634
2011

Berichte
zur Polar- und Meeresforschung

Reports on Polar and Marine Research

The Expedition of the Research Vessel "Polarstern" to the Antarctic in 2010/11 (ANT-XXVII/2)

Edited by
Eberhard Fahrbach
with contributions of the participants

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POLAR- UND MEERESFORSCHUNG
in der Helmholtz-Gemeinschaft
D-27570 BREMERHAVEN
Bundesrepublik Deutschland

ISSN 1866-3192

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Die "Berichte zur Polar- und Meeresforschung" (ISSN 1866-3192) werden ab 2008 ausschließlich als Open-Access-Publikation herausgegeben (URL: http://epic.awi.de).

Since 2008 the "Reports on Polar and Marine Research" (ISSN 1866-3192) are only available as web-based open-access publications (URL: http://epic.awi.de)

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Please cite or link this publication using the identifier
hdl:10013/epic.38039 or http://hdl.handle.net/10013/epic.38039

ISSN 1866-3192

ANT-XXVII/2

28 November 2010 - 5 February 2011

Cape Town – Punta Arenas

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ANNEXES

1. ZUSAMMENFASSUNG UND FAHRTVERLAUF

Eberhard Fahrbach
Alfred-Wegener-Institut

Am 28. November 2010 um 19:30 Uhr lief *Polarstern* von Kapstadt zur Antarktisreise ANT-XXVII/2 aus. Wir waren 44 Besatzungsmitglieder und 53 wissenschaftliche Fahrtteilnehmer/innen aus 12 Nationen an Bord.

Zunächst führte der Kurs nach Südwesten. Am 29. und 30. November erfolgten die Inbetriebnahme der Labors und Anlagen, Einweisungen und Belehrungen. Die erste Station mit der Messung eines Temperatur- und Salzgehaltsprofils mit der CTD-Sonde (Conductivity, Temperature, Depth) begann am 30. November um 1.55 UTC. Von nun an lief die Forschung in vollem Gang. Nach ruhigen Verhältnissen beim Auslaufen hatte der Wind inzwischen zugenommen. Unser Kurs führte entlang einer Linie von verankerten Pressure Inverted Echo Soundern (PIES), die zur Messung des Drucks am Meeresboden und der Schalllaufzeit bis zur Meeresoberfläche und zurück dienen. Diese Daten werden genutzt, um die Schwankungen des Wassertransports und der vertikal gemittelten Temperatur des Antarktischen Zirkumpolarstroms über mehrere Jahre hinweg zu erfassen. Die Geräte werden am Meeresgrund ausgesetzt. Auf ein akustisches Signal hin kommen sie nach Ablauf des Messzeitraums mit den gespeicherten Daten an die Meeresoberfläche zurück, wo sie vom Schiff aus aufgenommen werden. Leider konnten die ersten beiden aufzunehmenden PIES nicht wiedergefunden werden. Beim Auslegen des zweiten PIES traten Probleme auf, da er nach der Auslegung wider Erwarten an die Oberfläche zurückkehrte. Das schlechte Wetter (schlechte Sicht und Schaumkronen) erzwang Einschränkungen beim Walbeobachtungsprogramm. Bei 46°01'S 5°51'O trafen wir am 4. Dezember den ersten Eisberg an. Am 7. Dezember erreichten wir bei 51°25'S den Meridian von Greenwich. Von hier aus ging es mit Kurs Süd bis zum antarktischen Kontinent.

Während der gesamten Reise erfolgten Messungen von Temperatur, Salzgehalt und der Meeresströmung vom fahrenden Schiff aus. Entlang der Kurslinie wurden vertikal profilierende Driftkörper (Floats vom Typ NEMO - Navigating European Marine Observer und APEX) ausgelegt. Im Weddellwirbel erfolgte die Aufnahme und Auslegung von Verankerungen, die Strömungs-, Temperatur- und Leitfähigkeitsmessgeräte, Schallquellen zur Ortung von Driftkörpern (Floats), akustische Registriergeräte und Eisecholote (upward looking sonar, ULS) zur Messung der Eisdicke trugen. Standardmäßig wurden Messungen mit einem CTD-System (conductivity, temperature, depth) ausgeführt, das mit Wasserschöpfern ausgestattet war, um Proben zur Bestimmung der Konzentration von gelösten Nährstoffen, Sauerstoff, Spurenstoffen und CO_2-Parameter zu erhalten. Ferner wurde das Wasser zur Messung biologischer Größen und zur Durchführung von Experimenten bereit gestellt.

