Expeditionsprogramm Nr. 71

FS POLARSTERN

ANT XXII/1+2
2004/2005

Koordinator: Prof. Dr. P. Lemke

Fahrtleiter:

ANT XXII/1: Dr. S. El Naggar

ANT XXII/2: Prof. Dr. M. Spindler

ALFRED-WEGENER-INSTITUT
FÜR POLAR- UND MEERESFORSCHUNG
in der Helmholtz-Gemeinschaft

Bremerhaven, Oktober 2004

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FS POLARSTERN

ANT XXII/1

12.10.2004 – 04.11.2004
Bremerhaven - Kapstadt

ANT XXII/2

06.11.2004 – 19.01.2005
Kapstadt – Kapstadt

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EXPEDITION ANT XXII/1

1. ZUSAMMENFASSUNG UND FAHRTVERLAUF

Nach einem kurzen Hafenaufenthalt in Bremerhaven (03.10.04 -12.10.04) wird die POLARSTERN ihre 22. Antarktisreise am 12.10.04 antreten. Der erste Fahrtabschnitt (ANTXXII/1) wird zur Erprobung von wissenschaftlichen Geräten und zur Durchführung von atmosphärischen Messungen genutzt. Die Reise wird am 12.10.2004 gegen 13:00 Uhr in Bremerhaven beginnen und am 04.11.2004 08:00 Uhr in Kapstadt enden. Die POLARSTERN wird auf kürzestem Wege nach Kapstadt geführt (Abb. 1) und die Transferzeit wird ca. 22 Tage betragen. Die wissenschaftlichen atmosphärischen, meereschemischen und luftchemischen Mes–sungen werden bei voller Fahrt des Schiffes durchgeführt. Ein Teil der Testmannschaft (AWI, FIELAX, Atlas Hydrographic) wird am 19.10.2004 in Gran Canaria (Las Palmas) ausgeschifft.

Während ANT XXII/1 werden verschiedene wissenschaftliche Programme sowie Erprobungen, Tests und Abnahmen von technischen Einrichtungen durchgeführt. Auf dem ersten Teilabschnitt (Bremerhaven - Las Palmas) sind folgende technische Erprobungen und Tests geplant:

- Das Fächersonar HYDROSWEEP von ATLAS Hydrographic, Bremen, wurde mit neuen Rechnerhardware ausgestattet. Das System wird auf Integrität und Funktionalität geprüft. Eine neue Kalibrierung bezüglich der Navigationsplattform (MINS) wird zusätzlich vollzogen. Diese Maßnahme ist nach dem Austausch der defekten MINS erforderlich geworden.

- Das Tiefsee-Sedimentecholot PARASOUND DS II von ATLAS Hydrographic, Bremen, wurde im Juni 2004 modernisiert. Die Software hierfür wird im Oktober 2004 modifiziert. Bis Las Palmas wird das System durch AWI-Wissenschaftler und Techniker von FIELAX und ATLAS Hydrographic getestet und neu eingestellt.

- Ein neues EDV-Massenspeichersystem, SUN - System, wird im Oktober installiert. Das System wird durch die Mitarbeiter der Firma FIELAX und des AWI-Rechenzentrums an Bord in Betrieb genommen und während der Fahrt im realen Betrieb getestet.

- Die Beschleunigungen (Verzögerungen) in verschiedenen Orten an Bord der POLARSTERN werden mit Hilfe eines dreiachsigen Beschleunigungsloggers gemessen und analysiert.

Folgende wissenschaftliche Programme sind zusätzlich vorgesehen:

- Die UV-B-Gruppe des AWI wird während der Reise eine UV-B-Meßkampagne durchführen, die die spektralen UV-Verteilungen (UV-B&UV-A) in Abhängigkeit der geographischen Breite 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 Radiosonden zur Sondierung der Atmosphäre gestartet.

- Die IfM-GEOMAR-Gruppe wird die Langzeittrends und die saisonale Variabilität der 13C-Isotopie des gelösten anorganischen Kohlenstoffs (DIC) im Oberflächenwasser des Nordatlantiks untersuchen.

- Die Gruppe aus Heidelberg (IUP) wird die atmosphärischen Spurengase mit Hilfe des DOAS (Differential Optical Absorption Spectroscopy) entlang der Route messen. Hier handelt es sich um Ermittlung der Spurengasverteilung in der Atmosphäre und deren Transportmechanismen.

- Die Arbeitsgruppe der Universität Hamburg wird die gelösten organischen Substanzen im Tiefenwasser des Atlantiks (DOM) untersuchen. Hierfür werden Wasserproben gesammelt, filtriert und für die späteren Untersuchungen vorbereitet.

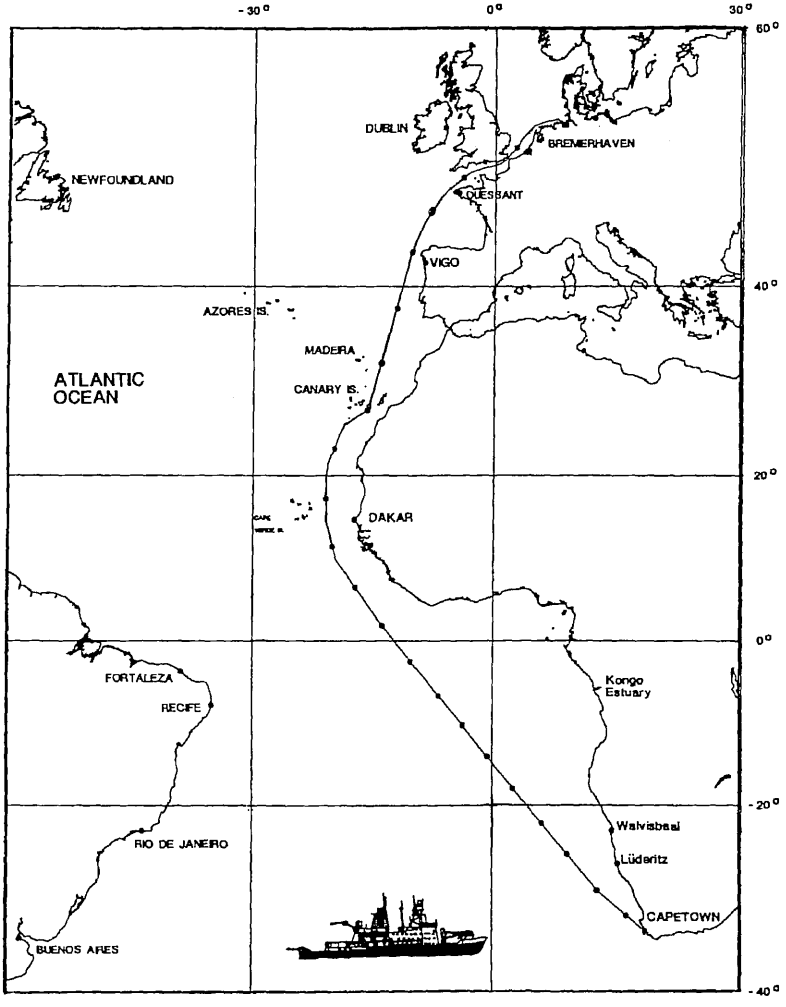

Abb.1: Geplante Route auf ANT XXII/1 FS POLARSTERN
Fig. 1: Planned Route on ANT XXII/1, RV POLARSTERN

2. MESSUNG VON UV-BESTRAHLUNGSSTÄRKEN UND UV-B-DOSIMETRIE (AWI)

Die solare UV-B-Strahlung in der Antarktis hat in den letzten 20 Jahren, bedingt durch den Ozonabbau, zugenommen. Die Auswirkung dieser Strahlenbelastung auf die Biosphäre ist ein Schwerpunkt vieler wissenschaftlicher Programme. Die Auswirkungen auf die Menschen, die sich in antarktischen Gebieten aufhalten, bedarf jedoch noch systematischen Studiums. Zu diesem Projekt sollen hier Basisdaten gewonnen werden.

Bedingt durch die erhöhte Einstrahlung und die hohe Albedo des Schnees in der Antarktis (bis zu 90% im UV-B-Bereich), ist die schädigende Wirkung der UV-B-Strahlung auf den Menschen sehr hoch. Mit Hilfe verschiedener Dosimetersysteme soll in einer Langzeitstudie die maximal vorkommende UV-B-Dosis auf der Neumayer-Station ermittelt werden, um Risikofaktoren abschätzen zu können. Dafür werden UV-B-Personen-Dosimetrie-Messungen an Überwinterern und Expeditionsteilnehmern durchgeführt werden. Für die Risikoabschätzung werden Vergleichsdaten benötigt. Diese sollen auf den meridionalen Abschnitten zu verschiedenen Jahreszeiten ermittelt werden. Dadurch kann die maximal zu erwartende UV-B-Dosis auf Meeresniveau und ihre Variationen bestimmt werden.

Ziele des Forschungsvorhabens sind:

- Untersuchung der spektralen UV-Strahlung (A + B) zwischen 290 – 400 nm und deren Transfer durch die Stratosphäre
- Bestimmung der globalen UV-B-Dosis auf meridionalen Abschnitten zwischen Bremerhaven – Kapstadt unter Verwendung des elektronischen UV-B-Dosimeters ELUV-14 und des UV-B-Biometers
- Bestimmung der maximalen UV-B-Tagesdosis in Abhängigkeit von der Sonnenhöhe und Ozonkonzentration.

Das Arbeitsprogramm umfasst:

- Messung der spektralen UV-A und UV-B Bestrahlungsstärken mit dem AWI-Spektrometer
- Direkte Messung der Erythem gewichteten UV-B-Bestrahlungsstärken und UV-B-Tagesdosen mit dem SOLAR LIGHT-Biometer, 501, und dem ELUV-14-Dosimeter
- Kalibrierung von neuen UV-B-Dosimetern (ELUV-14) unter realen Bedingungen.

3. MESSUNG DER DYNAMISCHEN BESCHLEUNIGUNGSKRÄFTE AN BORD DES FS POLARSTERN (AWI)

Um die Beschleunigungen (Verzögerungen) in verschiedenen Orten an Bord der POLARSTERN hochaufgelöst ermitteln zu können, wurde ein dreiachsiger Beschleunigungslogger entwickelt und soll hier eingesetzt werden. Die hiermit gewonnenen Daten werden zur Spezifikation von empfindlichen Geräten, die an Bord der POLARSTERN eingesetzt werden sollen, benötigt. Bis jetzt liegen nur

grobe Angaben über diese Verzögerungen für bestimmte Orte an Bord vor. Diese Daten reichen für eine Spezifikation nicht aus. Vor allem sollen hier die drei Achsen parallel gemessen und somit die Horizontalkräfte ermittelt werden.

Arbeitsprogramm

- Test des neuen Systems
- Installation und Durchführung der Messungen an verschiedenen Orten
- Auswertung der Daten.

4. TEST UND ABNAHME DES NEUEN EDV-MASSENSPEICHERS (AWI, LAEISZ, FIELAX)

Während der kommenden Werftzeit wird der neue Massenspeicher an Bord von POLARSTERN installiert. Der mechanische Aufbau sowie die Konfiguration werden durch FIELAX in Zusammenarbeit mit Lieferfirmen durchgeführt. Der Massenspeicher besteht aus SUN-Servern mit externen Plattenspeicher sowie einer Backup-Library (vergleichbar mit einem 'Mini-Silo' des AWI). Die Implementierung des gesamten Systems in das Server-Netzwerk an Bord von POLARSTERN ist zeitaufwändig und kann nur bei funktionsfähigen Servern und Computernetzwerk erfolgen. Während der Werftzeit sind diese Voraussetzungen leider nicht gegeben, da die SUN-Server gewartet werden müssen und das gesamte Glasfaser-Netzwerk des E-Decks an den Anschlüssen im Rechnerraum neu gespleißt wird (Dauer 5 Werktage). Weiterhin ist mit Unterbrechungen der Klimatisierung im Rechnerraum zu rechnen, die ein komplettes Abschalten der Server und Netzwerkkomponenten erforderlich macht. Der neue Massenspeicher schafft einen Standard für den Datenaustausch an zentraler Stelle zwischen POLARSTERN und dem AWI. Auf dem Teilabschnitt zwischen Bremerhaven und Las-Palmas soll das System im realen Betrieb getestet und abgenommen werden.

Arbeitsprogramm

- Fortsetzung der Installation und Funktionstest des Systems, falls erforderlich ist
- Konfiguration, Einstellung und Tests
- Abnahme und Inbetriebnahme des gesamten Systems.

5. LANGZEITTRENDS UND SAISONALE VARIABILITÄT DER 13C-ISOTOPIE DES GELÖSTEN ANORGANISCHEN KOHLENSTOFFS (DIC) IM OBERFLÄCHENWASSER DES NORDATLANTIKS (IfM-GEOMAR)

Dieses Projekt stellt die Fortsetzung des bereits seit der POLARSTERN-Reise ANT XXI/1 durchgeführten längerfristigen Beobachtungsprogramms zur 13C-Isotopie des gelösten anorganischen Kohlenstoffs (δ13C-DIC) im Oberflächenwasser des Atlantiks dar. Die zweimal jährlich auf den An- und Heimreisen von FS POLARSTERN durchgeführte Beprobung soll zum einen Einblick in die Saisonalität und interannuelle Variabilität des δ13C-DIC in unterschiedlichen Regimen (subtropisch – subpolar, oligotroph – mesotroph, thermische vs. biologische Kontrolle

des CO_2-Systems) bieten. Zum anderen sollen Trends im δ13C-DIC, die aufgrund des ^{13}C-Suesseffekts auftreten, über einen längeren Zeitraum erfasst werden.

Eine ähnliche wissenschaftliche Fragestellung wird bisher im wesentlichen an Zeitserienstationen wie der Bermuda Atlantic Time Series Study (BATS) und der Hawaii Ocean Time Series bearbeitet. Zusätzlich werden „Volunteer Observing Ships" in Nordpazifik und Nordatlantik für eine regelmäßige Beprobung eingesetzt. So sollen im Rahmen des auf 5 Jahre ausgelegten EU-Projekts CarboOcean ab 2005 vom IfM-GEOMAR regelmäßig δ13C-DIC-Daten entlang einer transatlantischen VOS-Route im Nordatlantik gewonnen werden. Die Beprobung während der POLARSTERN-Transits stellt eine wichtige Erweiterung dieses Forschungsvorhabens dar.

6. MAX-DOAS-MESSUNGEN ATMOSPHÄRISCHER SPURENGASE ZUR SCIAMACHY-VALIDIERUNG (IUP)

Einführung

Ein wichtiger Aspekt der Umweltforschung ist die Kenntnis von Spurengasen sowie deren Konzentration und Verteilung in der Atmosphäre. Besonders interessant sind dabei etwa NO_2, H_2O, HCHO, IO und SO_2 in der Troposphäre sowie O_2, NO_2, BrO, OClO, H_2O, HCHO, O_2 und IO in der Stratosphäre. Entsprechende Messungen werden beispielsweise mit Satelliten vorgenommen, wie etwa durch das Instrument SCIAMACHY auf dem am 1.3.2002 in einen polaren Orbit gestarteten ENVISAT. Zur Überprüfung und zur Bestimmung der Genauigkeit der vom Satelliten gelieferten Daten sind aber erdgestützte Instrumente unerlässlich, die an der Umlaufbahn des Raumfahrzeugs entsprechenden Orten Kontrollmessungen durchführen. Im Fall von SCIAMACHY bieten sich dabei Messungen auf der FS POLARSTERN an, deren Generalkurs auf der Fahrt zu und von der Antarktis der polaren Umlaufbahn von ENVISAT entspricht.

Das DOAS-Messinstrument

Die vom Satelliteninstrument angewandte Methode zur Messung atmosphärischer Spurengase ist das bewährte Differential Optical Absorption Spectroscopy Prinzip (DOAS). Hierbei macht man sich zunutze, dass durch die Atmosphäre fallendes Sonnenlicht an Gasmolekülen gestreut wird und danach der Gasart und -menge entsprechende, mehr oder minder tiefe Absorptionslinien in dessen Spektrum sichtbar sind. Davon kann auf die vorhandenen Gase und deren Konzentration in der Atmosphäre geschlossen werden. Bei erdgestützten Messungen kann die Beobachtung von Sonnenlicht aus verschiedenen Richtungen auch Aufschluss über die Höhenverteilung der Spurengase geben: bei vertikal einfallendem Licht sind stratosphärische Absorber bestimmend, weil hierbei der Lichtweg durch diese hohe Atmosphärenschicht am längsten ist. Bei eher horizontal einfallendem Licht ist der Lichtweg durch die Troposphäre länger und deren Absorber kommen verstärkt vor. Dies ist das sogenannte Multi-Axis-DOAS.

