ppears to be biologically mediated although the mechanism is not clear at present. The effect of iron release on iodine speciation will be studied during CARUSO. Samples will be taken from the CTD and from near-surface water inside the patch and analysed at UEA.

13. CHANGES IN DISSOLVED ORGANIC NITROGEN AND PHOSPHORUS DURING CARUSO

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A large fraction of primary production is released to the water column as dissolved organic material. Some of this material is rapidly metabolised by bacteria and remerineralised to CO_2 and inorganic nutrients. Some fraction, however, accumulates in the water as relatively refractory organic material, which degrades slowly. The exact fraction of material, which is lost to the water column and accumulates, is a function of many different variables and may represent a substantial component of production under some circumstances. We will quantify the fraction of iron induced nitrate and phosphate drawdown, which accumulates in the water column as dissolved organic nitrogen and dissolved organic phosphorus by making measurements of these parameters on both the inpatch and out of patch CTDs. Samples will be drawn into sterile 60ml containers and stored frozen, they will then be returned to the SOC and analysed for their inorganic nutrient levels before and after UV

oxidation which quantitatively converts inorganic nutrients to organic nutrients. The concentration of organic nutrients will then be determined by difference.

14. IRON FERTILISATION EXPERIMENT IN THE ATLANTIC SECTOR OF THE SOUTHERN OCEAN

Research to be conducted during the iron enrichment experiment by Netherlands scientific team of the Netherlands Institute for Sea Research (NIOZ), Rijksuniversiteit Groningen (RUG) and Interfacultair Reactor Instituut Technische Universiteit Delft (IRI/TUD), one guest investigator from CRIEPI (Japan). The Netherlands participation is supported by the EU program CARUSO, the bilateral Netherlands-Bremen Oceanography (NEBROC) program, and three grants of the Netherlands Antarctic Programme on (i) Biological Availability of trace metals for Antarctic phytoplankton, (ii) Postive feedback of UV-B via iron chemistry of seawater on phytoplankton growth and CO2 fixation, and (iii) In situ iron enrichment experiment in the Southern Ocean.

Rationale

The Southern Ocean is the world's largest High-Nutrient, Low Chlorophyll (HNLC) region. The availability of iron, and the effect of light, are the most likely causes for the fact that in HNLC regions phytoplankton densities stay low. The overruling roles of light-limitation and iorn limitation were demonstrated in a recently published ecosystem simulation modeling as verified by real diatom bloom evolution during the 1992 austral spring season.
After several joint venture expeditions (1988-1999) during which iron was measured and the effects of iron enrichments of natural phytoplankton in bottles were studied, an in situ iron enrichment experiment will be performed in the Southern Ocean. A suite of physical, chemical and biological rate and state variables will be measured inside and outside an iron enriched patch. The response of the natural phytoplankton and bacterial community on the iron addition will be followed over a period of three weeks, and will be compared to the activity of the phytoplankton and bacteria outside the enriched patch.
From the previous joint investigations aboard RV Polarstern in the 1988-1999 era, as well as the 1999 SOIREE experiment with CARUSO partnership, we already know that iron is the prime limiting nutrient in Antarctic waters. Hence upon iron addition and under suitable light (read wind and sea-ice) conditions evolution of a bloom of large diatoms is now hypothesized. Therefore the objective of the experiment is not so much in demonstrating that Fe is a major limitation, as this was shown already extensively shown, by our joint (AWI-NIOZ) work in the 1988-1999 era, as well as the recent 1999 SOIREE in situ experiment. Rather we intend by designing a controlled bloom of likely large diatoms, to assess quantitatively the biological, and global geochemical, implications of Fe-stimulated productivity of the Southern Ocean, both in the present and with major implications for the past during the Last Glacial Maximum.

One of the added values of the Polarstern ANT XVIII/2 experiment lies in the use of a dual tracer approach (SF6 and 3He) which not only serves (i) to track the patch, and (ii) to assess mixing parameters both within the sea and for air/sea gas exchange, but also allows in principle (iii) to make quite accurate volumetric budgets of the patch evolving over the period of days to weeks. Such budgets in turn also allow budgeting the changes of inventories of biological important chemical elements, as well as of the various pools of biota. The concept of constant proportions of major elements C, N, P and O2 after Redfield, Ketchum and Richards (RKR, 1963) can therefore be validated for the expected diatom bloom evolution. In previous Polarstern cruises we have seen major deviations of the RKR proportions in waters where blooms of the large diatom Fragilariopsis kerguelensis were dominant. Interestingly during 1999 SOIREE the blooming of exactly this diatom species was also the major response to iron enrichment. Therefore during the Polarstern ANT XVIII/2 experiment we may well see deviant RKR proportions as well.

Objectives of Netherlands contributions

Special attention will be given to (i) measurements of iron, its abundance, chemical speciation and (photo)-chemical kinetics, (ii) the depletion of other essential trace metals, (iii) the CO_2 system and dissolved O2, (iv) phytoplankton/bacterial abundance and diversity, (v) physiological and molecular diagnostics in the phytoplankton/bacteria, as well as (vi) large scale surveying with a towed undulating instrument package. It is expected that especially the large diatoms will show a clear response to the iron enrichment. The in situ experiment will be accompanied by on-board iron enrichment experiments with natural phytoplankton assemblages as well as uni-algal Antarctic phytoplankton, notably large and small diatoms, from laboratory cultures. In addition to the effect of iron, the effects of light on phytoplankton growth and in particular the iron-light co-limitation will be studied. As the Fe-limited Southern Ocean comprises about 15% of the surface of the planet it is evident that effects of iron addition under natural conditions (i.e. in situ) is vital for proper understanding of the global CO_2 budget and hence the global climate, notably also during the Last Glacial Maximum when Fe input was higher and atmospheric CO2 and temperature much lower than nowadays.

Specific scientific objectives: to study the effects of iron addition on the natural phytoplankton and bacterial community, and follow the chemical and biological changes followed by the iron enrichment. Special attention will be given to the effect of UV radiation on both the speciation of iron and the growth of phytoplankton. The experiment should shed further light on the importance of iron (and light) on structure and function of the Antarctic ecosystem. The expected shift to larger, opportunistic, phytoplankton species not only determines the key role of the Southern Ocean in global CO_2 budgets and climate, but also supports the classical Antarctic food-chain, from diatoms via copepods, krill, salps to ultimately penguins and whales.

Research methodology.

First, a hydrographic and chemical survey of a region surrounding the proposed site is made to ensure that the surface waters are not subject to subduction or excessive shear, that natural iron levels are low and that biological activity is at a uniform and low level. During the iron release, iron sulphate is dissolved into acidified seawater in large tanks on the afterdeck of the research vessel, and pumped into the propeller wash of the ship as it steams a pattern of order 10 km in size centred on a drifting buoy. Simultaneously, a pre-prepared solution of sulphur hexafluoride (SF_6) in water is released. Subsequently, for a period of order 18 – 21 days the fate of the marked water is tracked using tracer measurements as a guide to its dilution and advection. Biological response is measured by chlorophyll production, carbon and nutrient uptake and species counts/abundance. Specifically, the capacity of the system to alter the sink for carbon dioxide in the Southern Ocean is measured by the response of surface ocean pCO_2. We anticipate releasing about 15000 kg of iron sulphate over a period of four days to initiate the experiment and would expect it to spread over an area of order 400 km2 during the~up to 28 days of the experiment.