In der Nacht vom 9. auf 10. Dezember begegneten wir vereinzelten Bruchstücken zerfallener Eisschollen. Am 10. Dezember wurden sie häufiger (verbunden mit dem ersten Schneefall) und am Nachmittag kam eine fast geschlossene Eisdecke in Sicht. Von da an durchquerten wir offene Schollenfelder, die zwar den Seegang dämpften, aber unsere Fahrt nicht beeinträchtigten. Allerdings verändern sich die Eisbedingungen rasch, da wir am kritischen Punkt der Frühjahrsschmelze waren. Am 11. Dezember erreichten wir die erste Verankerung im Strömungssystem des Weddellwirbels, AWI-227. Leider konnte sie nicht geborgen werden, obwohl wir mit Posidonia akustisch mit ihr korrespondieren konnten. Die Beobachtung bei späteren Verankerungen, dass Auftriebskörper in mehr als 4.000 m Tiefe implodiert waren, legt nahe, dass dies auch hier erfolgt war und die Verankerung somit ohne Restauftrieb war. Das für diese Gegend typische Wetter (schlechte Sicht und Schaumkronen) hat zu Einschränkungen beim visuellen Walbeobachtungsprogramm geführt.

Am 12. Dezember, haben wir 60°S überschritten und damit die Antarktis erreicht. Zwischen 59° und 65°S erstreckte sich ein breiter Eisgürtel, südlich davon waren wir wieder in offenem Wasser. Allerdings handelte es sich überwiegend um offene Schollenfelder, die unserer Fahrt keinen Widerstand entgegensetzen, sondern durch die Dämpfung des Seegangs trotz beträchtlichen Windstärken für ein ruhiges Schiff sorgten. In diesem Eisgürtel begannen die Meereisbeobachtungen und die ersten Eiskerne wurden erbohrt. Durch die Hilfe der Helikopter konnte dies während CTD-Stationen geschehen.

Die Aufnahme von Verankerungen im Eis stellte eine besondere Herausforderung dar. Verankerungen sind autonome Systeme, die mehrere Jahre im Ozean verbleiben, um an einer bestimmten Stelle eine Vielzahl von ozeanographischen Größen in hoher zeitlicher Auslösung zu messen. Eine Verankerung besteht aus einem Grundgewicht, einem Seil und den Auftriebskörpern, die das Seil senkrecht in der Wassersäule halten. Am Seil sind Messgeräte befestigt, die z.B. Temperatur, Salzgehalt, Strömungsgeschwindigkeit und Richtung, Eisdicke und die Laute von Meeressäugern in internen Speichern aufzeichnen. Ist die Messzeit zu Ende, so wird mit Hilfe eines akustischen Signals, das mit der Posidonia-Anlage der *Polarstern* gesendet wird, das Seil mit den Geräten vom Grundgewicht getrennt, worauf es von den Auftriebskörpern an die Meeresoberfläche gezogen wird. Dies kann mit dem Posidonia-System verfolgt werden. An der Meeresoberfläche wird ein Satellitensender aktiviert. Sehen wir die aufgeschwommene Verankerung nicht mit bloßem Auge, dann hilft uns das Satellitensignal, sie zu finden. Bei den Verankerungen im Eis hatten sich die Auftriebskörper ihren Weg zwischen den Eisschollen an die Oberfläche gesucht. Dann näherte sich das Schiff geschickt der Verankerung, ohne sie zwischen den Schollen zu zerquetschen. Die letzten Meter wurden mit Hilfe des Mammy-Chairs überwunden, von dem aus eine Seilverbindung zum Schiff hergestellt wurde. Bei sehr kleinen Verankerungen ist die Wahrscheinlichkeit allerdings gering, sie im Eis zu finden, deshalb mussten wir bei der Verankerung MARU 2 auf die Aufnahme verzichten. Doch auch im offenen Wasser war die Bergung der Verankerungen nicht immer einfach. Teilweise stellte der Nebel, der uns begleitete, nachdem wir wieder ins offene Wasser gekommen waren, ein Problem dar. Es erfordert besonderes Können, wenn der Wind mit einer Stärke bläst, wie es in dieser Gegend der Normalfall ist. Dann muss die Schiffsführung das Schiff gegen den Wind behutsam an die Verankerung annähern, ohne sie dabei zu beschädigen.