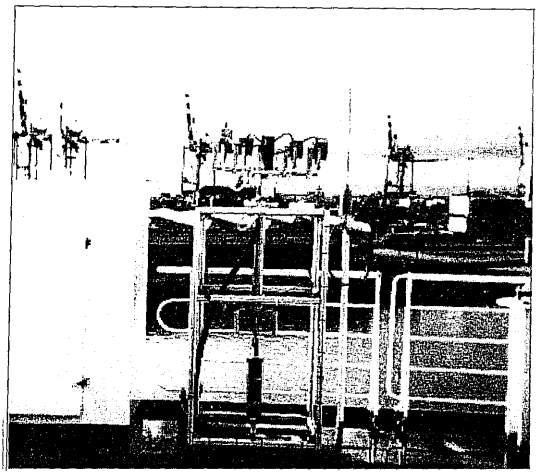

Abb.2: Das Teleskopsystem des MAX-DOAS-Instruments auf der Backbordseite des Beobachtungsdecks der FS POLARSTERN. Je zwei Schwenkteleskope sind auf beiden Seiten eines zentralen Verteilerkastens sichtbar. Unter dem Verteiler ist das Kardangelenk, dann das Gegengewicht und eine einfache pneumatische Dämpfung zu sehen.

Das zur Validierung verwendete Instrument auf des FS POLARSTERN wendet entsprechend dem Satellitengerät natürlich ebenfalls das DOAS- bzw. das MAX-DOAS-Prinzip an. Da manche der interessanten Spurengase wie etwa BrO, SO_2 sowie HCHO aber nur im ultravioletten, andere wie H_2O sowie IO nur im visuellen Spektralbereich absorbieren und da in beiden Bereichen unterschiedliche Anforderungen an die spektrale Auflösung gestellt werden, besteht das schiffsgestützte Instrument aus zwei separaten Systemen für UV und Vis. Beide benutzen Schwenkteleskope für MAX-DOAS, das UV-System jedoch drei statt des einen für Vis, da der UV-Anteil des Sonnenlichts geringer und die Belichtungszeit bei Aufnahme eines UV-Spektrums daher länger als im Vis ist. So kann die Messzeit reduziert werden.

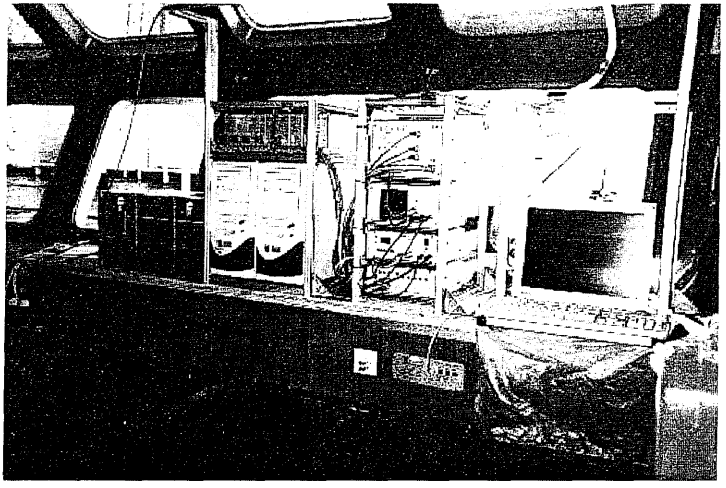

Abb. 3: Fast direkt unter den Teleskopen, auf der Backbordseite der Beobachtungsgalerie, sind die Spektrographen, Computer, Elektronik, Versorgung u.ä. untergebracht. Die Metallrahmen dienen zu Transport und Befestigung der Einheiten.

Die an Deck an einem kardanisch gelagerten Gestell montierten vier verwendeten Teleskope sind baugleich und haben in ihren Gehäusen neben den notwendigen Fahrmotoren auch Schutzblenden und HgNe- sowie Halogen-Lampen zur Kalibrierung des Systems. Das einfallende Licht wird bei den drei UV-Teleskopen jeweils per siebenadrigem Lichtleiter zu nur einem Spektrometer geführt. Dort bilden die Adern drei übereinanderliegende Eintrittspalte von je ca. 1200 μm x 170 μm. Die entstehenden Spektren werden auf unterschiedliche Bereiche der angeschlossenen zweidimensionalen CCD-Kamera mit 1024 x 256 Pixeln abgebildet und zur späteren Auswertung aufgenommen. Dieses System ermöglicht die simultane Aufnahme von Spektren aus drei unterschiedlichen Blickrichtungen. Das Licht vom Vis-Teleskop wird von einem einfachen Lichtleiter zu einem Spektrographen mit einer 2048-Pixel-Detektorzeile für das erzeugte Spektrum gebracht. Dieses System beobachtet nacheinander verschiedene Blickrichtungen. Das ganze Instrument ist weitgehend automatisiert und sammelt 8-10 GB an Messdaten pro Monat.

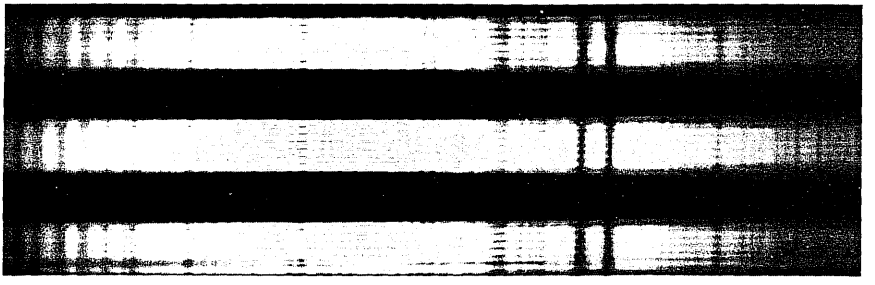

Abb. 4: Aufnahme von drei UV-Spektren auf einem CCD-Detektor. Die einzelnen Adern der Lichtleiter von den Teleskopen sind zu erkennen.

Ergebnisse

Bei Messungen auf der Fahrt ANT XIX des FS POLARSTERN mit dem Vorgänger des jetzigen Geräts (gleiche Geräte, aber anderes System der Teleskopeinheiten für MAX-DOAS) wurden z.B. die Konzentrationen von BrO und NO_2 während der Fahrt von Bremerhaven nach Kapstadt ermittelt. Die Maxima der jeweiligen Werte traten während der Kanal-Durchfahrt auf: 3.1 +/-1.1 parts per trillion für BrO und 0.36 +/- 0.13 parts per billion für NO_2. Dies war aufgrund der Luftverschmutung über Europa zu erwarten. Daneben zeigte sich eine Antikorrelation zwischen Brom- und Stickstoffdioxid auf dieser Fahrt: Wahrscheinlich bildet sich eine Reservoirsubstanz aus beiden Gasen (siehe auch Diplomarbeit von Herrn J. Boßmeyer). Derartige Ergebnisse sollen auch durch Messungen von der Fahrt ANT XXI bestätigt und erweitert werden. Außerdem sollen natürlich Erkenntnisse über andere messbare Spurengase gesammelt werden. Neben derartigen hauptsächlich zur Validierung des Satelliteninstruments durchgeführten Messungen sind aber auch Messungen in der Antarktis wichtig für die Atmosphären- und Klimaforschung.

Ähnliche Messungen auf Fahrten des FS POLARSTERN sind schon in den Jahren 1990, 1993, 2001/2002, 2002/2003 und 2003/2004 vom Heidelberger Institut für Umweltphysik mit gutem Erfolg durchgeführt worden.

Weiterführende Literatur

Kreher, K.; Messung der Breitenverteilung (50°N – 70°S) von stratosphärischem Ozon mittels optischer Absorptionsspekroskopie, Diplomarbeit, Universität Heidelberg, 1991

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Senne, T.; Stutz. J.; Platt, U.; Measurement of the latitudinal distribution of NO2 column densities and layer heights in Oct./Nov. 1993, Geophys. Res. Let., 23, 805-808, 1996.

Boßmeyer, J.; Ship-Based Multi-Axis Differential Optical Absorption Spectroscopy Measurements of Tropospheric Trace Gases over the Atlantic Ocean, Diplomarbeit, Universität Heidelberg, 2002.

7. UNTERSUCHUNG GELÖSTER ORGANISCHER SUBSTANZ (DOM) AUS TIEFENWASSER DES ATLANTIKS (IfBM)

DOM im Ozean ist ein Kohlenstoffresevoir von vergleichbarer Größe mit dem atmosphärischen CO_2. Seine Dynamik ist nur partiell verstanden, der überwiegende Teil des DOM (ca. 70%) konnte bisher nicht chemisch charakterisiert werden. Es ist ein heterogenes Gemisch unterschiedlich großer Moleküle, wobei die „echt gelöste" Fraktion (<1000Da) gegenüber der „kolloidalen" Fraktion (>1000Da) überwiegt. Datierungen an Untereinheiten des marinen DOM zeigen, dass das 14C-Alter mit abnehmendem Molekulargewicht zunimmt (Loh et al. 2004). In eigenen Vorarbeiten zur terrestrischen Quelle von marinem DOM haben wir Molekulargewicht, Huminstoffanteil und Kohlenstoffisotope des DOM sibirischer Ästuare und der Kara-See untersucht (Spitzy et al. 2002). Da in der Kara-See ein rein marines Endglied aufgrund der hohen terrigenen Einträge nicht gewonnen werden kann, wollen wir für vergleichende Untersuchungen fernab terrigener Einflüsse aus atlantischem Tiefenwasser im Bereich des Angola-Beckens eine Großvolumenprobe (ca. 1000 l) nehmen. Die Probe wird an Bord zur weiteren Bearbeitung in Hamburg ultrafiltriert.

Loh, A.N., J.E. Bauer & E.R.M. Druffel (2004) Variable ageing and storage of dissolved organic components in the open ocean. Nature 430: 877-881.
Spitzy, A., S. Ertl & H.Köhler (2002) Dissolved humic matter in Arctic Estuaries. EOS 83(47).

8. WARTUNGS- UND ÜBERPRÜFUNGSARBEITEN AM HYDROSWEEP DS2 MULTIBEAM-SYSTEM (AWI, LAEISZ, FIELAX, Atlas Hydrographic)

Während des Hafenaufenthaltes der POLARSTERN im Herbst 2004 wurde das Multibeam-System Hydrosweep DS2 mit neuen Computern und aufdatierter Software im Bereich Steuerung, Bedienung und Visualisierung modernisiert. Diese umfangreiche Umrüstung erfordert eine Überprüfung aller Funktionen des Systems unter realen Messbedingungen am Schelfrand und in der Tiefsee. Zur Überprüfung der Langzeitstabilität wird Hydrosweep während des gesamten Fahrtabschnittes betrieben. Die außerhalb der "ausschließlichen Wirtschaftszone" (AWZ) gemessenen bathymetrischen Daten werden aufgezeichnet und bearbeitet. Sie dienen so der Vervollständigung und Verbesserung internationaler bathymetrischer Karten, wie z. B. der GEBCO.

Beide Laserkreisel-Systeme (MINS), mit denen u. a. der Stampf- und Rollwinkel des Schiffes gemessen wird, wurden während der Arktisexpedition 2004 ausgetauscht, bzw. repariert. Das erfordert eine Kalibrierung beider Systeme zur Bestimmung von Korrekturwerten für die Stampf- und Rollwinkel. Die Kalibrierung wird durch mehrfaches Abfahren eines geraden, ca. 5 nm langen Profils über einem möglichst ebenen Meeresboden durchgeführt.

Das Hydrosweep-System wird auf allen diesem Abschnitt folgenden Fahrtabschnitten eingesetzt. Zur Vorbereitung werden die Datenarchive und die für die Bearbeitung der Hydrosweep-Messdaten benutzten Computer und Auswerteprogramme auf neuesten Stand gebracht.

9. ÜBERPRÜFUNG, TESTS UND ABNAHME DES TIEFSEE-SEDIMENT-ECHOLOT PARASOUND DS II (AWI, LAEISZ, FIELAX, Atlas Hydrographic)

Das Tiefsee-Sediment-Echolot PARASOUND DS II von ATLAS Hydrographic, wurde im Juni 2004 modernisiert. Hierbei wurde das System von DS I auf DS II erweitert. Die Steuerungshardware sowie die dazugehörige Software wurden ausgetauscht und während ARK XX erprobt und eingesetzt. Die Leistungselektronik ist dabei unverändert erhalten geblieben und soll bei der zweiten Stufe auch ausgetauscht werden. Eine neue erweiterte Softwareversion wird im Oktober 2004 eingespielt. Das komplette System soll zwischen Bremerhaven und Las Palmas durch AWI-Wissenschaftler und Techniker von FIELAX und ATLAS Hydrographic getestet, neu eingestellt und abgenommen werden.

Expedition ARK XXII/1

1. ITINERARY AND SUMMARY

After a short harbour stop in Bremerhaven (03.10.04 - 12.10.04) the RV POLARSTERN will carry out its 22th cruise to Antarctica. The first leg of this cruise (ANTXXII/1) will start in Bremerhaven on 12.10.04, 13:00 and will be completed in Cape Town on 04.11.04 8:00. During this cruise scientific instrumentation 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 22 days including 1 day for station works and sea trials of instrumentation. A part of the testing crew (AWI, FIELAX, Atlas Hydrographic) will disembark on 19.10.04 in Gran Canaria (Las Palmas). The following sea trials and instrumentation tests will be carried out beween Bremerhaven and Las Palmas:

- The Multi-Beam Echo Sounder (Hydrosweep DS II, Atlas Hydrographic) will be equipped with a new hardware. The complete system will be tested under real conditions at sea and a sea trial will be performed. In addition, a calibration of the system in connection to the replaced navigation platform (MINS) will be carried out. The stability, reliability and the functionality of the system will be tested during the complete cruise.

- The Deep Sea Sediment Echo Sounder (PARASOUND DS II, Atlas Hydrographic) was upgraded in Jun 2004 to DS II. An upgrade of the software will be performed in October in Bremerhaven. A sea trial and a final tuning of the complete system will be carried out.

- A Data Mass Storage Unit will be installed on board of RV POLARSTERN during the stay in shipyard in Bremerhaven. The installation will be completed during this cruise and a sea trial and an acceptance test will be carried out on real conditions during this time period.

- The acceleration forces will be measured at different locations on board of RV POLARSTERN by using a special mobile acceleration data logger. The data collected herewith will be used to specify sensitive equipment, which has to be installed and used on board.

In addition, the following scientific programmes are planned to be performed during the complete cruise:

- 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, sounding of the atmosphere by using the VAISALA radio sonde will be carried out.

- The IfM-GEOMAR group will study the long-term trends and the seasonal variability of the 13C signature of Dissolved Inorganic Carbon (DIC) in surface waters of the Atlantic Ocean.

- The Institute of Environmental Physics of the University of Heidelberg (IUP) will carry out Differential Optical Absorption Spectroscopy (DOAS) measurements during the cruise to determine the distributions of different chemical tracers in the atmosphere.

- The group of University of Hamburg will study the Dissolved Organic Matter (DOM) in the Atlantic deep water. Large volume samples from the deep Atlantic (Angola Basin) will be collected, ultra-filtrated on board and prepared for further processing in the laboratory in Hamburg.

2. MEASUREMENTS OF THE UV-IRRADIANCES AND UV-B-DOSIMETRY (AWI)

Due to the ozone depletion in Antarctica during the last 20 years, increased UV-B-solar radiation was observed. Since 1994 a personal dosimetry program has been established at Neumayer-Station to quantify the impacts of the UV-B-radiation on human beings in Antarctica. This programme includes the use of different personal and global dosimeter (ELUV-14, Biometer, Solar Light 501). The ELUV-14 was specially developed for this purpose. During the cruise ANT XXII/1 of RV POLARSTERN the global UV-B doses and those at personal related level will be carried out. The UV-B doses distributions will be measured as a function of latitude. We expect to measure the maximal available UV-B exposures at sea level. These data are needed to calculate the risk factor of UV-B exposure on the ice shelf. Calibration of the ELUV-14 dosimeters will be done by using the spectral measured UV-B- irradiance during the cruise. The AWI-UV-Spectrometer will be used to measure the spectral distribution of UV-A and UV-B radiation.

Working programme

- Measuring the spectral UV-A and UV-B irradiance distributions between 290 and 400 nm using the AWI-spectrometer (ISI-UV)

- Determination of the global UV-B doses as a function of latitude, sun elevation and ozone column concentration by using the ISI-UV-Spectrometer

- Determination of the erythemal weighted global UV-B doses as a function of latitude, sun elevation and ozone column concentration by using different dosimeters (Eluv-14, ,Biometer, Solar Light 501)

- Calibration of new UV-B-Dosimeter (ELUV-14) under real conditions.