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The specific Netherlands contributions during the Polarstern ANT XVIII/2 iron enrichment experiment will focus on six (interrelated) topics which furthermore are in close collaboration with colleagues from other nations, as well as closely related to other topics studied by others:

1) Iron distributions, speciation and (photo)-chemical kinetics
2) Depletion of essential metals Zn, Mn, Co and Cd
3) The CO_2 system and dissolved O2 in context of RKR proportions4) Phytoplankton responses (In cooperation with AWI)
5) Bacterial responses
6) Surveying with undulating scanfish (In cooperation with AWI)

15. IRON DISTRIBUTIONS, SPECIATION AND PHOTOCHEMICAL KINETICS

H. de Baar, P. Croot, M. Boye (RUG), P. Laan, M. Rijkenberg, J. Nishioka (guest investigator from CRIEPI, Japan), A. Fischer (IRI/TUD), K. Kroon (IRI/TUD).
Collaborations for shipboard bioassays with AWI group (Riebesell and co-workers)

Rationale

The chemistry of Fe in seawater is still poorly understood. The availability of Fe is crucial for life in seawater. On the one hand iron is a key factor in the light harvesting and electron transport system which provides the energy for fixing CO_2. On the other hand UV-B radiation and other parts of the irradiance spectrum affect the chemical forms of Fe, hence its biological availability in seawater (positive feedback).The Fe(III) state to be expected from thermodynamic reasoning in oxygenated waters, is in fact for 90-99% bound by dissolved organic moieties including Fe(III)-siderophores. Moreover, photo-reduction by irradiance in the visible but mostly in the UV part of the spectrum produces dissolved Fe(II) which at noon may account for 30-70% of all dissolved Fe in seawater. This Fe(II) has a positive effect on phytoplankton growth. The photo-production of Fe(II) in seawater constitutes the transfer of iron between chemical states which differ in their ability to supply iron on a time scale required for phytoplankton growth. During the preceding 1999 SOIREE experiment major shifts in chemical speciation of Fe were observed by one of us (P. Croot) and interpreted in terms of the relatively slow oxidation kinetics of Fe(II) in the cold polar waters. The

speciation (determination of the different existing forms) of dissolved Fe will be determined as a function of uptake by the diatoms and as a function of the wavelength of the incident light. The kinetics of the reactions between the 3 major dissolved Fe pools (inorganic Fe(III), organic-complexed Fe(III) and inorganic Fe(II)) and its relation to biological uptake will be assessed using tracer techniques with both radiotracers 55Fe and 59Fe and stable isotopic tracer 57Fe.

Methodology

During the iron release experiment, the trace metal group from NIOZ will be responsible for measuring dissolved iron both inside and outside the SF_6/3He/Fe enriched patch. Continuous mapping of the patch will be made using surface samples obtained using a towed fish and ultra clean pumping equipment. Samples will be analysed in near real time within two NIOZ clean containers by onboard chemiluminescence techniques, using 3 parallel FI-CL analyzer systems. The daily surface mapping of dissolved iron will furthermore be used to understand the kinetics and dynamics of processes affecting the chemistry of iron in seawater as well as providing valuable information for the planning of further iron infusions during the experiment.

Vertical profiles of iron will be obtained daily inside and outside the patch by using GOFLO samplers deployed from a kevlar line. Selected samples will also be analysed for both particulate and dissolved Fe(III), while the Fe(II) will also be determined as a measure of redox speciation. At selected stations, measurements of the organic speciation of iron will be performed using cathodic stripping voltammetry. All of the iron parameters measured will be used to follow the time course of the physical and biological processes occurring during the experiment which effect the biogeochemical cycling of iron. Shipboard experiments will also be performed to examine the kinetics of changes in iron speciation due to sunlight, phytoplankton growth and zooplankton grazing.

The positive feedback hypothesis of UV-B on iron availability (and thus phytoplankton growth) will be investigated performing deck incubations with natural phytoplankton assemblages form within and outside the Fe-enricghed patch, as well as with and single species of phytoplankton brought from the home laboratory. The deck incubations will be held under three different light regimes (PAR, PAR+UVA, PAR+UVA+UVB). Part of these incubations will have Fe isotope additions (^{55}Fe and ^{59}Fe, as well as 57Fe). As a check cultures are run in controlled light in climate cabins. Also part of these incubations contain Fe isotopes. The combination of incubations with mixed populations from within and outside the patch, with those of singel species, is powerful for interpreting the mecahimsms of bloom evolution in the in situ Fe-enriched patch.

Sample treatment, filtration and analysis, will be done under ultra clean conditions in a clean lab container. The isotopes will be counted by a γ-counter and pulse tracers. The stable isotope 57Fe will be determined afterwards at the NIOZ home laboratory with High

Resolution ICP MS. On shipboard the natural Fe will be determined by voltammetry, and several flow injection techniques.
Other analyses necessary for interpretation are measurement of the spectrum of the natural light by a spectroradiometer on deck, analysis of peroxide, of characteristics of the diatoms by flow-cytometry, cellular autofluorescence and ^{15}N uptake rates (cooperation with Dr Timmermans, NIOZ).
Sampling for the distribution and speciation of iron will be done by using the torpedo towed along-side Polarstern as well as by using GO-FLO bottles mounted on a Kevlar wire.

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16. DEPLETION OF ESSENTIAL METALS ZN, MN, CO AND CD

P. Croot, H. de Baar (NIOZ) , M Boye (RUG)

Rationale

Upon alleviating the overruling Fe deficiency of the Southern Ocean by in situ Fe addition, and with adequate major nutrients available as well, the intended/expected prolonged bloom of e.g. diatoms will likely run into limitation by other essential metals, notably Zn, Mn or Co. Conversely in order to be able to properly interpret the bloom evolution and its ultimate demise, its is crucial to also monitor these essential trace metals. Moreover Cd may or may not be essential, or substituting for Zn. Both during the 1992 spring diatom blooms in the Polar Front, and during 1999 SOIREE major changes in the concentrations of Zn, Mn, Cu and Cd were observed. The depletion of Cd was very dramatic during 1999 SOIREE and this is of major interest for the application of the oceanic relationships between Cd and phosphate to assess past productivity of the Southern Ocean during the Last Glacial Maximum (LGM, e.g. Elderfield and Rickaby, 2000, Nature) when such higher productivity was possible due to about 15-fold higher Fe input into Southern Ocean waters.

Methodology

Unfortunately due to both lack of shipboard berths and lack of extra expert scientists, it will not be possible to do direct shipboard determinations of dissolved Zn and Mn with the dedicated NIOZ Flow Injection instruments for Zn and Mn. Nevertheless filtered seawater as well as the particulates on the filters will be collected from the daily GOFLO-kevlar wire casts within and outside the patch. These samples will be stored for analyses in the NIOZ home laboratory by both FI for most dissolved metals, and HR-ICP-MS for the metals including Fe on the suspended particles. Latter HR-ICP-MS also produces values for particulate phosphorus, such that the particulate ratio Cd/P can be determined accurately. This will shed light on the oceanic fractionations of Cd and P as the crucial link for the reconstructions of iron-induced LGM productivity of the Southern Ocean.