Auf dem Meridian von Greenwich wurde das CTD/Wasserschöpfer-Programm mit einem Stationsabstand von 30 sm fortgeführt. Eine besonders große und vor allem eisenfreie Wasserprobe wurde von der Phytoplanktongruppe mit einem Schleppfisch an Bord gepumpt, der mehrere Stunden in sicherem Abstand vom Schiff geschleppt wurde, um die Kontamination durch das Schiff zu vermeiden. Das Wasser wurde an Bord zu Experimenten verwendet, die den Einfluss eines veränderten CO_2-Gehalts der Atmosphäre auf das Wachstum des Phytoplanktons nachweisen sollen.

Auf der Anreise bis 51°S und dem Meridian von Greenwich führten wir 46 CTD/ Wasserschöpfer-Stationen aus. Wir nahmen 7 Verankerungen und 6 PIES auf und legten 5 bzw. 13 wieder aus. Es wurden 25 NEMO bzw. APEX-Floats ausgesetzt.

Am 20. Dezember erreichten wir die Neumayer-III-Station zur Versorgung. Am frühen Morgen lagen wir vor der Atkabucht. Die Eisverhältnisse waren günstig und so gelangten wir zügig an den Nordanleger an der Kante des Ekström-Schelfeises. Die Stationsmannschaft kam mit Pistenbullies zur Schelfeiskante. Schließlich wurde eine günstige Position mit 11 m Kantenhöhe gefunden, wo sich *Polarstern* bis zum 22. Dezember mit ihren Strahlern hielt. Die Entladung der Container begann und der Tankschlauch wurde auf die Schelfeiskante ausgebracht. Nach der Ankunft der Tankcontainer wurden 280.000 l Arctic Diesel und 27.000 l Kerosin abgegeben. Die Ent- und Beladung der Versorgungsgüter ging zügig voran. Es wurden 120 t abgegeben und 50 t aufgenommen. Ferner wurden Umstauarbeiten ausgeführt. Die Helikopter waren unterwegs, um Schneeproben zur Schadstoffmessung in sicherer Entfernung vom Schiff zu nehmen, so dass eine Kontamination ausgeschlossen werden konnte. Das Walbeobachtungsprogramm wurde fortgesetzt. Die Betreuer der PALAOA-Station wurden zur Neumayer-Station gebracht, von wo aus sie mit Skidoos weiter fuhren. Wenn es die Sichtverhältnisse zuließen, erfolgten Personentransporte zur Neumayer-III-Station.

Bei der Neumayer-Station musste ein wissenschaftliches Crewmitglied von Bord gehen, da es schwer erkrankt war und die Reise nicht fortsetzen konnte. Dank des DROMLAN-Flugnetzes, konnte die Person innerhalb einer Nacht von der Neumayer-Station über Novolazarewskaya nach Kapstadt geflogen und dort ins Krankenhaus gebracht werden, von wo aus sie dann den Heimflug antreten konnte.

Am 21. Dezember erreichte das südafrikanische Versorgungsschiff *S.A. Agulhas* die Schelfeiskante in 1,5 sm Entfernung von *Polarstern*. Am 22. Dezember waren die Versorgungsarbeiten beendet. Unmittelbar vor dem Meereisgürtel lag die *S.A. Agulhas* und führte Stationsarbeiten durch. Beide Schiffe grüßten sich beim Vorbeifahren durch das Blasen der Hörner. Am Eisrand nahm *Polarstern* die Forschungsarbeiten mit einer CTD-Station wieder auf.