3. MEASUREMENTS OF THE DYNAMICAL ACCELERATION FORCES ON BOARD OF RV POLARSTERN (AWI)

Acceleration forces on board of a vessel due to waves and weather are a function of location on board and have large variations. To measure the acceleration forces at different locations on board of RV POLARSTERN, a special mobile acceleration data logger was developed and will be used during the ANT XXII/1 to quantify the

occurred forces on board. The data logger has a high resolution and is able to measure the acceleration in three axis, so the horizontal forces could be measured directly. The collected data will be used to specify sensitive equipment, which has to be installed and used on board.

Working programme

- Function tests of the logger
- Installation an carrying out of the measurements on different location
- Data processing.

4. SEA TRIAL AND ACCEPTANCE TESTS OF THE DATA MASS STORAGE UNITS (AWI, LAEISZ, FIELAX)

A Data Mass Storage Unit will be installed on board of RV POLARSTERN during the stay in shipyard in Bremerhaven (03.10.04 - 12.10.04). Due to the short time in the shipyard and because the systems on board are not completely running during this time, a complete installation of the system in Bremerhaven might not be possible. The installation should be completed during the cruise ANT XXII/1 between Bremerhaven and Las Palmas. A sea trial and acceptance test will be carried out under real conditions during this time period. The mass storage unit including all SUN servers, hard disks and buck-up tape machine will be integrated into the computer systems and the network on board. A final configuration and tuning is necessary to use this system efficiently. This new system is compatible with the main storage system at AWI. It will offer an efficient data transfer between POLARSTERN and AWI and realise a high integrity of the data on board.

Working programme

- Complete the physical installation of the mass storage unit
- Configuration and tuning of the system
- Carrying out the sea trial and the acceptance tests.

5. LONG-TERM TRENDS AND SEASONAL VARIABILITY OF THE 13C SIGNATURE OF DISSOLVED INORGANIC CARBON (DIC) IN SURFACE WATERS OF THE ATLANTIC OCEAN (IfM-GEOMAR)

The project is a continuation of a long-term observation study of the ^{13}C signature of dissolved inorganic carbon (DIC) in surface waters of the Atlantic Ocean, which commenced during the POLARSTERN cruise ANT XXI/1. The biannual sampling based on transits of R/V POLARSTERN to/from the Southern Ocean will provide insight into the seasonality and interannual variability of the δ13C-DIC in contrasting climatic and biogeochemical regimes (subtropical vs. subpolar, oligotrophic vs. mesotrophic, thermally vs. biologically controlled CO_2 system). It may also permit quantification of the Suess effect on $\delta^{13}C$-DIC if maintained as a long-term project.

A similar scientific question has been addressed successfully at the oceanic time-series stations such as the Bermuda Atlantic Time Series Study (BATS) an the Hawaii Ocean Time Series. In addition, sampling programmes have been mounted on „Volunteer Observing Ships" in the North Pacific and North Atlantic. Within the EU-funded project CarboOcean, the IFM-GEOMAR will measure δ^{13}C-DIC along a trans-Atlantic VOS line from 2005 on for about 4 years. The present long-term sampling programme based on POLARSTERN transits represents a significant extension of the CarboOcean study.

6. MAX-DOAS-MEASUREMENTS OF ATMOSPHERIC TRACE GASES FOR SCIAMACHY-VALIDATION (IUP)

Introduction

An important aspect of environmental sciences is the knowledge on trace gases and their concentration and distribution in the atmosphere. Especially interesting are tropospheric gases like NO_2, H_2O, HCHO, IO and SO_2 as well as stratospheric ones like O_3, NO_2, BrO, OClO, H_2O, HCHO, O_4 and IO. Measurements of these are possibly done by satellites, as by the instrument SCIAMACHY onboard ENVISAT launched into a polar orbit in March 2002. To validate satellite-provided data, however, ground-based control-measurements done at locations beneath the satellite's orbit are necessary. In case of SCIAMACHY, measurements onboard RV POLARSTERN seem best suited for that purpose, because during a cruise to Antarctica, the ship follows a polar course corresponding to ENVISAT's orbit.

The DOAS instrumentation

The method used by the satellite's instrument is the proved Differential Optical Absorption Spectroscopy DOAS. For this principle, the fact is used that solar light passing through the atmosphere is strayed by gas molecules and will thereby gain characteristic absorption lines within the measured spectra. From these lines, identity and amount of atmospheric trace gases can be obtained. For ground-based measurements it is even possible to decide on height profiles of these trace gases: light coming in vertical will show mainly absorption of stratospheric gases because of this part of the atmosphere's height. Light coming in more horizontal contains absorption of mainly tropospheric gases due to the longer way of the sunlight through this sphere. This is the so-called Multi-Axis-DOAS principle.

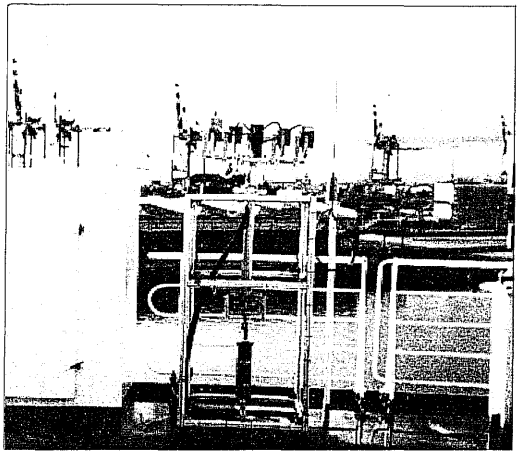


Fig. 2: The on-deck instrumentation of the MAX-DOAS instrument. Four telescope units on both sides of a cable and glass fibre box in the centre are visible as well as the cardanic mounting and the simple pneumatic damping at the bottom.

The validation instrument onboard RV POLARSTERN uses the same (MAX-)DOAS-measurement principle as the satellites apparatus, of course. Since some of the interesting trace gases like BrO, SO_2 and HCHO show absorption only in the UV and others like H_2O and IO only in Vis spectral range and because both ranges require a different spectral resolution, the ship-based instrument consists of two separate systems for UV and Vis. Both are using mobile telescopes for MAX-DOAS-measurements, but the UV-system three and the Vis-system only one. This is because the UV part of the observed light is less intensive than the Vis one and therefore it takes more time to get bright spectra. This reduces measurement time.

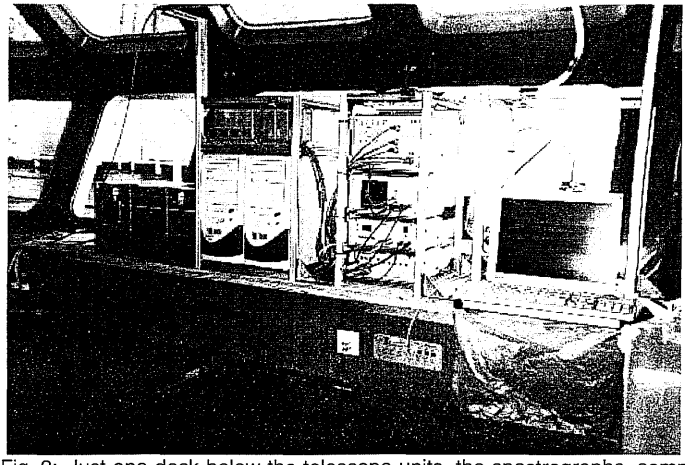


Fig. 3: Just one deck below the telescope units, the spectrographs, computers, supply units etc are mounted.

The telescopes are mounted on a cardanic system to reduce the movements from the ship. They are all of the same type, containing in their housings not only a stepper motor for movement, but also protective shutters and HgNe- and Halogen calibration lamps for the apparature. The in-coming light of each UV telescope is conducted to one spectrometer by seven-fold glass fibres making also one of three 1200 μm x 170 μm entrance slits for the system. The spectra from the spectrometer are projected on a two-dimensional 1024 x 256 pixel CCD detector and recorded for further measurements. This enables simultaneous measurements of light from three different lines of sight. The light coming to the Vis telescope is conducted by a normal glass fibre to a spectrograph with one-dimensional 2048 pixel detector row. The Vis-system works consequentally. The whole instrument is working automatically as far as possible and can gather about 8 to 10 GB of data within one month.

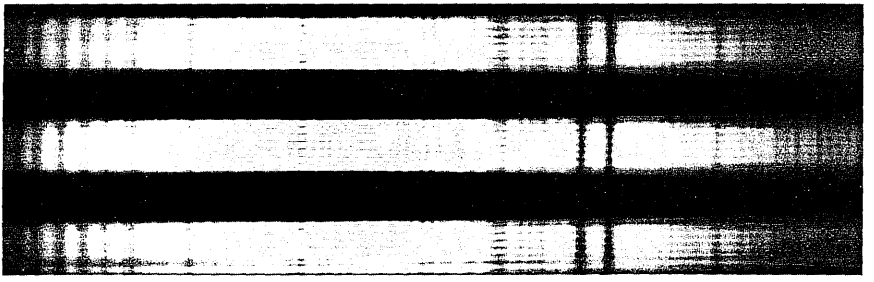


Fig. 4: Image of three UV spectra on one two-dimensional CCD array. The seven fibres of coming from each of the three UV telescopes are also visible.

Results

Measurements performed during the ANT XIX-cruise of RV POLARSTERN from Bremerhaven to Cape Town using the precursor of the nowadays instrumentation (same instruments, but another configuration of telescope units) feature the concentration of BrO and NO_2: The maxima were reached when the ship passed the English Channel with 3.1 +/-1.1 parts per trillion for BrO and 0.36 +/- 0.13 parts per billion for NO_2. This was to be expected from the high air pollution in Europe. Another point is an anti-correlation of both trace gases pointing to a reservoir substance. To gather more data on this and new data principally available with the ship-based DOAS instrumentation is a major point for further participations in cruises of RV POLARSTERN to Antarctica. Besides these measurements done mainly for validation purposes, gathering data in Antarctic seas is important for further atmospheric- and also climate research.

Ship-based DOAS measurements have been carried out before in the years 1990, 1993, 2001/2002, 2002/2003 and 2003/2004 with good success from the Heidelberg Institute for Environmental Physics.

Literature

Kreher, K.; Messung der Breitenverteilung (50°N – 70°S) von stratosphärischem Ozon mittels optischer Absorptionsspekroskopie, Diplomarbeit, Universität Heidelberg, 1991
Platt, U.; Differential optical absorption spectroscopy (DOAS), in Air Monitoring by Spectroscopic Techniques,M. W. Sigrist (Ed.), Ch. Analysis Series Vol. 127, John Wiley, New York, 1994
Senne, T.; Stutz. J.; Platt, U.; Measurement of the latitudinal distribution of NO2 column densities and layer heights in Oct./Nov. 1993, Geophys. Res. Let., 23, 805-808, 1996.
Boßmeyer, J.; Ship-Based Multi-Axis Differential Optical Absorption Spectroscopy Measurements of Tropospheric Trace Gases over the Atlantic Ocean, Diplomarbeit, Universität Heidelberg, 2002.

7. DISSOLVED ORGANIC MATTER (DOM) FROM ATLANTIC DEEP WATER (IfBM)

DOM in the ocean represents a carbon pool comparable in size to atmospheric CO_2. Its cycling is only partially understood and less than 30% of DOM has been characterized chemically so far. It is a heterogenous mix of molecules covering a wide range of sizes, whereby the „truly dissolved" fraction (<1000Da) exceeds the „colloidal fraction" (>1000Da). Radiocarbon dating of different size classes of DOM revealed increasing age with decreasing molecular size (Loh et al. 2004). In previous work on the terrestrial source of marine DOM we studied molecular size, humic component and carbon isotopes of DOM in Siberian estuaries and the Kara Sea (Spitzy et al.2002). Since the Kara See receives very high terrigenous DOM inputs, we plan to obtain a pure marine endmember large volume sample from the deep Atlantic (Angola Basin) for comparative study. The sample will be ultrafiltered on board and further processed in our Hamburg laboratory.

Loh, A.N., J.E. Bauer & E.R.M. Druffel (2004) Variable ageing and storage of dissolved organic components in the open ocean. Nature 430: 877-881.
Spitzy, A., S. Ertl & H.Köhler (2002) Dissolved humic matter in Arctic Estuaries. EOS 83(47).

8. HYDROSWEEP DS2 MULTIBEAM SYSTEM MAINTENANCE (AWI, LAEISZ, FIELAX, Atlas Hydrographic)

During the port time of RV "Polarstern" in autumn 2004, a major upgrade of the operator hard- and software system Hydrosweep was installed. This upgrade requires a check regarding its general functionality and longterm stability. This must be performed under real deep sea conditions during ANT-XXII/1. In addition, data outside the Exclusive Economic Zones (EEZ) will be recorded, stored, processed and used for improvement of international bathymetric charts, like GEBCO.

Because both laser gyro systems (MINS), which measure the ship's attitude, were changed during last Arctic 2004 expedition, a calibration has to be done for estimating roll and pitch correction values for the Hydrosweep system. This will be done by a repeated survey of a straight track line over approx. 5 nm in an area with smoothly shaped seafloor.

The Hydrosweep system will be utilized during all subsequent ANT-XXII legs. In preparation of this cruises, the database as well as the processing hard- and software must be maintained and updated.

9. SEA TRIAL AND CALIBRATION OF THE DEEP SEA SEDIMENT ECHO SOUNDER PARASOUND DS II (AWI, LAEISZ, FIELAX, Atlas Hydrographic)

The Deep Sea Sediment Echo Sounder (PARASOUND DS II, Atlas Hydrographic) was upgraded in Jun 2004 to from DS I to DS II. An upgrade of the software will be performed in October 04 in Bremerhaven. A sea trial and a final tuning of the complete system will be carried out.

10. BETEILIGTE INSTITUTE / PARTICIPATING INSTITUTES ANT XXII/1

Atlas Hydrographic	Atlas Hydrographic Kurfürstenallee 130 28211 Bremen
AWI	Alfred-Wegener-Institut für Polar- und Meeresforschung in der Helmholtz-Gemeinschaft Postfach 120161 27515 Bremerhaven
DWD	Deutscher Wetterdienst Bernhard-Nocht-Str. 76 20359 Hamburg
FIELAX	FIELAX Gesellschaft für wissenschaftliche Datenverarbeitung mbH Schiffer-Str. 10 - 14 27568 Bremerhaven
IfBM	Inst. f. Biogeochemie u. Meereschemie Universität Hamburg Bundesstraße 55 20149 Hamburg
IfM-GEOMAR	Leibniz-Institut für Meereswissenschaften an der Universität Kiel Düsternbrooker Weg 20 24105 Kiel
IUP	Institut für Umweltphysik Universität Heidelberg Im Neuenheimer Feld 229 69120 Heidelberg
LAEISZ	Reederei F. LAEISZ Barkhausen-Str. 37 27568 Bremerhaven

11. FAHRTTEILNEHMER/INNEN / PARTICIPANTS ANT XXII/1 Bremerhaven – Cape Town

El Naggar, Saad	AWI
Fiedler, Björn	IfM-GEOMAR
Köhler, Hayo	IfBM
Niederjasper, Fred	AWI
Sinreich, Roman	Uni Heidelberg
Sonnabend, Hartmut	DWD
Spitzy, Alejandro	IfBM
Truscheit, Thorsten	DWD
Ewert, Jörn	Atlas Hydrographic
Kuhn, Gerd	AWI
Niessen, Frank	AWI
Pfeiffenberger, Hans	AWI
Wübber, Chresten	AWI

12. SCHIFFSPERSONAL / SHIP'S CREW

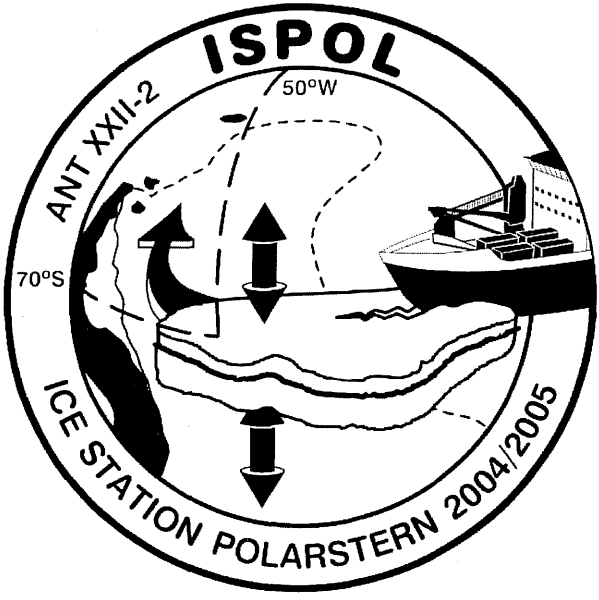
Reederei F.Laeisz G.m.b.H.
Name of Ship : POLARSTERN
Nationality : GERMAN