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17. THE CO_2 SYSTEM AND DISSOLVED O2 IN CONTEXT OF RKR PROPORTIONS

H. de Baar, H . Thomas (NIOZ), C. Harms, C. Hartmann (AWI), D. Bakker (UEA), R. Bellerby (PML)

Rationale

During the IRONEX II experiment in the equatorial Pacific Ocean the uptake of major elements C, N, P and the photosynthetic production of O2 were assessed by Steinberg and Millero (1998) who found alomst perfect stoichiometry of the ratio's C:N:P:O2 in keeping with the classical description by Redfield, Ketchum and Richards (1963). On the other hand anomalous ratios of N:P were observed during (i) spring diatom blooms in 1992 in the Antarctic Polar Front, (ii) at stations in the Circumpolar Current during the preceding 1999

Polarstern cruise, and (iii) within the Fe-enriched patch of 1999 SOIREE. Therefore assessment of the RKR stoichiometry is of significant interest.

Methodology

Accurate determinations of TotalCO2, NO3, PO4 and O2 in the ambient waters will be done in combination with proper budgeting of the amount of water and its dilution by mixing, this derived from the information and calculations based on the dual tracers SF6 and 3He. This topic will be pursued jointly with the AWI nutrients analyses team who will take responsibility for measurements of dissolved nitrate, phosphate and silicate. The Netherlands team will do measurements of total dissolved CO2 (TCO2) as well as dissolved oxygen (O2).

For dissolved O2 two identical accurate sensors will be mounted on both the CTD-Rosette frame and the undulating Scanfish as to ensure optimal coverage in time and space. In addition water samples will be collected from both a ships pump in underway mode and from discrete samples taken of the Rosette. These water samples will be analyzed with a modern version of the Winkler titration principle with final high precision spectrophotometric determination. The O2 data of these water samples will also be used to calibrate the sensor collected data, also guarding for instrument drift of the sensors. This will be obtained directly for the O2 sensor mounted on the CTD/Rosette frame. Regularly this will be replaced temporarily by the sensor of the Scanfish as to also calibrate latter O2 sensor versus bottles collected from the CTD/Rosette.

Using the combined datasets of nutrients, TCO2 and O2 the daily budgets will be made of the inventories within the iron-enriched patch. For the CO2 and O2 these budgets also need to take into account their air/sea gas exchange, where the applied transport coefficient for gas exchange will furthermore be verified versus the loss rates of SF6 and 3He tracers from the patch of water to the atmosphere. The derived budgets will be compared with both the classical RKR and the previously reported deviations thereof in diatom blooms, as well as the assimilation ratios in laboratory incubations of major diatoms. Moreover this work includes the ratio of dissolved silicate versus the other essential elements, in relation to suggestions of variations of siliceous opal formation as function of iron availability.

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18. PHYTOPLANKTON RESPONSES TO IRON ADDITION

K. Timmermans, M. Veldhuis, H. de Baar (NIOZ), T. van Ooijen (RUG).
Collaborations for shipboard bioassays with AWI group (Freier, Assmy, Smetacek, Riebesell and co-workers)

Rationale

Phytoplankton in the Southern Ocean is not only the base of the complete Antarctic food chain up to penguins, seals and whales, it is also fixing CO_2 (both natural and from fossil fuels) out of the atmosphere, thus affecting the present and future climate. All around Antarctica the growth of phytoplankton is controlled by light and iron, with several ways of interaction between these two factors. Deck incubations with the natural phytoplankton assemblages inside and outside the patch will be done. In addition, single species cultures of Antarctic diatoms (brought from the home laboratory) will be cultured in filtered seawater from inside and outside the patch. For these bioassays it is crucial to utilize the natural ambient seawater as the medium, in order to allow and detect the various chemical forms of Fe in seawater, as this chemical speciation is driving the diatom productivity. Moreover the use of a small and a large diatom species allows insight in the expected size-class related response to addition of iron.

By using these two approaches good insight can be achieved on the (changes in) bioavailability of iron inside and outside the patch. Moreover by bringing along a suite of pure cultures of the major bloom-forming Antarctic diatoms, we hope to have available the very same diatom species which in the outside Fe-enriched patch will become the major bloom-forming species. For example during 1999 SOIREE the eventual dominant large diatom was Fragilariopsis kerguelensis, where now due to collaboration with Freyer (AWI) we have been able at NIOZ to unravel its light-Fe responses in natural seawater. Then by assays on shipboard of the physiology (Fe and light requirements as function of UV-and-visible spectrum as well as function of Fe chemical speciation) general interpretations can be supported or falsified for the, by necessity, mixed population within the in situ Fe-enriched patch.

Specific attention will further be given to changes in carbohydrate metabolism of natural phytoplankton populations of the Southern Ocean (Tim van Oijen, RUG), The initiation of a microalgal bloom may partly depend on the ability of the cells to store energy in the form of storage polysaccharides during favourable light conditions. During the ANTXVIII/2 cruise, the changes in phytoplankton carbohydrate amount and composition that are expected as a consequence of the response of algal physiology to iron enrichment will be determined. Attention will be paid to diatoms during the enrichment experiment. In particular, it will be

determined if the production of storage carbohydrates is strongly enhanced by the iron addition, e.g. as the consequence of a more efficient photosynthetic apparatus. Further it will be determined if part of the carbohydrates that are produced will end up in the water column. The differences in carbohydrate metabolism before, during and after Fe enrichment of the sea will be assessed by *in situ* sampling and on-board incubations with natural phytoplankton populations.

Methodology

Collection of seawater will be done using the NIOZ clean sampling gear (either the torpedo, or the GO-FLO bottles on the Kevlar winch). All phytoplankton incubations will be coordinated so that as many samples can be drawn from the same incubation.

The incubations will be done in deck-incubators and/or climate cabins. Samples handling will be done under clean conditions in a clean-container. Parameters used to follow the response of the phytoplankton will include flowcytrometric analyses, cellular autofluorescence, microscopy, ^{15}N uptake rates (nitrate and ammonium) and chlorophyll a. The data will be combined with data on : Species composition and size distribution of the phytoplankton, size fractionated ^{14}C production ,

POC/PON measurements ,PI-curves, PAM, FRRF, DOC, and dissolved nutrients, (nitrate, nitrite, phosphate, ammonium, silicate).