Anschließend führte unser Weg wieder ein Stück zurück nach Norden, wo noch weitere Verankerungsarbeiten anlagen. Nach der Aufnahme und Wiederauslegung der Verankerung AWI-244 dampften wir zum südlichsten Punkt unserer Reise mit der Position 71°06,5' S 11°27'W bei Kapp Norvegia im Weddellmeer. Am 24. Dezember begannen wir mit dem CTD-Schnitt in Richtung Joinville Island an der Nordspitze der Antarktischen Halbinsel. Zum Heiligen Abend unterbrachen wir die Stationsarbeiten, um den Festtag würdig zu begehen.

Bis auf wenige offene Eisfelder, die in zwei nach Nordosten gerichteten Gürteln zwischen 14° und 23°W sowie zwischen 37° und 42°W wieder dichter wurden, trafen wir offenes Wasser an. Die Eisfelder im Weddellmeer haben sich weiter als erwartet nach Westen erstreckt. Am 3. Januar 2011 erreichten wir bei 42°W den Eisrand. Mit dem Eis war auch das sonnige Wetter dahin. Zwar blieb es schwachwindig, aber Warmluft von Norden brachte schlechte Sicht und zeitweise sogar dichten Nebel. Später ging der Regen in Schnee über. Am 7. Januar wurde es etwas stürmisch, aber der Windschatten der Antarktischen Halbinsel sorgte schon am 8. Januar wieder für ruhiges Wetter.

Mit dem endgültigen Verlassen des Meereisgebiets ging die Probennahme auf Eisschollen zu Ende, die mit Unterstützung der Helikopter auf Eisschollen erbohrt wurden. Ziel dieser Arbeiten war es, den Luftgehalt des Eises im Labor zu bestimmen. Dies stellt eine besondere Herausforderung dar, da es dazu bisher keine etablierte Technik gab und diese somit erst entwickelt wurde.

Die Arbeiten auf dem Weddellmeer-Schnitt verliefen zügig, da wir überwiegend ruhiges Wetter und nur offene Eisfelder zu durchqueren hatten. Der Abstand zwischen den Stationen lag im zentralen Weddellmeer bei 40 bis 50 sm. Im Weddellmeer führten wir 56 CTD/Wasserschöpfer-Stationen aus. Wir nahmen 9 Verankerungen auf und legten 8 wieder aus. Es wurden 10 NEMO-Floats ausgesetzt. Die Walbeobachtungsflüge wurden fortgesetzt.

Am 8. Januar 2011 erreichten wir das Schelf der Antarktischen Halbinsel bei Joinville Island. Dort bogen wir nach Süden ab, um vorbei an Paulet und Rosamel Island in den Antarctic Sound zu laufen. Von dort aus ging es in die zentrale Bransfieldstraße, wo der vorwiegend biologische Teil der Reise mit einem Hol mit dem Epibenthosschlitten eröffnet wurde. Am 9. Januar begannen die Arbeiten auf einem Gitter westlich der Antarktischen Halbinsel bei Trinity Island in Richtung der Südshetland-Inseln. Auf 10 parallelen, senkrecht zur Küste ausgerichteten Schnitten erfolgten mit einem Abstand von 20 sm Stationen mit je einem Hol mit dem Rectangular Midwater Trawl (RMT) und einem Profil mit CTD/Wasserschöpfer-System. Zwischen den Südshetland-Inseln vorbei an Deception und Snow Island ging es nach Nordwesten in Richtung hohe See. Nach 160 sm war der nordwestliche Eckpunkt erreicht, wo zusätzlich ein Epibenthos-Schlitten eingesetzt wurde. Etwa 50 sm weiter nach Südwest setzte der landwärts gerichtete Schnitt an, der uns an Smith und Low Island vorbei führte. In der Nacht vom 12. bis 13. Januar erreichten wir das landseitige Ende des zweiten Schnittes bei Hoseason Island und drehten nach Südwesten ab, um den dritten Schnitt zu beginnen. Doch Wind und Seegang hatten dermaßen zugenommen, dass der sichere Einsatz des RMT nicht mehr gegeben war. Als klar wurde, dass mit einer baldigen Wetterbesserung nicht zu rechnen sei, beschlossen wir am 13. Januar, die am Ende der Reise geplanten Stationen in der Gerlache-Straße vorzuziehen, weil dort unter dem Windschutz der Berge die Arbeiten mit dem RMT möglich sein sollten. Wir fuhren zwischen Brabant und Anvers Island in die Gerlache-Straße. Die Annahme des Windschutzes durch die Berge bestätigte sich und im ruhigen Wasser war ungestörtes Arbeiten möglich. Die Sicht war gut genug, um diesen erzwungenen Umweg zu einem landschaftlichen Erlebnis zu machen. Auf dem Weg war ein kurzer Besuch einer kleinen Gruppe mit dem Helikopter bei der chilenischen Station Gabriel Gonzales Videla möglich. Nach Abschluss der Stationen 142 und 143 und Wetterbesserung begann am 14. Januar der dritte Schnitt nach Nordwesten, der am 15. Januar am landfernen Ende mit einem weiteren Hol mit dem Epibenthos-Schlitten abgeschlossen wurde. Am 17. Januar wurde bei Anvers Island der vierte Schnitt abgeschlossen.