Reise ANT XXII/ 1
12.10.2004 - 04.11.2004
Bremerhaven - Kapstadt

No	NAME	RANK	NATION
01.	Pahl, Uwe	Master	German
02.	Schwarze, Stefan	1.Offc.	German
03.	Schulz, Volker	Ch.Eng.	German
04.	Spielke, Steffen	2.Offc.	German
05.	Bratz, Herbert	3.Offc.	German
06.	Koch, Georg	R.Offc.	German
07.	Erreth, Gyula	1.Eng.	German
08.	Kotnik, Herbert	2.Eng.	Austria
09.	Simon, Wolfgang	2.Eng.	German
10.	Holtz, Hartmut	Elec.Tech.	German
11.	Nasis, Ilias	Electron.	German
12.	Verhoeven, Roger	Electron.	Germa
13.	Kahrs, Thomas	Fielax-Elo	German
14.	Clasen, Burkhard	Boatsw.	German
15.	Neisner,Winfried	Carpenter	German
16.	Kreis, Reinhard	A.B.	German
17.	Schultz, Ottomar	A.B.	German
18.	Burzan, G.-Ekkehard	A.B.	German
19.	Schröder, Norbert	A.B.	German
20.	Moser, Siegfried	A.B.	German
21.	Pousada Martinez, S.	A.B.	Spain
22.	Hartwig-Labahn, A.	A.B.	German
23.	Niehusen, Arne	Apprent.	German
24.	Beth, Detlef	Storekeep.	German
25.	Toeltl, Siegfried	Mot-man	German
26.	Fritz, Günter	Mot-man	Austria
27.	Krösche, Eckard	Mot-man	German
28.	Dinse, Horst	Mot-man	German
29.	Scholl, Christoph	Apprent.	German
30.	Fischer, Matthias	Cook	German
31.	Tupy,Mario	Cooksmate	German
32.	Martens, Michael	Cooksmate	German
33.	Dinse, Petra	1.Stwdess	German
34.	Schöndorfer	Stwdss/KS	German
35.	Streit, Christina	2.Stwdess	German
36.	Schmidt,Maria	2.Stwdess	German
37.	Schmutzler, Gudrun	2.Stwdess	German
38.	Tu, Jian Min	2.Steward	China
39.	Wu, Chi Lung	2.Steward	German
40.	Yu, Chung Leung	Laundrym.	China

Additional crew members:

Name	Institution
Gerchow, Peter	FIELAX
Hoffmann, Mathias	FIELAX
Dimmler, Werner	FIELAX


ISPOL
ANT XXII-2
50°W
70°S
ICE STATION POLARSTERN 2004/2005

EXPEDITION ANTXXII/2 (ISPOL)

1. ZUSAMMENFASSUNG UND FAHRTVERLAUF

ISPOL ist eine Feldstudie, die unsere Kenntnisse über die Rolle des Meereises im frühen antarktischen Sommer erweitern soll. Vor allem sind physikalische und biologische Interaktionen im System Atmosphäre-Eis-Ozean des Weddellmeeres von großem Interesse sowie ihre Auswirkungen bis hin zu globalen Prozessen. Für diese Untersuchungen während ISPOL wird eine Eisdriftstation im westlichen Weddellmeer eingerichtet, die etwa 50 Tage besetzt sein soll. Das Vorhaben ist multinational und interdisziplinär angelegt und wird vom Alfred-Wegener-Institut für Polar- und Meeresforschung organisiert. Beteiligt sind an der Untersuchung Glaziologen, Biologen, Ozeanografen und Meteorologen verschiedener Institute und Nationen. ISPOL wird einen wesentlichen Beitrag zu den internationalen Antarktisprogrammen iAnZone und ASPeCT leisten.

Wissenschaftliche Fragestellung

Das westliche Weddellmeer ist ein einzigartiges Meeresgebiet innerhalb der antarktischen Meereiszone, da es den größten Anteil an mehrjährigem Meereis des südlichen Ozeans besitzt und so einen bedeutenden Einfluss auf Ozeanografie, Meteorologie und Biologie ausübt. Die zu erwartenden Ergebnisse sollen Antworten auf folgende Fragekomplexe liefern:

- Was kontrolliert das sommerliche Überdauern des Eises und in welcher Weise beeinflusst es die permanente Eisbedeckung auf langen Zeitskalen?
- Welche Rolle spielt die ständig von Meereis bedeckte Region für den Süßwasserhaushalt des Weddellmeeres?
- Wie sind die hydrografischen Bedingungen auf dem westlichen Kontinentalschelf (von dem angenommen wird, dass er ein bevorzugter Platz von Tiefen- und Bodenwasserbildung ist) nach dem Ende der Eisbildung?
- Wie sind Primärproduktion im Meereis und im freien Wasser sowie die Verteilung von Krill beeinflusst durch das Meereisregime im Weddellmeer?

Aufgaben und Ziele

- Untersuchungen von physikalischen, biogeochemischen und biologischen Prozessen, die die Veränderungen und Interaktionen im System Atmosphäre-Eis-Ozean beim Übergang von Frühjahr zu Sommer kontrollieren. Ein Hauptaspekt gilt der Veränderlichkeit des Meereises unter Berücksichtigung der Prozesse an den Grenzschichten zur Atmosphäre und dem Ozean. Diese sind von oben nach unten:
  - Metamorphose und Schmelzen des Schnees sowie entsprechende Veränderungen der Oberflächenalbedo
  - Wiedergefrieren von Schmelzwasser und Bildung von aufliegendem Eis an der Schnee-Eis-Grenze
  - Überflutung und Ausbildung von seewassergefüllten Lagen im Eis
  - Enstehung von hochproduktiven biologischen Gemeinschaften innerhalb der Spalten

  - Salzlaugenkanal-Entwicklung, Zerfall und Schmelzen an der Eisunterseite
  - Austausch von Salzlauge und Seewasser zwischen Eis und Meer.
- Erstellung eines umfassenden Datensatzes des Meereissystems zur Validierung von numerischen Modellen und von Satellitendaten
- Bestimmung von hydrografischen Daten nach der Gefrierperiode am westlichen Weddellmeerschelf und deren Bedeutung für Tiefen- und Bodenwasserbildung
- Vervollständigung der Meereis- und ozeanografischen Befunde und Prozessstudie, die während der amerikanisch-russischen „Ice Station Weddell" (ISW I) in der Sommer-Herbst-Phase 1992 erhoben wurden
- Verbesserung unserer Kenntnisse über die saisonal ablaufenden Prozesse innerhalb des Meereises.

Projektzusammenhänge

- BIOPPSI (BIOlogical and Physical Processes in Sea Ice): interdisziplinäres Projekt am AWI, das physikalische, biologische und biogeochemikalische Untersuchungen am Meereis durchführt
- ASPeCT (Antarctic Sea-ice Processes and Climate): internationales SCAR/GLOCHANT Programm
- IAnZone (International Antarctic Zone Program): SCOR-angebundenes Programm.

SUMMARY AND CRUISE TRACK

ISPOL is a field experiment designed to improve our understanding on the role of early summer physical and biological atmosphere-ice-ocean interactions in the western Weddell Sea in global processes. ISPOL involves a 50-day drift station in the western Weddell Sea. It is a multi-national, interdisciplinary study organized by the Alfred Wegener Institute for Polar and Marine Research, Germany, involving glaciologists, biologists, oceanographers, and meteorologists from different institutes and nations. ISPOL contributes to the goals of the international programs in Antarctica **iAnZone** and **ASPeCt**

Overall objective

The western Weddell Sea is unique among Antarctic sea ice regions, as it comprises the largest perennial ice zone of the Southern Ocean and thus exerts a major influence on the oceanography, meteorology and ecology in this region. The results are expected to provide answers to the following questions:

- What controls ice survival during the summer, and how does this affect the perennial ice cover on longer time scales?
- What is the role of the perennial ice region for the fresh water budget of the Weddell Sea?
- What are the hydrological conditions on the western continental shelf (supposed to be the prime site for deep and bottom water formation) after completion of the freezing season?
- How are primary production in sea ice and phytoplankton as well as krill distribution affected by the sea ice regime in the Weddell Sea?

Tasks

- To investigate physical, biogeochemical and biological processes controlling the transformation and interactions in the atmosphere-ice-ocean system from austral spring to summer. Main focus of the project is the sea ice system with emphasis on the study of processes as a function of meteorological and oceanographic boundary conditions. These processes are, from top to bottom:
  - Metamorphism and melt of snow, and related changes in surface albedo
  - Refreezing of meltwater and formation of superimposed ice at the snow/ice interface
  - Flooding and near-surface formation of seawater-filled gap layers in the ice
  - Development of highly productive biological communities within the gap layers
  - Brine channel development, rotting and bottom melting of sea ice
  - Exchange of brine/seawater between ice and ocean.
- To provide a comprehensive data set of the entire system, in support of the development of numerical models and as ground-truth information for satellite remote sensing studies.
- To determine the post-freeze hydrographic conditions on the western Weddell Sea continental shelf related to deep and bottom water formation.

- To complement sea-ice and oceanographic observations and process studies performed during the US/Russian Ice Station Weddell (ISW-1), carried out in the summer-to-fall period 1992.
- To improve our understanding of the seasonal interaction between biota and sea ice.

Framework

- BIOPPSI (BIOlogical and Physical Processes in Sea Ice): Interdisciplinary project at AWI involving physical, biological, and biogeochemical studies of sea-ice processes.
- ASPeCt (Antarctic Sea-ice Processes and Climate): International SCAR/GLOCHANT program.
- iAnZone (international Antarctic Zone program): SCOR affiliated program.

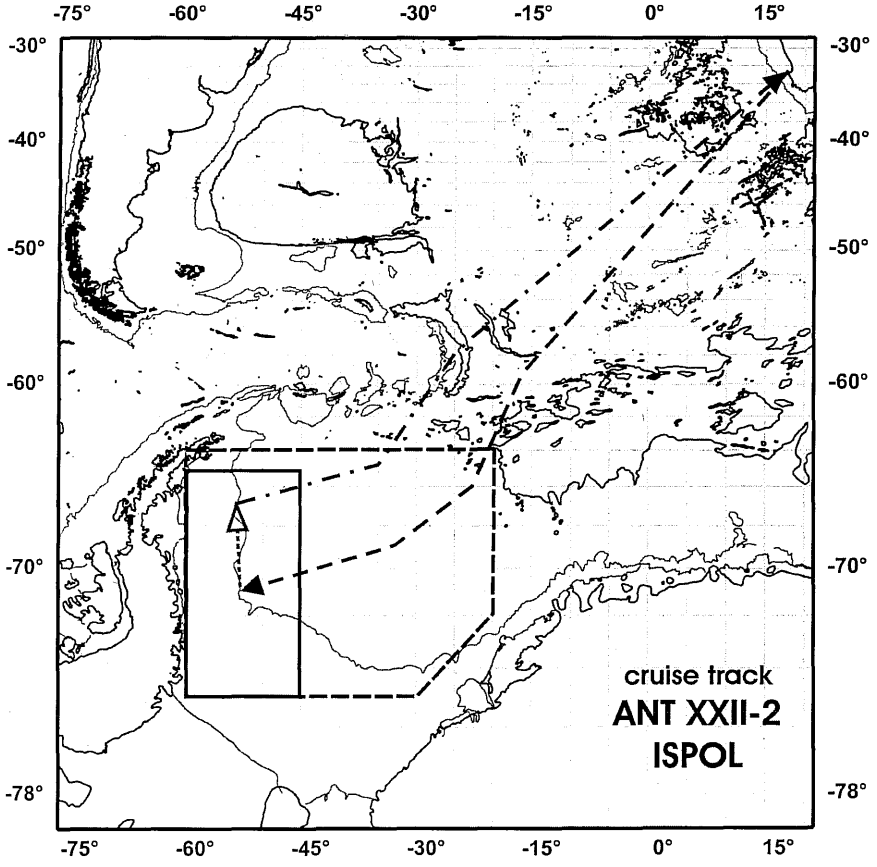


Abb.1: Geplante Route auf ANT XXII/2 FS POLARSTERN
Fig. 1: Planned Route on ANT XXII/2, RV POLARSTERN

2. CHANGES OF SEA ICE PHYSICAL PROPERTIES DURING THE ONSET OF SUMMER MELT (AWI, UTR)

The German sea ice geophysical programme focuses on three main objectives which are however closely related to each other: Snow melt and superimposed ice formation, changes of ice thickness, and satellite observations of surface changes. The project is partially funded by DFG (Project: Beobachtung und Modellierung der Aufeisbildung auf sommerlichem antarktischem Meereis).

Boundary conditions of superimposed ice formation

During the spring/summer transition, sea ice and snow properties change considerably in response to warming and the eventual reversal of temperature gradients within the snow and ice. One major process during the onset of melt is superimposed ice formation at the snow/ice-interface. This is due to snow melt water percolating down towards the colder snow/ice interface, where it refreezes. In the Antarctic, recent observations show that superimposed ice may actually form layers of some decimeters in thickness. At the end of summer, ice floes in certain areas may consist almost exclusively of superimposed ice, which is responsible for the survival of the floes.

Simultaneously, surface gap layers form underneath the superimposed ice. These host extremely high diatom standing stocks. The environmental conditions for their development is not clear so far, and there is a dispute whether they are mainly formed by biotic or abiotic factors. The meteorological boundary conditions for superimposed ice formation are little studied, as it has not been recognized so far to be important for the history of an ice floe. The first objective of this study is to investigate the main processes and boundary conditions for superimposed ice and gap layer formation, in recognition of their importance for Antarctic sea ice, and their possible importance for Arctic sea ice in case of environmental changes due to future climate change. This will be performed by means of combined measurements of ice properties and the energy budget at the ice and snow surface.

Work content

We will perform simultaneous measurements of ice and snow properties and of the meteorological boundary conditions.

Snow temperature, grain size, density, wetness, snow depth and water equivalent will be determined at selected snow pits on a daily basis. Surface properties as temperature and spectral albedo will be derived from radiometer measurements. At these sites, ice cores will be extracted and their temperature profile will be measured. In the cold laboratory, they will be analyzed for salinity and crystal texture. To account for lateral heterogeneity, several surface cores will be obtained every 2-4 days and thermistor chains will be used to determine vertical temperature profiles through the ice.

Furthermore lateral and vertical fluid flow will be observed to allow for hydrological analysis, which is fundamental in describing superimposed ice and melt pond formation or general melt progress due to run off.

Along extended profiles (several hundred meters) of ice thickness will be measured by non-destructive means (EM, radar), and the gap layer development will be observed through small drill holes.

The energy budget will be observed continuously with a weather station and radiometers.

Changes of the ice thickness distribution due to melting and ice deformation

The second goal of this project is the determination of changes in the ice thickness distribution. Clearly, these changes will be dominated by a steady decrease of thickness due to summer melt. However, it is unknown to what extent the ice cover melts inside the closed pack ice, and how it contributes to the freshwater budget before the floes actually fracture and break apart in the marginal ice zone. It is also unknown how thin ice is distributed into thick ice categories during deformation events. A drift station offers the unique opportunity to monitor these changes in a certain ice field. During ISPOL, we will know regional deformation fields from a large number of buoys deployed by several projects within the International Program for Antarctic Buoys (IPAB).

Measurements are also performed as ground-truth for satellite radar altimeter measurements of sea ice freeboard.

Work content

A helicopter-borne EM ice thickness sensor (HEM bird) will be flown regularly along the same profiles of several ten kilometers length to monitor changes in the ice fields thickness distribution. The profiles will be defined by the trajectories of the drifting buoys, which trace the same ice floes during the expedition. These data will be compared with the thermodynamic and dynamic forcing and used to improve ice thickness estimates of numerical sea-ice models.

Satellite remote sensing for operational ship routing and observations of changes of sea ice properties

Superimposed ice formation results in marked increases of radar backscatter as visible in satellite data. Snow wetting and melt are detectable by changes in spectral reflectivity in optical and near-infrared imagery. Therefore, our study aims to provide ground-truth information for coincident remote sensing studies. We will obtain a most extensive data set on changes in physical surface properties as well as ice dynamics, and their detection with satellite data.