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19. BACTERIAL RESPONSES TO IRON ADDITION

T. Arrieta (NIOZ)

Rationale

Over the last 2 decades our understanding of marine food webs has been revolutionized. It became clear that bacterioplankton represent the largest living surface and biomass in the ocean. It has been recognized that heterotrophic bacterioplankton exhibit an abundance of 10^5 to 10^6 ml^{-1} in the photic zone of the open ocean. Because of their high metabolic activity they play an essential role in the carbon and energy flux through marine food webs

by converting dissolved organic carbon (DOC) into living biomass and CO_2.
Bacterioplankton are basically the only consumers of the DOC pool and their activity is intimately linked to phytoplankton activity. In HNLC areas the bacterioplankton are limited in their activity by the availability of iron in a similar way as phytoplankton but also, and occasionally even more so, by dissolved organic carbon (DOC). As a consequence of the Fe-limitation of phytoplankton, the production of labile DOC by phytoplankton is low. Since only about 1% of the bacterioplankton present in the marine environment can be cultured, the species composition of the bacterioplankton remained essentially unknown until recently. Only by molecular analysis of the DNA and RNA contained in the cells, information on the species composition can be obtained. These bacterioplankton are controlled in their abundance by heterotrophic flagellates and viruses.
Objectives
During the POLARSTERN ANT XVIII/2 iron enrichment experiment we will determine the shifts in the species composition of the bacterioplankton upon Fe-enrichment. Since virioplankton is highly host-specific, we expect also major changes in the virioplankton community reflecting the changes in the bacterioplankton community composition. During the viral lysis of the bacterioplankton large amounts of labile intracellular organic material is released from the lysed bacterioplankton as well as complexed iron. These dynamics are in the bacterio- and virioplankton and in the dissolved organic matter pool, and will be investigated.

Science performed and approach:
Hypotheses/questions addressed:
1) Fe- enrichment of Fe-deficient water bodies induces a shift in the species composition of the bacterioplankton and in the virioplankton community
2) The shift in the bacterioplankton community leads initially to reduce viral lysis since the virioplankton is highly host-specific. After a lag phase enhanced viral lysis leads to an enhanced release of dissolved organic matter (DOM) and complexed iron.
3) The diatom frustule might serve as a protection mechanism against viral infection. Diatoms are the only group of organisms from which, up to now, no virus-host systems were found. We will use specific primers targetted against phyto-viruses in diatoms to determine whether diatoms are really not infected by viruses.
4) The bacterioplankton ectoenzymatic activity is the rate limiting step for the transformation of DOM by bacterioplankton. Some ectoenzymes are metalloproteins such as protease requiring Zn. Thus the availability of metals indirectly influences also the transformation of DOM. We will measure alpha-, and beta-glucosidase activity, protease and phosphatase activity, the latter being also expressed by phytoplankton. It is expected that there are major changes in the ratio between glucosidases to proteases activity detectable related to the availability of metals.

5) Using capillary electrophoresis to separate bacterioplankton species/groups alive from the complex bacterioplankton community (BAC-PACE, recently developed in our lab), we will perform abundance and activity determinations of the dominant bacterial species/groups. Major shifts in the dominant bacterioplankton species composition are expected upon Fe-enrichment. Subsequently the individual bacterioplankton fractions are collected for later molecular analysis. Thereby, we are able to determine species-specific metabolic rate measurements which, up to now, were not possible to obtain.
6) Bacterioplankton respond to nutrient limitation with an increase in hydrophobicity of the capsular layer. We will determine the development of the hydrophobicity of the bacterioplankton capsule during the course of the Fe-enrichment experiment and relate this to the overall bacterial activity. Increased hydrophobicity of the cell surface, however, also increases the grazing pressure by flagellates. Thus there is a trade off for the bacterioplankton between more efficiently acquire nutrients and increased grazing pressure.

The approach on regular CTD casts at all depths collecting water for determining the following parameters:

bulk bacterioplankton abundance by flow cytometry (done at sea) and preparing slides for later epifluorescence microscopy (in the lab, level1) bulk bacterioplankton activity via ^{3}H-thymidine and ^{3}H-leucine incorporation (microcentrifuge technique)(level 1, done at sea) (100 ml incl. abundance determination) flagellate abundance (heterotrophic and mixotrophic) by epifluorescence microscopy (done in the lab, level 1) (50 ml) DOC measurements (done in the lab, level 1) (20 ml) 10)^{3}H D- versus L-amino acid uptake by bacterioplankton (100ml at 5 depths) ectoenzymatic activity by fluorgenic substrate analogs (at sea, alpha-, beta-glucosidase, protease, phosphatase activity) (50 ml) for enantiomeric amino acids determination (tracer of bacteroplankton derived DOM, by HPLC analysis in the lab) (20 ml) for virioplankton abundance (in the lab, 10 ml) hydrophobicity of bacterioplankton cells (done at sea, 50 ml) for viral lysis rate determination (# of infected cells and burst size; done at the GBF Braunschweig using TEM, 50 ml, 5 depths every other day) for collecting diatoms and the presence of viruses in the diatoms using specific primer (done in the lab, 1 l, 1 depth every other day)

on specific casts:

a) for bacterio- and virioplankton community composition (later analysis in the lab by T-RFLP and DGGE and sequencing of major bands for bacterioplankton diversity and pulsed field electrophoresis for virioplankton) (100 l, 1 depth per day)
b) for BAC-PACE (capillary electrophoretic separation of the dominant bacterial groups/species for group/species specific activity measurements, done at sea) (100 l, 1 depth per day)

Expected results:

1 Bacterioplankton growth rates and ectoenzymatic activity pattern und Fe-repleted and -depleted conditions.
2 Relation between bacterial and viral abundance and lysis rates under the 2 contrasting conditions.
3 Role of variations in the lysis rate on the contribution of bacterial-derived DOM to the bulk DOC pool by measuring the enantiomeric amino acid concentrations.
4 Turnover rate of D- versus L- amino acids by bacterioplankton.
5 Development of the bacterial and viral diversity and its linkage.
6 Group/species-specific growth rates of the dominant bacterioplankton groups/species determined by BAC-PACE.

Development of the hydrophobicity of the bulk bacterioplankton under the 2 contrasting situations and its relation to activity and DOC concentration.

20 . SURVEYING WITH UNDULATING SCANFISH

S. Gonzalez, H. de Baar (NIOZ), V. Strass (AWI)

The Scanfish surveying will be done in close collaboration with the AWI physics group of Dr. Strass and co-workers, also combining Scanfish data with that collected by the hull-mounted ADCP.

Rationale

One important task is to adequately map the chosen research area as to verify suitability in terms of vertical and lateral stability. The collected data will also serve as the initial conditions before the iron enrichment and SF6/3He labeling will start. Moreover there is the option of further Scanfish surveys during the course of the experiment, as deemed desirable there and then.

Methodology

The Scanfish with its sensor package allows mapping several physical and biological variables down to 200 - 300 m depth at high horizontal resolution in quasi-synoptic manner. The Scanfish undulates vertically through the water column while being towed behind the ship moving at 6 - 7 knots; it will carry sensors for the measurement of temperature, conductivity, and pressure (depth, salinity and density as derived variables), dissolved oxygen and for core biological variables such as the chlorophyll concentration. The dissolved O2 dataset from the Scanfish will also be used in context of the above topic 2. on the RKR proportions of O2 and other major chemical elements.

The Scanfish *MKII 1250* is an undulating towed vehicle scanning system designed for simultaneous measurements of variety oceanographic parameters. The Scanfish undulates vertically through the water column while being towed behind the ship moving at 6-8 knots.