Mit Ausnahme des Sturmes am 13. Januar war das Wetter günstig. Es begann mit ruhigem Wetter und Sonnenschein, das bedeutet günstiges Helikopterflugwetter, was die Fortsetzung des Walbeobachtungsprogramms ermöglichte. Die Chemiker konnten nach Low Island zu einer Probennahme fliegen, wo sie 0,25 m^3 Schnee in Behälter abfüllten. Seit dem 14. Januar war es windmäßig wieder ruhig, doch die Sicht wechselt stark. Zeitweise erschwerte dichter Nebel den Weg und Walbeobachtungsflüge konnten nur begrenzt stattfinden. Doch im Ganzen war das Wetter eher günstig und die kräftigen Tiefdruckgebiete blieben weit draußen auf dem Pazifik.

Bis zum 20. Januar wurden die Arbeiten bei gutem Wetter im Krillgitter bis zum Abschluss des sechsten Schnitts fortgesetzt. Schwache Winde und auch häufig Sonnenschein machten die Arbeit leicht. Dann wurden die Arbeiten des Krill-Programms unterbrochen und wir erreichten in der Nacht zum 21. Januar die Marguerite Bay und die britische Station Rothera auf Adelaide Island, wo 140.000 Liter Flugzeugtreibstoff anzuliefern waren. Fahrteilnehmer und Besatzungsmitglieder, die frei gestellt werden konnten, hatten die Gelegenheit mit dem Schlauchboot an Land gebracht zu werden. An der Station wurden wir herzlich wie alte Freunde empfangen. Am Abend lief *Polarstern* wieder aus, nachdem wir unserer Dankbarkeit für den herzlichen Empfang mit einer Abschiedsparty auf dem Arbeitsdeck Ausdruck verliehen hatten. Alles geschah im strahlenden Sonnenschein vor einer märchenhaften Kulisse. Die Ozean-Akustik-Gruppe fand bei Rothera Point die Gelegenheit, am Strand ein Hydrophon im Wasser auszulegen, um die Geräusche von See-Elefanten entfernt vom lärmenden Schiff aufzunehmen. Zwar konnten sie keine See-Elefanten hören, dafür aber eine Vielzahl anderer interessanter Geräusche, wie z.B. das des schmelzenden Eises. Das Walbeobachtungsprogramm wurde auf weiteren Beobachtungslinien senkrecht zur Küsten mit dem Helikopter fortgesetzt.