In March 2005, CryoSat will be launched by European Space Agency ESA to measure sea ice freeboard both in the Arctic and Antarctic. As part of CryoSat pre-launch validation activities, we will perform freeboard and snow thickness measurements and compare these with our ice thickness profiles. Measurements will be synchronized with overflights of Envisat carrying a radar altimeter as well.

The target area of ISPOL is far within the closed sea ice pack. However, reaching an ice floe far enough south is essential for a successful conductance of the expedition. In order to support ice navigation in possibly heavy second-year ice conditions, a large number of near-real-time high-resolution radar images and visible imagery will be obtained on board, in close cooperation with German Aerospace Center DLR.

Work content

During the access voyage to the ice floe ERS-2 Synthetic Aperture Radar (SAR) and MODIS visible and infrared imagery will be received at the German Antarctic Receiving Station O'Higgins and will be transmitted to the ship in near real time to support ice routing. These data will be complemented by passive microwave (SSM/I, AMSR-E) and optical and near infrared (NOAA-AVHRR) data received on board. During the ice drift phase, we will also order acquisition of numerous Envisat-ASAR and Radaraltimeter data. Measurements of spectral albedo (see above) will complement several ground-truth observations.

3. VALIDATION OF SEA ICE MELT PROCESSES OBSERVED WITH REMOTE SENSING SATELLITE DATA (AAD)

Objectives

- Determine the relative importance of surface, bottom and lateral melt on the retreat of Antarctic pack ice.
- Compare new theoretical developments of sea ice fracture with measurements of Antarctic sea ice deformation and fracture patterns.
- Determine the accuracy of algorithms to routinely estimate sea-ice concentration, ice temperature and snow thickness from satellite passive-microwave data.
- Carry out a validation of ice thickness data derived from the ESA Cryosat satellite (to be launched in 2004).

Work content

Aerial photos will be collected in the field and placed on a mass media storage (e.g. DVDs). These will be analyzed in Australia using existing algorithms and image processing software to determine concentrations of open water, new ice, melt ponds and snow covered ice. Ridge distributions and heights will also be calculated and used to estimate total ice volume and changes due to deformation.

Deformation and drift will be calculated using buoy position data, including buoys deployed by other groups. High resolution satellite data, and aerial photography will be used to determine changes in fracture and ridging patterns within the sea ice zone. These data will then be compared with theoretical predictions of fracture by Schulson and Hibler (2000). This work on deformation will be done in collaboration with Prof. Hibler.

Melt processes

Sea ice extent in the Weddell Sea typically increases from a minimum in February to a maximum 8 months later in September. The decrease is much more rapid, lasting only about 4 months from October through to January. This rapid decrease in extent is typical of the rest of the Antarctic pack ice, yet the relative importance of different melt and decay mechanisms is not well understood. The relative importance of lateral melt was recently demonstrated in the Arctic during the SHEBA experiment where solar radiation absorbed in the open water regions between sea ice floes rapidly melted the floes laterally. Hence, the role of dynamics in breaking up floes and divergence was found to have a large impact on the melt rates. We know, however that the Antarctic environment and melt processes are different than the Arctic. For example melt ponds are rarely observed in Antarctica whereas they play a key role in the Arctic. Past studies in the Antarctic have shown that swell from the open ocean often penetrates the pack ice. This swell may break up floes or result in sea water washing up on the surface, changing the albedo of the snow cover. Past (winter) studies in the Weddell Sea have shown that the ocean heat flux from below the mixed layer can have a large impact on melt of the underside of the sea ice. (Lytle and Ackley, 1996). Surface flooding and snow ice formation is also common in Antarctic pack ice, and hence can rapidly alter ocean-atmosphere heat fluxes and ocean salt fluxes (Lytle and Ackley, 2001). Each of these processes have been shown to have a significant impact on the decay and melt of sea ice, in this study we will quantify the relative importance of each component of the decay process, and the driving forces behind them.

Sea Ice deformation and fracture

Numerical sea ice models are continually increasing in resolution (both time and space). In addition, the satellite data available to validate and test these new formulations is continuing to increase in resolution, and areal coverage. For example, high resolution Synthetic aperture radar (SAR) will become increasingly available in the Antarctic from the Envisat satellite. These data from Radarsat have been limited due to the orbit configuration and lack of onboard data recording. In addition, Cryosat is expected to provide, for the first time, information on sea ice freeboard. These improvements in numerical models and satellite data have motivated an improved formulation of sea ice mechanics which can now describe individual fracture zones. Recent research describes sea ice as being imbedded within the ocean surface layer and resulting in deformation due to inertial motion of the pack ice (Hibler et. al., 1998). In addition, variations in yield curves and anisotropic flow laws have been used in sea ice models to predict oriented leads, ridges and slip lines within the sea ice (Hibler and Schulson, 1997). The orientation of these features is dependent on the far field stress. This has resulted in predictions of fracture patterns which are locations of repeated deformation (Hibler and Schulson, 2000). To date, most of the studies to validate and calibrate this model have been in the Arctic. This will be the first large scale in-situ validation of these new theories in the Antarctic. By a combination of a large buoy array to measure the strain field, and aerial photos to define fracture and lead patterns, we will be compare theoretical predictions with in-situ data.

Satellite comparisons

Data collected during the experiment will be used to validate satellite products. A range of satellite sensors, including NASA's MISR and MODIS, will provide broad-scale information on both surface albedo and physical temperature (under cloud-free conditions). This experiment will provide an important opportunity to calibrate/validate sea-ice thickness products from the ESA CryoSat satellite. This important satellite, to be launched in 2004, will measure the ice freeboard. These data will be used to extract sea ice thickness information from space for the first time. Data from other satellite instruments (e.g. Aqua, Landsat, Envisat, ALOS) may also be compared with the in-situ measurements to understand the influence of such things as surface flooding or refreezing of ice layers within the snow pack (Drinkwater and Lytle, 1997).

Conversely satellite data will be used to expand the results of the experiment temporally and spatially. For example, the buoy array will cover a much wider region than is possible to survey with aerial photographs. In addition, this array is expected to operate for at least 6 months after the field experiment. By combining these strain data with high resolution satellite imagery, we hope to obtain an improved understanding of the fracture mechanics of the sea ice over several cyclonic cycles and during the freeze-up period. We will investigate the possiblilty of determining sea ice deformation using high resolution SAR imagery from ENVISAT similar to what has been done in the Arctic using Radarsat data. Increased snow accumulation measured at selected buoy locations (deployed by other groups) will be compared with changes in snow thickness products derived from AMSR-E.

4. MONITORING HIGH RESOLUTION SEA ICE DEFORMATION DURING ISPOL (IARC, AAD)

In collaboration with Dr. Haas, AWI and Dr. Launiainen, Finnish Institute of Marine Research, we will deploy a high spatial and temporal resolution (15km, 10 min - 1 hour) GPS buoy array to monitor sea ice deformation about the drifting station. The full array will be deployed for the duration of the ice station, to monitor changes in sea ice deformation as the station drifts northward into loser ice pack. Six buoys, contributed by the Australian Antarctic Division, will remain after the duration of the ice station to monitor summer and autumn sea ice deformation.

The deployment is part of an observational and monitoring programme aimed at elucidating the physical mechanisms that underlie the interactions of tides, boundary layer inertial oscillations and the non-linear mechanics of sea ice. Such high frequency processes are not fully included or successfully simulated in most ice-ocean models. The precise way in which tides interact with inertial variability and the mechanical behaviour of sea ice is not fully understood. We know that sea ice has a peak in power at the semi-diurnal time period (Kwok et~al. 2003). This peak is successfully modelled with an inertial embedded sea ice model (Heil & Hibler 2002), but the degree to which tides and non-linear mechanics are involved in this high frequency deformation is unknown. There is a deficiency of observations in both polar regions during all seasons with which to validate models of inertial-tidal interaction.

The spatial and temporal resolution of the array will be sufficient to resolve the propagation of waves (inertial and tidal) across the array. These measurements will enable us to deduce the effects of the ice mechanics on the tides (and vice-versa) by comparison of the observed tidal motion propagating through the ice cover (our buoy array) with the output from various models with and without non-linear mechanics. This will go a long way towards understanding the interaction of the pack ice cover, tides and inertial motion.

Complimentary to the direct measurements of sea ice deformation, we intend to collect SAR images for a short time period during the drifting station. Buoy positions will be used to validate a high spatial resolution sea ice deformation product from SAR analysis, in collaboration with Cathy Geiger, Cold Regions Research and Engineering Laboratory.

5. SURFACE FLUXES AND AIR-ICE COUPLING IN THE WESTERN WEDDELL SEA (FIMR)

For investigation of the air-ice-ocean interaction and physical coupling the objectives read:

- Determination of the local air-ice and ice-ocean interaction, of turbulent and radiative fluxes and ice thermodynamics, by field measurements and process studies and process modelling. In addition to the fluxes, special attention is given to the effects of superimposed ice and estimation of surface albedo.
- Derivation of the GCM sub-grid scale area representative fluxes composed from contributions from over ice, open water, cracks and leads. The study will be carried out by the field measurements (cf. above) and high resolution modelling and comparing the field and model data with GCM model fields (ECMWF, NCEP/NCAR).
- Study of ice dynamics and kinematics as seen from the point of the objective 2, and the mechanism of ice transport and fresh water balance in the Weddell Sea. The study is carried out as participation in the international drift buoy project (AWI, AAD, IARC, FIMR) and process studies and (past-campaign) modelling.

Field work

- Ship near-site station flux and ice/snow observations.
  - A downwelling and upward radiation (short- and long-wave) measurement bench will be installed to measure the various radiation fluxes. Special attention will be given to determination of the thermal (long-wave) radiation and variations and estimation of albedo.
  - A sonic anemometer (Metek Co., at 3.5 m height) and a 10 m high profile mast will be erected in a near- site ice field (<~400m). Turbulent surface fluxes (momentum, heat flux) defined from the eddy flux and from the profile mast will be compared and the bulk coefficients and universal functions studied. The resistance (roughness) lengths are studied with respect to wind and ice/snow roughness. The latent heat flux will also be estimated.
  - An in-ice/snow temperature chain (12 therm.) is deployed for the ice structure thermodynamics studies.

- Regular snow/ice measurements of snow/ice thickness and structure, surface roughness and density and moisture are made (+ visual, photo and video recording).

- Remote autonomous flux station (<~10 nm from the ship site).
  - A sonic anemometer for the momentum and sensible heat flux
  - Short- and long-wave radiation sensors
  - An in-ice/snow temperature chain
  - A satellite buoy with GPS position and air pressure.

  The equipment is comparable with that at the ship ice station. A kind of measurement site of different surface roughness and albedo from that of the ship site is preferred. The power supply is from batteries and wind generator and data is transmitted by UHF. For maintenance and calibration, the station is to be visited within approx. 5 days intervals.

- Three drift buoys with GPS location and air pressure and temperature will be deployed in the AWI-AAD-IARC-FIMR buoy network. 2 buoys are in the "small-scale" ice deformation array and 1 buoy will be deployed to measure the meso-scale and general ice drift. The buoys transmit the hourly positions and data. Daily (on wish) positions are transmitted to the ship by Iridium data-phone based automatic survey and the main data flow is gathered by cls Argos. Additionally, the data is transmitted to the real-time GTS/WMO network. After the ISPOL campaign the buoys are left in the area, to yield past-campaign data and contribute to the IPAB/WMO buoy program.

6. FIELD STUDY OF DENSITY CURRENTS ON THE WESTERN WEDDELL SLOPE AND SHELF (ESR)

Background and Justification

The western Weddell Sea is host to a number of processes that impact, directly or indirectly, the Southern Ocean freshwater balance and the provision of bottom waters to the global ocean. Dense waters form along the continental shelves of the southwestern and western Weddell Sea, consequent to densification through sea ice formation, and in the sub-ice cavities beneath the Filchner-Ronne and possibly the Larson ice shelves. These waters then cascade down the steep upper continental slope as density currents and veer, subject to the earth's rotation, to the left. In their final equilibrium state, these currents flow north approximately along the continental slope of the western Weddell Sea and contribute to a northward, slope-trapped bottom flow that appears much like a thick (up to 400 m), continuous sheet of dense water extending from near the shelf break down nearly to the base of the slope. Observations of these flows along the western Weddell margin are limited. Past results suggest a 5-6 Sv northward flow in this deep current. Its extent is defined by the temperature, salinity and dissolved oxygen distributions. We have a large-scale picture of this flow, but we have little information on the smaller-scale features that can impact flow dynamics.

The density flows that define deep conditions on the western Weddell continental slope are bounded shoreward by a complex shelf break frontal system. Separate from the deep flows, but perhaps dynamically coupled with them, the shelf break frontal system is continuous around Antarctica except for some regions such as the west Antarctic Peninsula. This system is believed to interact with transfer of water between the shelves and the deep ocean, but information is inadequate to define or to quantify such interaction. Like the density flows, we have a large-scale concept of the frontal system but possess inadequate information to understand its dynamics or to quantify its impacts.

The deep slope flows are bounded basinward by the continental rise, beyond which the Weddell Sea is weakly stratified and characterized by generally weak mean flows. Vertical thermohaline staircases observed in the upper warm water layer indicate the presence of active double diffusive processes and have implications for internal water mass modification and for the pack ice cover, and interval waves may contribute to vertical mixing having similar impacts. Significant mixing energy may radiate basinward from the slope and shelf break regions. As for the rest of this geographical region, the data are inadequate to define or quantify the important ocean processes.

The study area is characterized by tidal currents that become significant near the shelf break. These currents can generate turbulence through local boundary layer effects, and can also generate internal waves that transmit energy to the deep basins. Tidal excursions near the shelf break may, by periodically transporting dense bottom water to the shelf break, contribute to down-slope density flows, and turbulence generated by the currents interacting with the seabed may influence these flows. Spatially varying tidal currents, such as we expect to find associated with the shelf break, can be expected to contribute to ice divergence with consequent impact on local ice dynamic and thermodynamic processes.

Subproject objectives

The objectives ultimately addressed will depend on the extent to which POLARSTERN is able to penetrate winter ice pack toward the Western Weddell Sea margin. Optimally, the ship will attain the shelf break. This goal is uncertain, however, and the specific objectives of this subproject will shift in order to accommodate sampling opportunities that depend in turn on the station drift track. Three foci for the planned research can be specified, based in part on drift track location, as follows:

- Density flows, their observation in the field, and their kinematic and dynamic descriptions. This focus can be attained provided the drift track falls between the shelf break and the lower continental slope that serves as a deep limit for the density flows.
- Measurement of small and mesoscale processes associated with the shelf break frontal system. This focus requires that the drift track coincides fairly closely with the shelf break.
- Assessing the importance of small-scale processes such as double diffusion, internal waves, and equation of state effects such as thermobaricity, from the region extending from the shelf break to the deep basin. This focus will

become primary should the drift track remain over the outer continental slope or even in the westernmost deep basin of the Weddell Sea.

Methods

Several methods are planned to be used in addressing the project objectives. The primary measurements will be observations of vertical microstructure using a CTD-mounted microstructure profiling system (CMiPS) in conjunction with the shipboard CTD profiling system. The microstructure data will be used to estimate, throughout the vertical water column, turbulence-related parameters such as dissipation ε and the vertical turbulent viscosity Kv. Data from the hull-mounted ADCP will provide supplementary information on upper ocean shear which will be used, in conjunction with the CTD data, to provide an alternative means for estimating Kv to be compared to the microstructure-derived values. Intercomparisons will be made with turbulence measurements planned by Miles McPhee using direct observations of microscale scalar and vector parameters. Deeper currents will be estimated using a current meter attached to the CTD. Computed values of Kv, currents and distributions of temperature and salinity will be used to kinematically and dynamically describe features along the western Weddell margin.

Tides are expected to play a role in many of the processes being addressed, particularly approaching the shelf break, and time-series current data from the ADCP will be used to assess tidal excursions and their gradients across the shelf break. These data will be supplemented with near realtime predictions from tidal models that will be run aboard ship. Tidal current data, both realtime and predicted, will be provided to other program components such as those involving sea ice study.

Short CTD time series sequences are planned in order to detect interfacial internal waves that might impact mixing or indicate entrainment associated with the deep density flow. These sequences will be planned to coincide with spring and neap tidal current cycles. Carried out over a 24-hour period under the correct conditions, such time series data might reveal whether entrainment associated with the deep currents are tidally modulated.