According to special wishes from Netherlands Institute Sea Research (NIOZ) "our" instrument contains the following components:

-*Surface component*, means Scanfish MKII presentation, logging software, PowCom-Power and communication unit for vehicle interface. The navigational data from DGPS is incorporated in the data stream using the NMEA-interface of the Seabird deckunit.

-*Underwater vehicle and sensors*: inboard control unit, cables, depth sensor, altimeter, Seabird 911 interface, OBS, PAR, Oxygen sensor and Chelsea fluorometer.

-*Winch type Cormac 1500*, equipped with ca. 2300 m cable Ø8.3 mm, type 32-OHM COAX2-20. Weight: 2000 kg.

- *Scanfish measures*

Cord: 800 mm

Span: 1560 mm

Area: 1250 m2

System weight: 110 kg

In order to enhance the depth range of the Scanfish system, the winch is connected with the controller computer and by pay out/in of cable during ascent or descent the performance enveloppe from 5 to 400 m will be obtained.

Underway seawater pH and *in situ* pCO_2 measurements

Richard Bellerby, Solveig Kringstad (University of Bergen)

Shipboard seawater pH measurements

Under circumstances where the CO_2-system is changing rapidly (i.e. under bloom conditions) the high density data set furnished by the Automated Marine pH Sensor (AMpS) (Bellerby *et al.*, *submitted*) will provide great insight into the CO_2-system kinetics and dynamics. Recent detailed studies of the marine inorganic CO_2-system have shown that seawater pH measurements are now essential to measurement redundancy checks on data quality (McElligot *et al.*, 1998; Byrne *et al.*, 1999).

It is proposed to measure seawater pH_T (total hydrogen ion concentration) from the ship's underway supply every 2 minutes using the AMpS system. This method measures the spectral characteristics of a sulfonephthalein indicator (*e.g.* thymol blue, *m*-cresol purple) seawater solution using a flow injection manifold.

In situ measurements of seawater pCO_2 of the SF6/Fe patch.

These will be the first *in situ* pCO_2 measurements from within a Fe-induced bloom. The SAMI-CO_2 has the benefit over shipboard techniques in that the sensor will be monitoring the CO_2-system evolution within the same body of water throughout the study. Traditional, ship-based measurements cannot return to exactly to the same place in the patch each day. It is proposed to measure *in situ* pCO_2 every 30 minutes. The SAMI-CO_2 measures the pH of a bromothymol blue solution after equilibration, through a silicon membrane, with seawater pCO_2 (DeGrandpre *et al.*, 1995). These measurements will be the first pH measurements to be made during a study of an artificially Fe-induced bloom

Two SAMI-CO_2 sensors will be deployed on separate drifters. The initial depth of measurements will be between 5 and 20m dependant on the drogue depth. However, during recapture and redeployment of the drifters throughout the study, it is proposed that one of the SAMI-CO_2 sensors should be re-positioned at the depth of highest productivity (yet still above the drogue). Thus, one sensor will give a full history of a water parcel throughout the whole study whilst the other will give insight into the maximum CO_2 uptake rates.
Both pH and pCO_2 data collected in this study will be integrated and modelled with the other CO_2-system parameters measured onboard (de Baar, Watson, Bakkar and Thomas).

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21. EXPORTPRODUCTION MEASURED WITH ^{234}TH

M. v.d.Loeff, I. Vöge (AWI)

Background

^{234}Th is a tracer that allows us to quantify the export of particles out of the euphotic zone. The isotope is produced continuously from ^{238}U, which has an activity in seawater that is accurately known from the salinity. In a closed system, the two isotopes are in secular equilibrium, giving a ^{234}Th/^{238}U ratio of unity. But as thorium is highly particle-reactive, any export of particles from the surface layer removes ^{234}Th from the surface water, which is then observed as a depletion of ^{234}Th relative to its parent ^{238}U. After an export event, the depletion disappears by ingrowth of ^{234}Th with its halflife of 24 days, giving the time scale of flux variations that can be observed with the tracer. In pa revious expedition (ANT X/6, 1992) to the Antarctic Polar Front we have been able to distinguish two phases in the export following a bloom: first the bloom caused a transfer of activity from the dissolved to the particulate phase by adsorption without any export, whereas export was only observed in a second phase.

Objectives

We expect that iron enrichment will cause an increase in plankton concentrations in the surface water, which should be visible as an increased adsorption of Th. We do not know whether and when this development will lead to an export flux. During the SOIREE

expedition (Charette et al., presented at Ocean Sciences meeting, 2000) an export was not observed, which may have been due to the short duration of the experiment.
During the CARUSO experiment we will follow the $^{234}Th/^{238}U$ ratio within and outside the Fe-enriched patch. The data to be obtained during the survey before the iron addition will show to what extent export has taken place in the weeks preceeding the experiment. The development of the $^{234}Th/^{238}U$ ratio will tell us whether the fertilisation leads to enhanced export.

Methods
We plan to analyse samples from the ship's surface seawater supply and from Rosette casts. The method will follow either a procedure based on 20-L samples for precise separate analyses of the particulate and dissolved phase, or a procedure using 5-L samples for the analysis of total activities. The analysis involves beta counting, and data will usually be available 3 to 6 days after sampling.

22. PHYTOPLANKTON COMPOSITION AND SPECIES ABUNDANCE
P. Assmy, U. Freier, J. Henjes, C. Klaas, V. Smetacek (AWI)

Experience has shown that iron fertilisation results in accumulation of large-celled diatoms in the patch. Generally only a few species contribute to the bulk of biomass: our study is focussed on the ecology of these large diatom species, in particular *Fragilariopsis kerguelensis*, *Corethron pennatum* and *inerme*, *Thalassiothrix/Trichotoxon*, large *Chaetoceros* of the Phaeoceros group and *Pseudonitzschia*. We will follow the accumulation rates of these species and of course other large diatoms, *Phaeocystis* and protozoa that might also respond to iron addition, by microscopic assessment of field samples. The parameters we will follow are cell-size and chain-length spectra of the dominant species, frequency of dividing cells, empty and broken frustules (due to grazing) as well as semi-quantitative assessment of physiological state using various dyes (e.g. for lipids). The larger protozoa (tintinnids, radiolaria, foraminifera, acantharia) and metazoan faecal pellets will also be counted, the former according to species and size spectra and the latter according to size and shape. The results will provide comprehensive insight on processes occurring in the water column at the level of the dominant species.
Since the species and groups mentioned in first paragraph contribute substantially to the sediments, our measurements will provide information enabling more detailed interpretation of the sedimentary record.
In addition to the work focussed on microplankton, much of which will be carried out on fresh plankton samples on board ship, we will also take water samples for quantitative counting of nanoplankton in the home lab. Picoplankton will be assessed by the group working on bacteria.

Sample requirements
Rapid assessment of the plankton population based on bucket samples from the moving ship necessary for site selection and, following fertilisation, placing the control station, will be carried out by us.
At the long stations we will assess the parameters mentioned above at 6 discrete depths for which we will require the contents of an entire bottle. This will be from the 2nd or 3rd CTD cast at each long station. This will be in addition to water samples (400 ml) from the first CTD cast from every long and medium station for quantitative assessment of the entire micro- and nanoplankton population.
Fine-meshed hand nets will used at each long station to collect large protozoa and to take unialgal isolates.
Dominant species will be isolated from the patch and control water columns for experiments to assess grazer protection mechanisms and dissolution of frustules. The genetic diversity within species populations will also be addressed using molecular methods later in the home lab.