7. OCEAN TURBULENT FLUX PROJECT (MPR)

Objectives

The surface heat and mass balance of sea ice is highly dependent on the exchange of heat, mass, and momentum via turbulence in the boundary layer that develops when the ice is in motion relative to the underlying water. Understanding how turbulence distributes the combination of solar radiation penetrating the ice cover and latent heat exchanges at the ice/ocean interface, is crucial in understanding the summer evolution of the ice cover, as well as the exchange of nutrients and biota between the ice and upper ocean.

Our goal is to continuously measure three-dimensional velocity, temperature, and conductivity at at least two levels in the ice-ocean boundary layer, at resolutions

resolving turbulence well into the inertial subrange. These data will provide mean *u, T, S* properties along the vertical turbulent fluxes of momentum ($\tau = \langle w'u' \rangle + i\langle w'v' \rangle$); heat ($\rho c_p \langle w'T' \rangle$) and salinity ($\langle w'S' \rangle$). In addition, very high resolution (0.25 m) upward and downward looking acoustic Doppler current profilers will provide detailed current shear and Reynolds stress profiles. These data will provide the quantitative estimates of the eddy viscosity and diffusivity profiles in the upper ocean necessary for realistic modeling of scalar distributions and fluxes in the ice/upper ocean system.

If the drift of ISPOL brings us to within range of the continental shelf break, the turbulence measuring system is designed for depths in excess of 500 m, and may be used for limited studies of the bottom boundary layer. This would add a useful dimension to the experiment, by making direct flux measurements in a density flow transporting cold bottom water off of the eastern Antarctic Peninsula shelf.

Methods

Our primary instrumentation is a rigid mast spanning 6 m, lowered by winch to any chosen level in the upper ocean. The mast will feature two turbulence instrument clusters (TICs) separated by 4 m, plus upward and downward looking acoustic Doppler profilers. Each TIC comprises a SonTek 5 MHz ADVOcean acoustic Doppler velocimeter, mounted such that its measurement volume is in the same plane as nearby Sea-Bird Electronics temperature and conductivity meters. One cluster will include in addition a microstructure conductivity sensor. The upward sonar is a 1.2 MHz pulse coherent RDI ADCP allowing 0.5 Hz sampling with 0.25m bins; the downward looking instrument is a 5-beam 600 kHz that will cover most of the ocean boundary layer. The full bandwidth data will be logged by surface computer. Under weakly stratified or neutral conditions, the higher frequency instrument will allow Reynolds stress profiles to be estimated across the span of the mast, including the depths of the fixed TICs. The system will allow us to investigate entrainment processes at the bottom of the mixing layer, as well as fluxes near the ice/ocean interface. Of particular interest is a comparison of early summer evolution of the early summer ice/upper ocean system in the western Weddell with the evolution during a similar period in the western Arctic during the SHEBA project in 1998.

8. IDENTIFICATION OF SOURCE WATER MASSES INVOLVED IN DEEP AND BOTTOM WATER FORMATION ALONG THE WESTERN WEDDELL SEA CONTINENTAL SHELF (AWI)

Scientific Objectives

The formation of dense bottom water by mixing of highly ventilated, salty shelf waters with the warm and salty waters of circumpolar origin, and the interaction of both with very cold Ice Shelf Water in the Weddell Sea is of major importance for the renewal of bottom water in the world ocean. In 1992, measurements during the US-Russian drift station ISW-1 over the continental slope along the eastern coast of the Antarctic Peninsula gave a first enroute view of the stratification and pathways of deep and bottom water masses in the western Weddell Sea.

More recent expeditions onboard RV POLARSTERN together with data from two Brazilian/German expeditions show large spatial and temporal variations in the T/S-characteristics of the dense water masses in the northwestern Weddell Sea. These variations are a result of mixing processes which act over different time scales (seasonal, interannual to decadal) and involve waters with different histories from various sources along Weddell Sea's western rim. Therefore, the measured and calculated volumes of the newly formed Weddell Sea Bottom Water are still affected with big uncertainties ranging from 1.5 to 6 Sv. Even less is known about the quantities ventilating Weddell Sea's deep water, which has direct access to the world ocean through the deep passages in the South Scotia Ridge.

Model studies using virtual drifter show the sensitivity of the deep and bottom water formation and spreading on sea ice concentration and position of dense water injections along the western Weddell Sea continental shelf break. For the understanding of the formation processes of different bottom water types and for an accurate estimate of the ventilation rate of the deep Weddell Sea it is necessary to measure the source water mass characteristics as close as possible to their origin. Changes in configuration of ice shelves like Filchner-Ronne, and Larsen A, B, and C are of special interest with regard to the modification of shelf waters on the continental shelf and in the sub-ice cavity due to their significant freshwater input. Probably an equal amount of freshwater is added to the surface waters by melting of stranded and drifting icebergs with an impact on composition and amount of sinking dense water masses leading to a high variability in both T/S-characteristics and volume of newly formed bottom water.

Methods

Helicopter CTDs along cross-slope sections on the shallow side of the drift track and parallel to the track along the continental shelf break (at depth of ~500 m). CTD measurements and water bottle sampling for instrument calibration and various tracer studies onboard POLARSTERN. Use of vessel mounted ADCP for upper ocean velocity measurements. Deployment of drift buoys on icebergs of different size and constellation.

9. TRACER MEASUREMENTS: HELIUM, NEON, CFCS (IUP)

Objectives

The southwestern Weddell Sea is considered to be one of the few formation regions of deep and bottom waters in the southern ocean. Weddell Sea Bottom Water (WSBW) is produced from shelf water and Warm Deep Water (WDW). Uplifted WSBW mixed with WDW occupies the mid-depth water column and is named Weddell Sea Deep Water (WSDW). The analysis of tracer budgets (Helium, Neon, CFCs) gives insight into the processes that set the properties of the waters formed on the shelves and in the studies of deep and bottom water formation.

High Salinity Shelf Waters (HSSW) are formed along the broad shelves in the western Weddell Sea owing their high salinities to brine release during sea ice formation. HSSW with temperatures at surface freezing point enters the ice cavities

under the Filchner-Ronne Ice shelf. Pressure suppresses the melting point, so that HSSW is able to melt the ice forming Ice Shelf Water (ISW). There are three possible mechanisms by which HSSW on the continental shelves can be involved in bottom water formation in the Weddell Sea. It might become dense enough as result of brine rejection to flow down the continental slope directly, as was observed adjacent to the Larsen Ice Shelf. A second process is the mixing with off-shelf waters at the continental shelf break. The third alternative involves the modification of HSSW under the Ice Shelf to form ISW. Subsequently ISW flowing out from underneath the Filchner Ice Shelf spills over the sill that separates the Filchner Depression from the deep Weddell Sea and flows down the continental slope in an intense boundary current. Entrainment of WDW and WSDW leads to the formation of WSBW.

Helium trapped in air bubbles during formation of glacial ice are released into the water by melting at the underside of the ice shelf. Because of the low solubility of helium in water, pure glacial melt water is supersaturated in helium by roughly 1400%. Thus, Helium isotope data allow to calculate the amount of ISW entrained in the deep and bottom water.

Methods

During ISPOL sampling of helium on every second of the 50 planned CTD stations shall lead to 250 helium samples. Additional 50 samples will be taken from the helicopter-CTD casts, which will be located further onshore on the shelf reaching down to the bottom to investigate the contribution of ISW to the boundary current. The helium samples are stored in sealed copper tubes, and they are analysed later in the Bremen mass spectrometer lab.

At the CTD casts there are also 500 samples for CFC planned. CFCs enter the ocean by air-sea gas exchange and trace recently ventilated water masses and carry information about the time of the last contact of the water mass in which they are carried with the atmosphere. Thus these CFC measurements complement the tracer data set with a kind of an age tracer. Additional CFC samples on a section along the Greenwich Meridian and from Kapp Norvegia to Joinville Island during the following ANT XXII/3 cruise will complete the CFC data set. The CFC sampling will be performed 'off-line' in which water samples will be stored in glass ampoules and be sealed off after a CFC free headspace of nitrogen has been applied. The CFC samples are analysed later in the Bremen gas chromatography lab.

10. SEA ICE BIOLOGY (IPÖ)

Studies on Antarctic pack ice communities

Antarctic sea ice is colonized by a divers sympagic community, including bacteria, fungi, algae and proto- and metazoans (meiofauna). The aim of this study is to characterize environmental conditions in the ice (temperature, salinity, brine volume), and to describe the species composition, vertical distribution and community structures of the sympagic meiofauna in Antarctic pack ice. Special emphasis is on the experimental investigation of the meiofauna foodweb.

Our investigations will be carried out with drilled ice cores, characterizing the physical properties in respect to salinity, temperature and inorganic nutrients. Biological investigations will include measurements of chlorophyll a concentrations. Major emphasis is on the examination of the sympagic meiofauna, which consists basically of harpacticoid and calanoid copepods, foraminiferas, turbellarians and ciliates. We examine the vertical distribution of special groups of the sympagic meiofauna in relation to other biotic and abiotic parameters. Furthermore, feeding experiments are planned to identify trophic interactions within the sea ice food web.

Under-ice studies

The boundary layer between sea ice and the water column is a unique habitat with special abiotic (e.g. temperature, salinity) and biotic (e.g. food ressources) factors, which also vary with season and region.

During this expedition to the perennial sea-ice zone of the Weddell Sea, measurements of diversity, abundance and biomass of the under-ice fauna, as well as studies on the small-scale distribution (in vertical resolution of metres from the underside of the ice down to 5 m depth) in relation to several environmental factors (temperature, salinity, algal biomass) will be conducted. For this purpose, under-ice video, under-ice pumps, and several nets and probes will be deployed. The collection of life material, above all of amphipods (e.g. in baited traps deployed from an ice floe, collections made by diver-operated suction samplers) for experiments (e.g. ingestion-respiration-rates) will be a focus of our work.

Studies on the impact of UV irradiance on the under-ice habitat

Due to the observed strong seasonal decrease of stratospheric ozone concentrations over the Antarctic, resulting elevated UV-B intensities have received more and more attention also from biologists. A number of studies have been addressing the effects, like DNA-damage and increased mortality, but also protection mechanisms like UV-absorbing pigments, notably in phyto- and zooplankton organisms.

Some studies have also shown that solar UV-B radiation and its effects could be measured in the water column under landfast sea-ice cover in relevant doses. Because of logistical constraints and the complexity of the optical properties of sea ice, relatively little is yet known about the possible role of solar UV radiation in the Antarctic under-ice environment.

During the expedition, we are planning to measure the spectral under-ice light field under ice floes of different type and thickness. To achieve that, under-ice moorings will be placed at suitable locations for the duration of 24 h, where a spectral sensor will be paired with a spherical quantum sensor for measurements in suitable temporal logging intervals. Another quantum sensor at the surface will log synchronously and serve as atmospheric reference.

Furthermore, site-selective sampling of under-ice organisms (above all amphipods) and in-situ irradiance data will be performed with suction samplers, reference frames and the above mentioned sensor system to quantify both abundance and irradiance at the same location. Additional sampling will be done with hand-nets and baited traps, and the sampled organisms will also be preserved in liquid nitrogen and stored

at -80°C for later analyses of physiological and biochemical (e.g. MAAs, TOSC) parameters.

On board POLARSTERN, UV exposure experiments will be running simultaneously with sampled organisms in aquaria under different types of UV lamps and filters.

For the placement of sensor systems, the sampling of organisms as well as for the documentation of under-ice structures with digital still and video cameras, under-ice dives will be necessary to ascertain direct access to small-scale habitat structures under the ice and thus to the target organisms.

Molecular-biological studies on sympagic organisms

During this cruise adaptations of sympagic species to low temperatures and high salinities, which are the dominating abiotic factors in their habit, the brine channels, will be analysed with molecular-biological methods.

The transcription of DNA to mRNA is the first step during the synthesis of proteins, which are the main effectors of physiological functions and adaptations. As the protein synthesis is energy demanding, it is very important for the cell to control this first step very precisely. Therefore gene expression analysis is one of the first steps to understand physiological adaptation mechanisms on the transcriptional level. Therefore it will be searched for transcripts of sympagic species, whose proteins are responsible for adaptations to the extreme habit. Organisms of the same species will be isolated from the sea ice and the water column. From these two populations, which encountered strongly different temperatures and salinities, mRNA will be isolated and differentially expressed transcripts will be isolated using a molecular biological technique called "suppression subtractive hybridisation". Thereafter, these differentially expressed transcripts will be furthermore characterised with different molecular-biological methods.

The aim of this study is therefore a better understanding of physiological adaptation mechanisms on basis of the gene expression. This expedition will be mainly used for collecting samples of adequate species.

Sympagic primary production and spatial variability of chlorophyll concentration

The aim of this study is to examine the ice algal primary production within and beneath the pack ice of the Weddell Sea. Measurements will be conducted by means of an in-situ incubation method which allows for the incubation of ice-core segments (using C-14 labelled tracers) within the original core hole.

Sympagic primary production and the accumulation of ice algal biomass is greatly influenced by the prevailing light conditions and nutrient concentrations available within the sea ice. In different experiments we'll test the response of ice algal assemblages to varying light and nutrient conditions. We plan to collect under-ice algae by diving and incubate these assemblages in-situ under different light and nutrient scenarios. The aim of this study is to provide information about the in-situ capacity of ice algal production in the Weddell Sea and to increase our knowledge about the interaction of factors limiting ice algal growth.

In addition, we plan to investigate the spatial variability of chlorophyll and nutrient concentrations within the pack ice of the Weddell Sea. We aim to drill ice cores at different spatial scales (ranging from centimeters to kilometers) analysing the ice for chlorophyll a content as well as nutrient concentrations. Statistical analysis of results will provide us with information on the distribution and degree of variability at different spatial scales.

11. SEA ICE BIOGEOCHEMISTRY (AWI, SOS)

Objectives

The aim of our proposed work (in collaboration with other groups) is to make a detailed characterisation of the physical, biological and chemical environment of late winter/spring sea ice, with an emphasis on sites supporting growing biological assemblages. Currently, one of the main limitations of our sea ice studies is the paucity of data related to either the temporal variability and/or evolution of temporal changes in the environmental conditions in which these communities develop. ISPOL gives us the rare opportunity to make such studies, and the characterisation of sea ice processes on the turn from winter to spring conditions will be central to the suite of biogeochemical studies to be carried out.

Our specific objectives are:

- To make an extensive characterisation of the spatial variability in the physio-chemical environment (salinity, temperature, $\delta^{18}O_{H2O}$, oxygen, pH, alkalinity, NO_3^-, NH_4^+, $Si(OH)_4$, PO_4^{3-}, $\delta^{13}C_{DIC}$, DOC, DON, POC, PON, $\delta^{15}N_{PON}$, $\delta^{13}C_{POC}$) experienced by sea ice communities.
- To determine the respective scale and rate of temporal variation and evolution in the environmental conditions at sites displaying high standing stocks and active growth of microbial assemblages.
- To relate rates of DOM accumulation or utilisation to primary and bacterial production as well as environmental conditions.
- To determine the role of UV and non-UV photo-oxidation of DOM on ammonium (and/or urea) production and subsequent nitrite/nitrate production.
- To improve our understanding of the factors limiting algal and bacterial growth and those forcing community structure within sea ice on a transition form winter to spring conditions.
- To investigate the habitat range of the foraminifera *Neogloboquadrina pachyderma* using its stable isotopic composition for environmental reconstruction.

Field Sampling

The field work allows for the temporal fluctuations and development of the biogeochemical parameters to be quantified. We will employ standard ice coring techniques to sample the solid ice, and have the skills to sample surface gap layer and melt ponds along transects from the outside to interior of ice floes. Particulate (chlorophyll, POC/PON/, $\delta^{13}C_{POC}$, $\delta^{15}N_{PON}$, $\delta^{13}C_{foram}$ and $\delta^{18}O_{foram}$) and some of the dissolved parameters (nutrients, salinity) will be collected by tried and tested

sampling and processing of retrieved ice cores. No differentiation between live and dead foraminfera will be made. Cytoplasm, that provides the staining material, is likely to decompose at slow rates at the temperature of the sea ice and so many foraminifers may be designated live, when dead). For analytes that could be compromised by this sampling procedure (*in-situ* temperature, DOM, $\delta^{13}C_{DIC}$, $\delta^{18}O_{H2O}$, alkalinity, pH, O_2 & CO_2) we will also sample the brines at a range of depths using 'sackhole' sampling and/or brine drainage. Centrifugation of ice brines will also be employed for the non-gaseous components. For comparison of ice samples we will take routine samples for all parameters we are measuring from the water samples at various depths down to 200m.