23. MOLECULAR ASSESSMENT OF IRON-LIMITATION USING FLAVODOXIN/FERREDOXIN ASSAYS

J. La Roche, I. Peeken (IFM Kiel)

Objective: Measurements of flavodoxin and ferredoxin abundances to be made in parallel with the iron fertilisation experiment during Polarstern cruise ANT-XVIII/2 to determine the extent to which Southern Ocean phytoplankton populations are iron-limited. Specifically, the objective is to determine the responses of flavodoxin and ferredoxin abundance to iron enrichment by undertaking time series measurements both within the Fe-fertilized patch and in surrounding "control" waters.

Methods: Flavodoxin and ferredoxin abundance will be assessed by immuofluorescence assays on extracts of samples collected on polycarbonate filters and separated by gel electrophoresis. 20 L samples will be collected from surface waters using the clean seawater line, or from 2-4 depths within the water column using water bottles. Samples will be concentrated by filtration, followed by centrifugation. Samples will be collected for both bulk flavodoxin/ferredoxin assays and single-cell fluorescence immunoassays. Samples will be stored frozen until analysis on shore at IfM Kiel. It is important that sufficient samples be collected from outside the patch to characterise the temporal variability in the control waters. This is a requirement not only for the flavodoin/ferredoxin assays, but also for all experiment/studies that intend to assess the effects of iron-enrichment on the physiological and ecological responses.

24. VERTEILUNG DER NÄHRSALZE WÄHREND DES EISENDÜNGUNGSEXPERIMENTS

C. Hartmann, K.-U. Richter, C. Harms (AWI)

Die Verteilung und Dynamik der Nährsalze während des Eisendüngungsexperiments im Bereich der antarktischen Polarfront sollen untersucht werden. Hierbei steht die Wechselwirkung der einzelnen Nährsalzkomponenten mit der Phytoplanktonentwicklung im Vordergrund. Es ist davon auszugehen, dass durch die Eisendüngung ein Phytoplanktonwachstum initiiert wird. Die daraus resultierende Abnahme der Nährsalze soll durch quasi-kontinuierliche Messungen in der Oberflächenschicht verfolgt werden. Dazu ist eine kleinskalige Beprobung mit Hilfe des Seewassersystems der Polarstern in Zusammenhang mit der detaillierten hydrographischen Vermessung vorgesehen. Neben der Bestimmung im Oberflächenwasser soll auch der Einfluß der Eisendüngung auf die Nährsalze in tieferen Wasserschichten untersucht werden. Dafür ist die Bestimmung in Tiefenprofilen an ausgewählten Stationen vorgesehen. Es werden die Nährsalze Nitrat, Nitrit, Ammonium, Phosphat und Silicat mit einem Autoanalyzer System nach Standardmethoden bestimmt.

24. DISTRIBUTION OF NUTRIENTS DURING THE IRON EXPERIMENT

C. Hartmann, K.-U. Richter, C. Harms (AWI)

Distribution and dynamics of the major nutrients in the Polar Frontal Zone during the iron experiment will be determined. The interaction between nutrients and phytoplankton development is the major topic. We assume that a phytoplankton bloom is initiated by the iron fertilization. The resulting decrease in nutrients will be monitored in the surface layer. This will be done in high spatial resolution in connection with the detailed hydrography. The influence of the iron fertilization on the concentration of nutrients with depth will be determined at selected stations. The sampling program includes underway sampling by means of the membrane pump installed on board "Polarstern" as well as bottle samples from CTD-casts. The nutrients (nitrate, nitrite, ammonium, phosphate and silicate) will be measured with an Autoanalyzer system according to standard methods.

25. PHYTOPLANKTON PRODUCTION IN SITU

P. Falkowski, M. Gorbunov (IMCS) and Z. Kolber

Our effort in upcoming cruise will focus on determining the taxa-specific responses of phytoplankton to iron enrichment. Max Gorbunov and Zbigniew Kolber designed and constructed a single-celled fast repetition rate fluorometer. The instrument is capable of examining the photosynthetic properties of individual cells in semi-real time. We have some

capability of sorting cells by their fluorescence properties for later examination (e.g taxonomic affiliation).
The instrument is sea tested and the results from such analyses are extremely helpful in elucidating the structure of the autotrophic community and its response to a perturbation. Max will also bring one of our newer bench-top FRR fluorometers for underway profiling which should free up Geider's in situ instrument for vertical profiling analyses.
We would be very keen to examine how the addition of iron influences the partitioning of Si in diatoms. To that end, we would like to collect size-sorted particles under trace-metal clean conditions for analysis with our ICP/MS at Rutgers.
Obviously all our efforts are collaborative and supportive - we fully expect to contribute our data to AWI data set as soon as the data are available, and to work with AWI and the rest of the cruise participants to understand how iron additions potentially influence primary production in the Southern Ocean.

26. PHYTOPLANKTON DISTRIBUTION AND TAXON-SPECIFIC GROWTH RATES DURING AN IRON FERTILIZATION EXPERIMENT IN THE REGION OF THE ANTARCTIC POLAR FRONTAL ZONE

I. Peeken (IFM-Kiel)

1.1 Research Goals

During the Polarstern cruise ANT XVIII/2 "Iron Fertilization Experiment", a combination of water column sampling and incubations will give new insights about the reaction of phytoplankton to iron fertilization in the Polar Frontal Zone. Additional ground truthing of phytoplankton distribution on horizontal transects to and from the main investigation area will be monitored. The main goals are:

1. Development of biomass and composition of phytoplankton including their physiological state by means of pigment finger prints.
2. Growth rates of taxon specific phytoplankton groups
3. Development of different diatom groups and their interactions with protozooplankton.

1.2 Working concepts

Goal 1

While cruising from Cape Town to the investigation area and back, horizontal profiles of phytoplankton composition and biomass will be recorded by taking samples for algae pigments from the "sea surface sample device". The sample resolution will be 15 nautical miles in frontal regions and 60 nautical miles for the rest of the horizontal transect. Samples will be filtered on Whatman GF/F filters and frozen in liquid nitrogen for further pigment analysis in Kiel. Pigment analysis will be performed following a modified method of Peeken 1997, which determines all different marker pigments including the markers for Cyanophytes and Prochlorophytes.

These data will give the changes of phytoplankton distribution in the different water masses as well as the importance of the different fronts in this region during early and late spring. These data can further be used as a ground truthing data set for the remote sensing investigations of Belem (AWI).

During the iron fertilization experiments the distribution and phytoplankton biomass will be investigated with vertical samples for the upper 500 m of the water column inside and outside of the fertilized patch. Sample strategy will be discussed with other participants of this cruise (see agreement Damp Feb 2000). Samples will be filtered and stored in liquid nitrogen for home analysis of algae pigments.

Together with microscopy (Smetacek et al., AWI) and flow cytometry (Veldhuis (NIOZ) , these data will give the response of all different phytoplankton groups, including pico and nanophytoplankton. Together we can examine individual cell properties, which are grazer independent and population dynamics, which reflect the net result of growth and grazing.

Goal 2

During the iron fertilization experiment, investigations will be performed once per day at the same stations where phytoplankton distribution by means of pigment fingerprints will be monitored (Bio-stations, see report Damp Feb 2000). Sea water from the mixed layer is sampled with GOFLO-bottles, incubated in 4.4 l polycarbonate bottles with $H^{14}CO_3^-$ for 24 h. At the end of the incubation, samples are taken to determine ^{14}C incorporation into POC and into Chl a and taxon specific carotenoids. Phytoplankton growth rates are determined from the specific ^{14}C-activity of Chl a or taxon-specific carotenoids using functions which relate pigment specific activity to growth rates. Thus estimates of phytoplankton growth rate are unaffected by the recycling of carbon in the incubation bottles (e.g. algae respiration, zooplankton grazing) because specific ^{14}C-activity of a pigment a ratio is not affected when zooplankton remove and destroy pigments over the course of an incubation. The isolation of Chl a and the marker carotenoids will be performed according to Goericke and Welschmeyer (1993a; 1993b) in the isotopic lab in Kiel.

These results allow an exclusive estimation of how different algae taxa are affected by iron stimulation and will give actual growth rates for different groups of Antarctic phytoplankton. Together with grazing experiments of Verity (Skidaway) a strong correlation between high grazing pressure on Pico and Nanophytoplankton will be evaluated. These investigations will complement the measurements of the working group of Riebesell et al. (AWI).

Goal 3:

In collaboration with the working group of Smetacek a continuous microscopic monitoring of the diatom development will be performed during the experiment. Major focus will be placed on species composition, the number of diatoms as well as their physiological appearance. We plan to count different size classes and determine the number of dead to live cells. If possible, interactions with Protozooplankton will be monitored. This investigations will be

video taped Live plankton assemblages will be estimated semi-quantitatively and sub samples will be conserved for further microscopic investigations at the home lab. Since previous iron experiments have shown the strong reaction of diatoms to iron fertilization it is important, to get as much information as possible from microscope investigations of fresh phytoplankton, before they are destroyed by preservatives.

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27. MICROZOOPLANKTON
P. Verity (Skidaway)

Several projects will be addressed to the extent determined by sample opportunity, interactive experiments, and space availability. The breadth and frequency of studies described below will, of course, reflect available manpower. If the proposed studies are sufficiently interesting to overall project objectives, they would benefit tremendously from having another participant, dedicated or part-time (we had a team of four in the Barents Sea last summer).

Microzooplankton Grazing, Phytoplankton Growth Rates, and Predation by Copepods.
This generic group of studies will focus on the potential role of small zooplankton in the processing of primary production during system response to Fe fertilization. Despite their acknowledged role as grazers, microzooplankton have hitherto been largely ignored during prior Fe experiments. We will conduct dilution experiments measuring their grazing of chlorophyll a production (and perhaps also bacterial production, depending upon time and the interests of other scientists). These would be done using natural communities in the enrichment patch and preferably also in non-enriched communities (if that is part of the sample strategy). These experiments could be done in conjunction with sampling by other groups measuring pigment arrays (HPLC), bacterial production, phytoplankton-specific growth rates, metazooplankton grazing. The dilution technique yields estimates of both microzooplankton community grazing and phytoplankton community biomass growth (or that of other prey). Samples would be analyzed back in the lab using quasi-automated image

analyzed fluorescence microscopy, providing taxonomic and functional group specific growth and grazing rates. Separate experiments could be conducted in conjunction with metazooplankton scientists to quantify community or species-specific predation by larger zooplankton upon microzooplankton. That is, we could contribute to improved understanding of who eats who, and who (if any) seems to reduce/avoid being eaten. These studies will benefit from cooperative planning and implementation, especially prior to cruise departure.

Physiological State of Bacteria. Burgeoning evidence globally indicates that natural aquatic bacteria are not all metabolically active at a given moment, in fact most appear to be comparatively inactive. This surprising notion threatens to precipitate another paradigm shift in conceptual models of ecosystem function.

At the very least, it would imply that comparatively few bacteria in situ are growing (and respiring) much faster than previously thought, and that a substantial fraction of DAPI-stained bacteria are either inactive or operationally a component of detritus. We have developed a novel combination of a fluorescent stain and molecular probes which quantitatively identify those cells with compromised membranes, and those cells containing sufficient rRNA to be metabolically active. While neither approach might be considered sufficient to specify active from inactive, moribund, or dead cells, together they comprise a powerful tool to investigate the relative importance of these cell types in situ, and to postulate which sources of bacterial mortality may be important at a given time and place. Additionally, we have developed a method to quantify the volume and carbon content of detritus distinct from that of living auto- and heterotrophic carbon. Our preliminary data from northern Norwegian fjords suggests that larger percentages of bacteria are metabolically active when associated with detritus than in the absence of this substrate. Interestingly, metazooplankton fecal pellet flux was inversely related to detritus concentrations. Here we will investigate changes in physiological status of bacteria and accumulations of detritus as plankton communities respond to Fe additions. To our knowledge, such data from Fe experiments have not been collected. The results will support the quantitative basis for a revised conceptual model of the role of bacteria in transformations between nutrients, detritus, and bacteria in such waters.

Nitrate Utilization by Heterotrophic Bacteria. The importance of inorganic nitrogen for the nutrition and growth of marine phytoplankton has long been recognized, while the utilization of inorganic nitrogen by bacteria has historically received less attention. The primary role of bacteria is usually considered to be decomposition and mineralization of dissolved and particulate organic nitrogen. However, heterotrophic bacteria can exert considerable influence on the processing and export of nitrogen and carbon in the water column, and an increasing amount of evidence suggests that bacteria compete with phytoplankton for inorganic nitrogen. This competition is regulated by Fe availability in HNLC areas. We have

developed molecular tools (PCR and RT-PCR primer sets) that allow us to selectively isolate, characterize, and study the diversity and genetic expression (mRNA) of the structural gene responsible for the assimilation of nitrate by heterotrophic bacteria (*nasA*) . To date, our studies have revealed that bacteria capable of assimilating nitrate are ubiquitous in marine waters, and that the expression of *nasA* can be regulated in model organisms by the concentration of ammonium. Additionally, in controlled bioassay studies conducted *in situ* in the Barents Sea and Norwegian shelf waters, nitrate was utilized by bacteria size fractions indicated by the uptake of ^{15}N and corresponding increases in bacterial biomass. However, to our knowledge such data are unknown in the Southern Ocean, and linkages between bacterial nitrate use and Fe availability should be intriguing. Here, we plan to extend our observations concerning the diversity and abundance of heterotrophic bacteria capable of utilizing NO_3^-. We will collect and filter water samples (40L) that will be used back in the lab to determine the abundance and diversity of the *nasA* gene. After collection these filters will be stored frozen. On board the ship we will also attempt to isolate and grow bacteria capable of growth on NO_3^- as a sole N source. Samples will be stored either at ambient temperature or in a cold room.