The photo-oxidation incubations will be conducted in quartz and glass vessels that were procured for photo-oxidation experiments of estuarine and marine DOM currently running in Bangor. Use of both glass and quartz enables comparison of the relative effects of different wavelengths of light to be made. Several experiments will be conducted *in-situ* (by placing at different depths in the ice) as well as in the laboratory using a "sunshine-simulator" (AWI collaboration). The effects of photochemical reactions will be assessed by changes in DOC/DON concentrations, and the corresponding changes in nitrate, nitrite, urea and phosphate. These will be conducted in 0.2μm filtered samples to remove all bacteria. We will compare these incubations with experiments where bacteria and heterotrophic flagellates are not excluded, so that photochemical reaction rates can be compared with heterotrophic utilization of DOM pools. From previous experience in temperate waters incubation periods will extend from 1 day to several weeks, so that rates can be determined.

12. SEQUESTRATION OF CARBON BY "PUMPING" MICROBIAL REWORKED DISSOLVED ORGANIC MATTER TO THE ABYSSAL OCEAN (AWI, FSU)

Dissolved organic matter (DOM) in the oceans contains about the same amount of carbon as the global biomass or atmospheric CO_2 and exhibits an average age of several thousand years. Source, diagenesis and preservation mechanisms of DOM remain elemental questions in contemporary marine sciences and represent a missing link in models of global elemental cycles. The polar oceans are probably a primary source of DOM to the deep ocean because these regions are the only places where surface waters efficiently convect down to the oceans' bottom. Deep-water formation is directly linked to sea-ice formation, when salt is rejected and dense brine-enriched waters penetrate the deep ocean. Sea ice is one of the most productive marine environments, and DOM concentrations in the brine are among the highest measured in marine waters. The biogeochemistry of sea ice is widely unknown and it is not clear whether sea-ice DOM is persistent enough to survive downward convection. Based on a preliminary data set we roughly estimate that ~75 Tg of DOC may be exported annually from the surface Weddell Sea into the abyssal ocean and globally distributed via the thermohaline circulation. This comprises an early and very rough approximation, but it shows that the published models probably strongly underestimate the role of DOC export into the deep ocean. To date, the global DOC export into the abyssal ocean (>500 m) is estimated to be 130 Tg per year, completely disregarding the Southern Ocean.

The objective of this project is to investigate the formation of persistent DOM in sea ice and to trace its fate into the deep sea. In order to track microbial-derived molecular changes during DOM formation and degradation, a subsequent experiment will be initiated with various substrates from the extracted sample material. We hypothesise that "the refractory chemical structure of mature bulk marine DOM is similar in all oceans, largely independent of the source, and controlled by marine microbes". Broad significance is expected by answering the question: "Do ice-covered oceans act as a DOM pump to the abyssal ocean and so sequester carbon from active cycles?" The project should yield first quantitative estimates on the amount of carbon (Tg) annually sequestered by this process in the Weddell Sea and in ice-covered oceans world-wide. By combining several molecular tracer techniques we will be able to quantify the concentration of ice-algal derived DOM in the different water masses and along diagenetic pathways on a large scale in the Weddell Sea. A special focus will be on Fourier transform ion cyclotron resonance mass spectrometry (FTICR-MS) which is a highly promising new technique for the development of new molecular tracers. The results from this molecular fingerprinting will be integrated into physical models of regional and global ocean circulation, in order to obtain a detailed and quantitative biogeochemical model for DOM cycling in the ice-covered regions of the world oceans and beyond.

13. SUCCESSION, GROWTH AND ACTIVITY OF AUTO- AND HETERO-TROPHIC PROTISTS IN THE ICE (FIMR)

Protists (eukaryotic single-celled organisms) are both numerous and systematically diverse part of the Antarctic ecosystem. Photosynthetic protists (phytoplankton) are the basis of productivity in the ecosystem, but heterotrophic protists (protozoa) may as well be the major consumer group in the food web. Many protists are well capable in growing at extreme cold conditions.

Objectives

- Follow the succession of main species and systematic groups of phytoplankton and protozoa and link it to environmental characteristics.
- Follow the cell death of the main group of autotrophic producers, diatoms and relate that to environmental factors.
- Follow the changes in the size structure and known food preference of protozoa.
- Gather information on the growth rates of different protozoan groups.
- Link phytoplankton and protozoan population dynamics to nutrient and carbon characteristics in the ice.

Work content

The work is done in cooperation with several other projects (e.g. Dieckmann and Thomas). Most of the work is based on the microscopy of fresh samples as ISPOL is ideal for that kind of work. Both normal light and epifluorescence microscopy is used. Cell characteristics (e.g. the condition of chloroplasts) are used to evaluate the activity of phytoplankton. Chlorophyll fluorescence is also used to separate auto- and heterotrohic protists. Growth rates are followed experimentally in in-situ temperatures

using fractionated filtration. The results should give indication on the role of different trophic modes of protists in ice food webs and their possible interlinking with nutrient and carbon cycles.

14. ICE ALGAE: AN IMPORTANT SOURCE OF DMS? (WHOI, UG, UEA)

Scientific significance

Dimethyl Sulphide (DMS) is a volatile compound that is studied intensively because its oxidation products are involved in the formation of condensation nuclei and clouds. It thereby affects the albedo of skies and clouds and is thus highly relevant for "global change" discussions and models. Antarctic waters are estimated to contribute 10-30% to the global DMS flux. Considering these large amounts of DMS transferred to the atmosphere, it is conceivable that the oceanic productivity affects climate over a large area of the Antarctic continent and possibly over a much larger area of the Southern Ocean. Bio-physical processes in the Antarctic coastal waters and ice edges are therefore potentially very relevant in the context of global climate studies.

The estimations on Antarctic DMS flux are, however, based on a very limited number of data. From the data available, we know that extremely high concentrations of DMS in the water are often related to the presence of the alga *Phaeocystis antarctica* (Gibson et al.1990). There is also some data on DMSP (the algal precursor of DMS) from ice algae, which can be orders of magnitude higher than in the surrounding waters (Kirst et al. 1991). The efficiency of conversion of this DMSP into DMS and the subsequent flux to the atmosphere are, however never studied.

DMS fluxes are typically calculated by using a bulk aerodynamic approach. With this approach fluxes are calculated from the product of the concentration difference driving the flux and a kinetic factor, known as the transfer velocity (Liss and Merlivat, 1986; Wanninkhof, 1992). This kinetic term is uncertain and is highly dependent on meteorological conditions such as wind speed and temperature, which leads to disparities in calculated fluxes as high as 80% (Smith et al., 1996). In order to draw conclusions on the effect of the high DMS concentrations found during the Antarctic spring and summer on the climate, a more accurate measurement of the DMS flux is required.

The possibility to set-up sampling devices on the ice would give us the perfect scene for incubation experiments in order to study the effects of abiotic factors on the production and conversion of DMSP and DMS in ice communities and to study the spatial variability of DMSP and DMS production in ice and in the surrounding waters coupled to direct flux measurements. Although you might argue that the flux of DMS from the water will be prevented by ice formation, there is good reason to believe that a fair amount of DMS will originate from the ice algal community itself. Especially *Phaeocystis antarctica* is known to form thick patches on the ice surface.

Objectives

- to investigate the spatial heterogeneity of DMS and DMSP of sea ice and (if possible) its surrounding waters, in relation to a variety of biological and chemical parameters.
- directly measure the DMS fluxes from the ice and (if possible) its surrounding waters using the gradient flux and relaxed eddy accumulation techniques.
- to study the controlling factors of DMSP and DMS production by ice algae in incubation experiments.

The acquired knowledge will improve our understanding of how ice, oceans and atmosphere are linked via the flux of climatically important gases. It will provide essential and basic information on the influence of biological production on DMS emission to the atmosphere around Antarctica and improve scenarios of climate forcing by ice/ocean-atmosphere interactions and the significance of the Antarctic.

Methodology

Atmospheric trace gas measurements

DMS exhibits a strong concentration gradient between the ocean and the air and fluxes are always evident which makes the direct measurement of DMS fluxes feasible. In collaboration with the Netherlands Institute for Sea Research (NIOZ) and the Woods Hole Oceanographic Institution (dr. J. Dacey, E. Hintsa and W. McGillis) we have applied the gradient flux and the relaxed eddy accumulation techniques to measure DMS fluxes in recent experiments (Stoll, 2001, Zemmelink et al., 2001a,b,c). With these micrometeorological techniques we will be able to investigate gas exchange on temporal and special scales appropriate to understanding the controlling processes. Our approach will integrate fluxes over time scales of 20-30 minutes and over the surface footprint.

The REA and GF sampling systems will be based on the floe. Air samples for REA and GF measurements will be collected at a suitable elevation by pumping air to Teflon bags. The sampling time will typically be 20 to 30 minutes to average over atmospheric stability. Gas Chromatographic analysis of air samples will be similar to the procedures we used during the recent FAIRS and GasEX 2001 cruises. An important spin off of these recently conducted studies is that it seems feasible to use the air in the collection bags to measure other volatile sulfur gases (such as COS and CS2), we are determined to explore the possibility to use air left in the collection bags for further analysis of fluxes of these climatological relevant gases.

Spatial variability

The small-scale variability of surface DMSP, DMS, phytoplankton abundance, algal pigments, POC/N and temperature will be studied upwind from measurement systems. Samples for DMS and DMSP will be analyzed using a second gas chromatograph system. All other biological components will be analyzed at home. With this approach we can map out sources and fluctuations in DMS over the footprint of the DMS flux-measurements (≈ 0-500 meter depending on the height of the sampling inlets). For the sampling of ice cores, cooperation is envisioned with Dr. J-L Tison and collaborators.

Incubation experiments

Live in ice is stressful. Ice algae have to cope with a wide range of salinities, with light conditions ranging from limitation to inhibition (including high UVR) and with a steep temperature gradient of about 15 to 20 °C within the ice column. There is not much known on the dynamics of DMSP and DMS under such conditions, let alone on the possible physiological role these compounds can play within the algae (Stefels, 2000). Therefore, turnover rates will be studied using samples of local ice algal assemblages. They will be incubated on the spot or on board of POLARSTERN and subjected to a variety of light intensities, temperatures and salinities. Shock experiments (light and salinity) will be performed with assemblages taken from different habitats. Besides the standard measurements also taken from the cores (above), enzyme activity, primary production and photosynthetic parameters will be analysed.

Involvement of the project in other national / international projects

Marine Biology has a long history in investigating the production of DMS in pelagic systems (Stefels, 1997). Since the merger with the department of Physical Geography, DMS research has been extended towards the atmosphere. Besides several national projects within the framework of the National Research programme, two international projects have been financially supported by the EU and co-ordinated by Groningen ("Role and Significance of Biological Processes in DMS Release from Ocean to Atmosphere: A Close Examination of the Black Box" and ESCAPE – Entangled Sulphur and Carbon cycles in Phaeocystis dominated Ecosystems). Currently, DMS research is done in the framework of the national project "Micrometeorology of Air/Sea fluxes of Carbon Dioxide and Dimethyl Sulfide", EU-programme IRONAGES and in collaboration with Woods Hole Oceanographic Institution (USA) ("Fluxes, Air-Sea Interaction, and Remote Sensing" (FAIRS Experiment) and GASEX-II: the 2001 equatorial pacific air-sea CO_2 exchange experiment). Future continuation of this type of research is envisioned through 2 EU-projects that are currently under preparation. One of which will establish the cooperation with Dr. J-L Tison and coworkers.

15. CARBON, IRON, SULPHUR AND BIOLOGICAL INTERACTIONS DURING THE PROCESS OF SEA ICE MELTING (ULB, UOC)

General context

This field project comes in support of a long-term research programme aiming to assess to which extent ice-covered polar oceans contribute to processes regulating the Earth's Climate. The program involves a new multidisciplinary consortium combining the expertise of glaciologists, biologists, geochemists and ecosystems-modelers of the Université Libre de Bruxelles (ULB).

The main goal of the project is to study, understand and quantify the physical and biogeochemical processes associated with the sea ice biota that govern the emissions of marine gases of climatic significance. These processes are indeed presently unknown and therefore not integrated into Oceanic Biogeochemical

Climate Models (OBCMs). In this context, particular attention will be paid to Carbon Dioxide (CO_2) and Dimethyl Sulphide (DMS), both actively involved in the sea ice microbial metabolism. It has now been demonstrated that iron can play a crucial role in controlling primary productivity and the biological carbon pump in the Southern Ocean. The work programme will thus in addition focus especially on the biogeochemical cycle of iron (origin, availability and fate) in the sea ice environment.

Modeling effort will involve the development of a new sea ice biogeochemical model (SIMCO). Its parameterization will rely on the results obtained during process studies such as ISPOL.

The programme specifications described above fit adequately in the general objectives and tasks of ISPOL, more specifically:

- To investigate physical, biogeochemical and biological processes controlling the transformation and interactions in the atmosphere-ice-ocean system from austral spring to summer
- To improve our understanding of the seasonal interaction between biota and sea ice.

Objectives

Deciphering the complex biogeochemical processes governing the iron, carbon and sulphur cycle in sea ice has to rely on an integrated approach providing the best characterization of the sea ice environment during the time sequence involved. Therefore, ***sea ice sampling and measurements*** activities will address a whole set of physico-chemical and biological parameters both in the ice itself, in the sea water below, in the snow on top and in the atmosphere. Some of the measurements will be made in the field, others back in "home laboratories" (see details in Table 1). Ideally, sea ice access and logistics permitting, a "full" sampling session will occur every 4 days, in a "pristine" (10x10m) to (20x20m) area, as close as possible from the previous stations, and as far as securely possible from the ship. Some of the measurements (e.g. ocean-ice-atmosphere CO_2 fluxes) should however occur on a (twice) daily basis.

Further work will involve:

a) ***$^{14}C/^{55}Fe$ incubation experiments*** (2 to 5, time permitting) both "in-situ" and in a ship-based incubator

b) ***Shipboard microcosms experiments*** (2 to 4, time permitting)

Physico-chemical parameters

The following physico-chemical parameters will be measured on the ice cores: "in-situ" temperature, bulk salinity, ice texture, ice fabric, stable isotopes of oxygen (in collaboration with the geophysical sea ice programme, total gas content, gas composition in O_2, N_2, CO_2, CH_4 and DMS (in collaboration with the ice algae DMS programme).

The particulate material entrapped in the ice cores will be collected by filtration of the melted core slices after thawing. Major organic and inorganic components in the particulate phase will be measured in order to quantify 1) the Fe stored in the sea ice

and 2) the organic matter present related to algal growth. The following particulate elements will be analysed: Al, Fe, organic carbon, nitrogen and phosphorus, and the biogenic silica (BSi).

The filtrate collected will be analysed for dissolved elements. They include major dissolved cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) and anions (Cl^-, SO_4^{2-}), inorganic nutrients (NO_3, NH_4^+, PO_4^{3-}, H_4SiO_4, in collaboration with the sea ice biogeochemistry programme), dissolved organic component such as dissolved organic carbon (DOC), and also dissolved Fe.

DMSP filtrates from the sea ice cores will be analysed in collaboration with the ice algae DMS program and the Marine Botany Department of the University of Bremen in Germany (Dr. G.O. Kirst and Dr. O. Wandschneider).

The iron problematic

In the framework of the possible limitation effect of iron availability on the physiological state of the microbial community and therefore on the C and S cycles in sea ice, special attention will be given to the iron problematic.

The amount of iron which can be released during ice melting and surface flooding will be quantified by following the evolution of the dissolved iron concentration and its speciation (organic vs. inorganic, Fe^{2+} vs. Fe^{3+}), in addition to inorganic (NO_3^-, NH_4^+, PO_4^{3-}, H_4SiO_4) and organic (DOC, DON, DOP) nutrients during the field campaign (see physico-chemical parameters above). This allows the evaluation of the bio-available iron and its uptake.

Experiments will also be conducted to study the fate of dissolved Fe in the sea ice environment, and more specifically to assess the role of micro-organisms in the biogeochemical cycle of Fe in the sea ice. The assimilation of Fe by the micro-organisms will be measured using the ^{55}Fe radioisotope. This measurement will be coupled with the estimation of ^{14}C incorporation. The incorporation of C in the different cellular components of the algae: proteins, polysaccharides, lipids and small metabolites, will be assessed. The C incorporated in the proteins is a good indicator of algal growth. Fe :C uptake ratios will then be calculated and used in the sea ice biogeochemical model SIMCO. Experiments will be run with sea ice, seawater and brine samples both « in situ » and under controlled conditions (temperature and light) in a ship-based culture cabinet.