28. MESOZOOPLANKTON

S. Schultes, S. Krägefsky, U. Bathmann (AWI)

The main objectives for zooplankton work during EISENEX are stated in the following, accompanied by a brief description of the methods that will be used to address them.

Determine zooplankton biomass distribution inside and outside the Fe-fertilized patch and the dominance in species composition contributing to this biomass

There will be Multi-Net catches on a regular basis inside and outside the patch (at least once a day) for qualitative and quantitative estimate of ind per m^2 and m^3. Furthermore, we will try to locate zooplankton patches and estimate biomass distribution and species composition in the field based on continous acustic observations with with a SIMRAD EK60 echosounder system for the upper 300m of the water column. Calibrations and samples for species determinations will be carried out by means of Multi-Net catches at distinct different locations.

Determine the impact of herbivorous zooplankton grazing on phytoplankton carbon within and outside the Fe-fertilized patch

We will estimate grazing impact on the phytoplankton community (mg C per m^2 or m^3 and day) of the dominant mesozooplankton groups (copeopods, salps, krill, others if of interest) with the gut fluorescence technique. NH_4 excretion and respiration (O_2) rates will also be determined.

Quantify species specific selection in zooplankton grazing and its impact on the biogeochemical cycling on carbon and silicate
Grazing experiments will be conducted with the natural phytoplankton community (possibly concentrated) and addition of specific grazers. $Si(OH)_4$ and BSi will be measured during grazing experiments and a detailed taxonomic count will be done before and after to look for selective grazing on more or less silicified phytoplankton species. In addition, freshly caught zooplankton specimens will be preserved for a qualitative analysis of the gut content with REM back in the laboratory. Microscopy will be used to study grazed and ungrazed phytoplankton samples in order to interprete feeding behaviour, e.g. if the grazers take a bite, ingest the whole cell or suck out the cell content.
Dissolution experiments with fecal material and fresh phytoplankton with different iron "histories" will be performed and time series of $Si(OH)_4$ and BSi established. If possible, dissolution and BSi content of fecal material from greater depths (500 m) will also be investigated.

29. PARTICULATE ORGANIC CARBON (POC) AND NITROGEN (PON), DISSOLVED ORGANIC CARBON (DOC) AND NITROGEN (DON), CHL. A

U. Riebesell, U. Schneider, F. Gervais, A. Terbrüggen, A. Benthien (AWI)

Objective: To determine the development of phytoplankton biomass (POC, PON, Chl. a) and dissolved organic matter (DOC, DON) over the course of the bloom and in response to Fe enrichment.
Rational: These parameters will provide estimates of changes in bulk organic matter and phytoplankton biomass and – in combination with other measurements – will help to determine the response of the plankton community to iron enrichment. DOC and DON measurements will contribute in assessing the fate of organic matter produced in response to Fe fertilisation.
Methodology: Water samples will be collected from CTD-casts both inside and outside the patch of Fe-enrichment. Water samples will be filtered on GF/F filters (for POC, PON, and Chl. a). Chl. a measurements will be performed fluorometrically onboard the ship. POC and PON samples will stored frozen until analysis on a Europa Scientific ANCA SL 20/20 mass spectrometer in the home laboratory. DOC will be measured by high temperature catalytic oxidation and DON by wet chemical oxidation.
Size-fractionated primary production

Objective: To determine ^{14}C primary production in different phytoplankton size fractions within and outside iron-enriched waters.

Rational: Based on previous iron enrichment experiments it is expected that the response to Fe addition differs between phytoplankton size classes. In general, micro-phytoplankton (in particular diatoms) respond more strongly than pico- and nano-plankton.

Methodology: To measure size-fractionated ^{14}C primary production during the iron fertilisation experiment we intend to incubate samples from a maximum of 6 CTD-depths in a laboratory incubator according to Babin et al. (L&O 39: 694-702, 1994). Each sample will be incubated for 4 h at in situ temperature at about 12 different light intensities. Using different filter mesh sizes, we will quantify carbon uptake in two (>20 µm, < 20 µm) or three (<2 µm, 2-20 µm, >20 µm) size fractions and also exudation of organic carbon. The relationship between algal photosynthesis and irradiance (P/I curves) will be analysed. By combining these results with measurements of global radiation and the vertical light attenuation coefficient, areal daily primary production will be calculated. The use of a photosynthetron will enable us to measure ^{14}C-P/I curves of samples taken from the phytoplankton incubations of the NIOZ group which are intended to study algal responses to iron enrichment over several days in a mesocosm approach. It is presently (April 2000) not clear whether a XE-PAM fluorometer will be available to give additional information on variable fluorescence of the phytoplankton.

Stable carbon and nitrogen isotopes

Objective: To monitor changes in stable carbon and nitrogen isotopes in response to Fe-fertilisation.

Rational: The stable carbon and nitrogen isotopic compositions of marine organic matter ($\delta^{13}C$, $\delta^{15}N$) provide important insights into the environmental conditions under which the organic matter was formed. The isotopic signals incorporated in phytoplankton organic matter are known to be affected by the availability of inorganic carbon and nitrogen, by the form of carbon (CO_2 or HCO_3^-) and nitrogen (NO_3 or NH_4) taken up by the cells, by the rate of growth, and by the growth-limiting resource (among other factors). Significant differences in the isotopic compositions are therefore expected in Fe-fertilised relative to Fe-deplete phytoplankton. Such differences may help to determine changes in iron availability and related changes in primary production over the geological past from the isotopic compositions of sedimentary organic matter. To account for possible interference from non-phytoplankton organic matter, stable isotopes will be measured in both bulk organic matter and phytoplankton-specific (and where possible taxon-specific) biomarkers

Methodology: Particulate organic matter will be sampled from CTD-casts (for determination of bulk organic matter $\delta^{13}C$ and $\delta^{15}N$) and from the vessel's uncontaminated sea-water system (for measurement of $\delta^{13}C$ of individual biomarkers of marine autotrophic origin (e.g. phytol, sterols, alkenones). Sampling will be performed inside and outside the patch of Fe-enrichment during the period of bloom development. Water samples will be filtered on GF/F

filters and stored frozen until analysis on a Europa Scientific ANCA SL 20/20 mass spectrometer in the home laboratory.

^{17}O anomaly, O_2/Ar

Objective: To determine changes of *in situ* gross and net community primary production in response to iron fertilisation.

Rational: Estimates of primary production (bottle incubations, changes in O_2 concentration, calculations from P/I curves etc.) all have their advantages and shortcomings. An independent and potentially powerful method to determine *in situ* gross and net community primary production is through measurements of the triple isotope composition of dissolved oxygen and the ratio of O_2/Ar (see Luz et al., Nature 400, 547-550, 1999). The advantage of this method is that it provides spatially and temporally integrated estimates of gross and net primary production.

Methodology: Seawater samples (1 litre) will be taken from CTD casts inside and outside the patch of iron addition. Dissolved oxygen argon will be extracted onboard and stored in air-tight glass containers. Measurements of oxygen isotopes and determination of O_2/Ar will be performed according to Luz et al. (Nature 400, 547-550, 1999) at the Hebrew University of Jerusalem, Israel (collaboration with Prof. Boaz Luz).

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