Origin and biological pathway of iron in natural sea ice through isotopic signature

Snow, ice, brine, and seawater will be analysed for iron isotopes 57, 56 and 54 with a Nu-Instruments 'Plasma' Multicollector Inductively Coupled Plasma Mass Spectrometer (MC-ICP-MS). Iron isotopic compositions will be used in an attempt to determine the origin and fate of iron in sea-ice and to detect a bio-signature in the measured ratios due to biological activity. This will be achieved by comparing the natural isotopic composition of the sea-ice particulate material with particulate material (rock, soil, dust, sediments) from possible source regions surrounding the polar ocean basins of interest (e.g. Antarctic Peninsula, South-America, southern Africa).

Table 1. Ventilation of sea ice sampling and measurement activities of project S-263

PARAMETERS	FIELD ACTIVITY	HOME LABORATORIES
Temperature	- Sampling (1 core) - Direct measurement on immediate retrieval	
Bulk Salinity	- Sampling (1 core, same as temperature) - Direct slicing, melting and measurement	
Ice texture, fabrics	- Sampling 1 dedicated core and storage at –30°C - Thick sections on all cores used in-situ to check for location homogeneity	- Thin sections of all cores
$\delta^{18}0$, δD	- Sampling (1 core, same as textures)	- Measurements
Total gas content, O_2, N_2, CO_2, CH_4, DMS, DMSP	- Sampling (2 cores) and storage at –30°C in dark	- Measurements
Inorganic and Organic nutrients (dissolved iron, see special case below)	- Sampling (1 core) - Filtering for particulate - fixing of filtrate - measured/storage frozen	
DMS, DMSP	- Sampling (1 core) - Filtering of half core for DMSP - DMS measurement on the other half	- Measurements DMSP
CO2 fluxes (chamber method)	Direct flux measurements	
Iron isotopes	- Sampling (1 core) and storage at -30°C - Sampling snow, water (25 liters) - acidification and storage	- Measurements
Total, Dissolved iron and iron speciation	- Sampling (2 cores), snow, water - Melting of one core - Dissolved Measurement by Flow Injection Analysis with chemiluminescence detection - Experiments (melting one core) on fate of iron during ice melting in sea water and surface flooding	Total iron measurements
Sea ice micro-organisms taxonomy and physiological status	- Sampling (2 cores) - Melting 2 cores for taxonomy and physiological status measurements and experiments	Taxonomy, biomass and viability measurements

Biological measurements on the sea ice assemblages

Due to extreme environmental conditions occurring in the sea ice, it is essential to identify the microorganisms and to discriminate between those that are active (living cells with any detectable metabolic activity), growing (cells which participate in the production of biomass) and dead (representing organic particles). From different sea-ice assemblages, algae, protozoa and bacteria taxonomic diversity, biomass and specific physiological functions including cell viability and iron stress will be determined.

Microbial processes upon ice melting

To assess the role played by melting of sea-ice assemblage on the planktonic microbial food web and the formation of phytoplanktonic blooms, ship-based controlled microcosm experiments will be run under different conditions of brown (biologically rich) ice melting and seawater inputs. The experiments will simulate the following evènts: seeding of sympagic organisms, seeding of DOM, seeding of iron. Each microcosm will be run and daily sampled during 1-2 weeks. Measurements will include inorganic (NO_3, NH_4, PO_4, $SiOH_4$) and organic (DOC) nutrients, particulate and dissolved iron, microorganism abundance and biomass, physiological state, potential bacterial and algal growth (^{14}C-photosynthesis, ^{3}H-thymidine-bacterial production) and, nutrient uptake (^{55}Fe-^{32}Si nutrient uptake).

The CO_2 problematic

In addition to the laboratory CO_2 measurements in the ice cores, brines pCO_2 and ocean-ice-atmosphere CO_2 fluxes will be measured on a regular basis in the field. Direct measurements of brines pCO_2 using a dedicated portable equilibrator system will be performed by re-circulating brines collected in brine holes drilled at various depths in the ice cover. CO_2 fluxes will be measured, using adapted accumulation chambers devices, at different levels: snow surface, ice surface, above holes drilled through the ice cover and at various depths within the ice cover itself. These data sets will be correlated with the physico-chemical and biological variables measured into the sea ice, in order to decipher the controlling mechanisms.

16. ZOOPLANKTONECOLOGY AND PHYSIOLOGY AND CRYO-PELAGIC COUPLING (AWI)

Studies on the occurrence, distribution pattern and population structure of sea ice, under ice and water column communities have been carried out in the Weddell Sea since 20 years. However, all these studies have been snapshots and data covering longer periods of investigations are missing. These results indicate that only very few species are adapted to live in and underneath the sea ice. However, the physiological and biochemical adaptation, their energy budget and requirements of the ice organisms are still unknown. Hence, studies carried out during ISPOL should enable detailed descriptions of the seasonal development in population structure as well as the description of the life strategies of the dominant sea ice and pelagic copepod species. Another aim is to record particle flux, i.e. the transport of biogenic material from the sea ice to the water column.

Quantitative sampling and description of the seasonal change in the sea ice and pelagic fauna

As standard devices for the quantitative collection of zooplankton a 0,25 m^2 multi net and a 0,5 m^2 multi net equipped with 5 nets of 55 μm mesh size and 9 nets of 150 μm, resp will be used. The nets can be opened and closed sequentially. The small sized net collects mainly small sized zooplankton and faecal pellets while the large sized net samples mesozooplankton organisms. Species composition, abundances

and biomass, and vertical distribution patterns of dominant species and their developmental stages will be analysed from these samples.

The sampling of sea ice fauna will be carried out with ice corers and the sub-ice fauna with divers and pumps.

Experimental studies on physiological adaptations and cryo-pelagic coupling

Experiments on feeding, assimilation, defecation, respiration and reproduction will be carried out in a wide range of temperatures and salinities. Physiological indicators of thermal and salinity limits will be tested. The hypothesis that sloppy feeding produces a high DOC/ DON pool in sea ice and ammonium excretion is responsible for high NH_4 levels in sea ice will also be tested in the experiments.

Living pelagic animals will be caught by means of a of bongo net from the upper meters, the ice animals by divers.

For quantitative and qualitative studies on the feeding behaviour, experiments will be conducted in a cooling container. Different food organisms (phytoplankton cultures, naturally occurring particle including ciliates) will be supplied in different concentrations.

17. ANTARCTIC TOP PREDATORS AND THEIR PREY – WHO IS HIDING UNDER THE ICE? (ALTERRA)

In the Antarctic Ocean, the seasonal pack ice zone represents an important habitat for penguins, flying birds, seals and whales. At the ice edge, primary production is enhanced in the water column which in turn supports high stocks of macrozooplankton and micronekton (e.g. salps, krill, larval / juvenile fish, squid) - the prey of these top predators (Eicken, 1992). However, the ice-covered areas can also support considerable stocks of birds, seals and whales. In fact, their food demand based on abundance and species composition can persist towards the inner pack ice (Joiris, 1991, Franeker et al., 1997). Which sources do these top predators rely on?

Where an extensive ice cover limits the growth of algae in the water column, the productivity of ice algae in the sea-ice can still be considerable (Arrigo et al., 1997). Sea-ice can sustain primary and secondary consumers, such as sympagic microfauna and zooplankton. Major exchange with the pelagic community can occur through grazing at the water-ice boundary, or feeding on algae and animals released when the ice is melting (Eicken, 1992). Until now it is not known to which extent the ice-associated community attracts fish and/or squid, which in turn serve as prey for a number of bird, seal and whale species (Hoshiai et al., 1991, Lizotte, 2001).

Studying life in the inner pack-ice is difficult. Logistic problems in sampling the ice-ladden environment have so far limited our knowledge on this complex habitat. To date, a number of studies were performed which investigated life under and close to the ice, including diving observations, acoustic measurements, traps, trawling and ROV (Remote Operated Vehicle) operations (e.g. Gulliksen & Lonne, 1991, Siegel et al., 1992, Kaufmann et al., 1995). Most of these studies indicated that the sea-ice

itself as well as the water-ice boundary layer play an important role in the Southern Ocean ecosystem.

The Antarctic group of Alterra Texel focuses on the abundance of top predators and the occurrence of their prey in the upper layer of the water column, both in ice-free and ice-covered areas. Earlier this year, Alterra's specially developed SUIT net (Surface and Under Ice Trawl) yielded first data on the distribution of surface makrozooplankton in relation to sea ice and top predator distribution on POLARSTERN cruise ANT XXI-4 in the Lazarev Sea (Flores et al., 2004, Franeker et al., 2004).

ISPOL with its 50 days' drift station gives a great opportunity to follow the pathways of the food web from sea-ice through the water column up to the top predators, both in time and in space. During the sampling period, a system of weirs and guide nets will be mounted under the ice floe. The weir system is designed to catch makrozooplankton and micronekton in the water-ice boundary layer. Additional data will be collected by diving observations, top predator observations above the ice, and acoustic zooplankton recordings. Diet investigations on the animals caught in the weir system, or on accidental findings of mammal faeces / dead birds will hopefully contribute to our understanding of the sea-ice system.

18. BATHYMETRY (AWI)

The multibeam system Hydrosweep DS2 installed onboard RV POLARSTERN is used to provide depths data as basic information for marine sciences. In addition to the depths measurements echo amplitudes are recorded by the system. They can be converted into multibeam sidescan and angular backscatter data. The main application of sidescan is to detect small scale features which cannot clearly be recognised in the bathymetry (e. g. shallow channels or iceberg plough marks). Angular backscatter shows the same resolution as the depths measurements but supplies additional information about physical properties of the seafloor (surface- and volume roughness).

It is planned to record bathymetric data during the entire ISPOL expedition including the drift station in the Weddell Sea and the transit from and to Cape Town. Continuous depths recording during transit time is necessary to expand the existing data base and to improve nautical charts (e.g. GEBCO 5.13/5.16, IHO INT Chart Scheme 904, 905, 9055, 9056, 9057, 906, 9060). Data gaps need to be avoided, since additional ship time or further expeditions would be necessary to close the gaps.

Bathymetric data are also recorded along the track of the drift station in the Weddell Sea and will provide first depth information of that area. Cleaned and processed data are submitted to the IHO (International Hydrographic Organization) afterwards to expand nautical charts. Precise depth information of the seabed and morphological structures is essential for investigations of ocean circulation and geological, biological and geochemical processes, that are achieved within the scope of the ISPOL expedition. However, during the drifting of the ship continuous depths recording is stopped in case the angle between the heading of the ship and the direction of

drifting exceeds 75 degrees. In that case, the area covered by depths measurements is reduced to one forth of the usually achievable coverage. Therefore, sound emission into the water is reduced during unfavourable survey conditions.

In addition to the depths recording, the recently introduced transmission mode ASLC (Automatic Source Level Control) will be tested. It is used to adjust the source level of the multibeam system based on the quality of the received echo. Therefore the source level will be reduced as much as an appropriate echo can be detected. The aim is to minimize survey time utilizing maximum source level in order to reduce the impact of the sound emission on the marine environment. The amount of reduction mainly depends on the seabed. Using ASLC it is possible to generate charts that indicate the source level necessary for bathymetric measurements. They can be used for planning purposes of forthcoming cruises.

19. TOPOGRAPHY AND STRUCTURE OF THE UPPER LAYERS OF SEDIMENTS OF THE OCEAN FLOOR (RAS)

Under way from Cape Town to the most southern part of the Weddell Sea, the area of the Riser-Larsen ice shelf and Coats Land, the bathymetry survey will have the goal to obtain additional information about the morphology of the rift of the axial zone of the Indian-Antarctic midoceanic ridge and its transform faults. After arrival at the area of the Coats Land on the track headed to the west along the margin of the Filchner and Ronne ice shelves the most interesting will be the study of the previously poorly studied area of the probable dissipation of the rifted structure of the eastern part of the Trans-Antarctic Rift. It is possible that the general scheme of a dissipated rifted structure would be similar to scheme of rifted structure at the west end of the Trans-Antarctic Rift in the area of the Ross Sea.

At the western side of the Weddell Gyre the bathymetry survey will be concerned with the examination of the morphology of submarine canyons on the continental slope and their continuation at the foot of the slope, on its accumulative apron and deep-sea channels. Special interest is focused on evidences of meandering of deep sea channels, morphology of the channels and their levees.

In the area of the Powell Basin and the South Scotia Ridge, on the way to Cape Town attention has to be paid to intersections of system of rifts and transform faults of the America-Antarctic midoceanic ridge unsufficiently investigated previously.

20. THE FLOE (Die Scholle)

Claus-Peter Lieckfeld, Ingo Arndt

It is our intention to publish a popular book that covers the whole ISPOL-expedition in a way that invites a broad public to take part in the expedition and to understand the very meaning and importance of Antarctic research.

It is becoming more and more obvious that the poles are playing a substantial role in (what is dicussed as) „climate change"; therefore public awareness has risen to a rather high level over previous years.

We will focus on the various aspects of ISPOL. The pictures, taken by the highly qualified, award winning GEO-photographer Ingo Arndt, will probably be the highlights of the book. Arndt will mainly focus on „small structures" in the ice and in the water rather than the well known „double page-eye-catchers" ... which of course does not mean that these will not be covered in the book.

Members of the expedition will ensure, that facts and figures represent the high standard that POLARSTERN and „Alfred-Wegener-Institut" is known for.

The publisher of the book, Frederking & Thaler, is Germany`s Nr. 1 when it comes to sophisticated photo-publications. Moreover Germany's GEO Magazine will publish an „appetizer"-story in order to promote the book, which will probably be published by the end of summer 2005.

21. BETEILIGTE INSTITUTE / PARTICIPATING INSTITUTES ANT XXII/2

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ALTERRA	ALTERRA Texel University of Groningen Postbus 167 1790 AD Den Burg (Texel) The Netherlands
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ESR	Earth & Space Research 1910 Fairview Ave. E Seattle, WA 9802 USA
Ferra Dynamics	Ferra Dynamics Inc. 4070 Powderhorn Cres Mississauga, ONT Canada
FIMR	Finnish Institute of Marine Research Lyypekinkuja 3 A P.O. Box 33, FIN-00931 Helsinki Finland
FSU	Florida State University Department of Oceanography Tallahassee- FL 32306-4320 USA
HeliTransair	HeliTransair GmbH Am Flugplatz 63329 Egelsbach

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UG	University of Groningen Dept. of Marine Biology PO Box 14, 9750 AA Haren the Netherlands
ULB	Université Libre de Bruxelles Bvd. Du Triomphe, 1050 – Bruxelles Belgium

UOC	Unite d'Oceanographie Chimique Université de Liège Allee du 6 Aout, 17-BAT B5 4000 Liège Belgium
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23. SCHIFFSPERSONAL / SHIP'S CREW

Reederei F.Laeisz G.m.b.H.
Name of Ship : POLARSTERN
Nationality : GERMAN

Reise ANT XXII/ 2
06.11.2004 - 19.01.2005
Kapstadt - Kapstadt

No	NAME	RANK	NATION
01.	Pahl, Uwe	Master	German
02.	Spielke, Steffen	1.Offc.	German
03.	Schulz, Volker	Ch.Eng.	German
04.	Grimm, Sebastian	2.Offc.	German
05.	Hartung, Rene	2.Offc.	German
06.	Wunderlich, Thomas	3.Offc.	German
07.	Kapieske, Uwe	Doctor	German
08.	Koch, Georg	R.Offc.	German
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10.	Kotnik, Herbert	2.Eng.	Austria
11.	Simon, Wolfgang	2.Eng.	German
12.	Holtz, Hartmut	Elec.Tech.	German
13.	Nasis, Ilias	Electron.	German
14.	Verhoeven, Roger	Electron.	German
15.	Schulz, Harry	Electron.	German
16.	Kahrs, Thomas	Fielax-Elo	German
17.	Clasen, Burkhard	Boatsw.	German
18.	Neisner,Winfried	Carpenter	German
19.	Kreis, Reinhard	A.B.	German
20.	Schultz, Ottomar	A.B.	German
21.	Burzan, G.-Ekkehard	A.B.	German
22.	Schröder, Norbert	A.B.	German
23.	Moser, Siegfried	A.B.	German
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25.	Hartwig-Labahn, A.	A.B.	German
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27.	Beth, Detlef	Storekeep.	German
28.	Toeltl, Siegfried	Mot-man	German
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33.	Fischer, Matthias	Cook	German
34.	Tupy,Mario	Cooksmate	German
35.	Martens, Michael	Cooksmate	German
36.	Dinse, Petra	1.Stwdess	German
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38.	Streit, Christina	2.Stwdess	German
39.	Schmidt,Maria	2.Stwdess	German
40.	Schmutzler, Gudrun	2.Stwdess	German
41.	Tu, Jian Min	2.Steward	China
42.	Wu, Chi Lung	2.Steward	German
43.	Yu, Chung Leung	Laundrym.	China