Am 22. Januar war die Schön-Wetter-Periode vorüber und wir mussten in der Nacht das Krill-Programm unterbrechen, da der Wind und der Seegang zu stark geworden waren, um das RMT-Planktonnetz sicher einzusetzen. Die Arbeiten konnten am 24. Januar wieder aufgenommen werden. Am 27. Januar gelang bei Station 196 ein seltener Fang. Im Beutel des RMTs befand sich mit 334.000 Exemplaren pro 1.000 m^3 befischten Wassers eine extrem hohe Konzentration an Krilllarven. Dies war die zweithöchste Konzentration, die seit 1980 gemessen wurde.

Am 30. Januar wurde der letzte Schnitt des Krill-Gitters abgeschlossen und wir liefen durch die Bismark-Straße zur Gerlache-Straße, wo die letzte Station mit dem Epibenthos-Schlitten stattfinden sollte. Sie musste allerdings aufgegeben werden, da sich der Boden in der Gerlache-Straße als zu rau für das erfolgreiche Schleppen dieses Geräts erwies. Deshalb wurden nur das RMT und das CTD/Wasserschöpfer-System eingesetzt.

Bei der Einfahrt in die Gerlache-Straße passierten wir die Goudier-Insel, auf der eine britische Sommerstation liegt. Die ehemalige Station „Base A“ wurde 1944 im Rahmen der Operation Tabarin errichtet und wird heute vom Antarctic Heritage Trust unterhalten.

Nach der Fahrt durch die Gerlache-Straße gelangten wir in die Drake-Straße. Die Antarktis verließen wir am Dienstag, den 1. Februar um 17:30 LT, als wir 60°S nach Norden überquerten. Danach wurden auf den beiden letzten Stationen in der zentralen Drake-Straße noch zwei weitere Argo-Floats ausgebracht und CTD-Profile zur Sensor-Kalibrierung gefahren. Am 2. Februar um 10:18 LT bei 58°20'S 63°30,4'W wurden die Forschungsarbeiten abgeschlossen. Nach der Fahrt durch den Lemaire-Kanal und die Magellan-Straße erreichten wir am Sonnabend, den 5. Februar 2011 um 8:00 die Mardones Pier in Punta Arenas, Chile, wo die Reise endete.

Wir waren 68 Tage auf See und haben 8.479 sm zurück gelegt. Auf 195 Stationen haben wir 188 CTD/Wasserschöpfer-Profile, 82 RMT-Hols und 6 Epibenthosschlitten-Hols ausgeführt. Es wurden 13 Verankerungen und 6 PIES aufgenommen sowie 13 Verankerungen und 13 PIES ausgebracht. Insgesamt wurden 38 Floats abgesetzt. Die Helikopter waren 176 Stunden im Einsatz. Die Walbeobachtungsgruppe konnte 15.200 km Hubschrauber-Profile abarbeiten. Die En-Route-Messungen chemischer und physikalischer Parameter und die Walbeobachtung vom Schiff aus, visuell und mit dem Thermosensor, vervollständigen den reichhaltigen Datensatz, der uns in den nächsten Monaten und selbst Jahren intensiv beschäftigen wird.

Die Fahrtroute ist in Abbildung 1.1 dargestellt.

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

Im atlantischen Sektor des antarktischen zirkumpolaren Wassergürtels entsteht der größte Teil des Antarktischen Bodenwassers, einer wesentlichen Komponente der globalen Umwälz-Zirkulation. Messungen im Tiefen- und Bodenwasser des Weddellmeers haben gezeigt, dass sich seine Eigenschaften im Zeitraum der letzten 25 Jahre merklich verändert haben. Gegen Ende der 80er Jahre fanden eine Erwärmung und die Salzgehaltszunahme des von Norden einströmenden Zirkumpolaren Tiefenwassers statt. Im weiteren Verlauf wurde die Temperaturzunahme in den tieferen Schichten des Boden- und Tiefenwassers sichtbar und breitete sich bis in das westliche Weddellmeer aus. Anschließend hat das Zirkumpolare Tiefenwasser eine Abkühlungsphase durchlaufen und erwärmt sich inzwischen wieder. Die Daten dieser Reise ergeben, dass sich diese Erwärmung fortgesetzt hat. Im Bodenwasser hält die Erwärmung am Meridian von Greenwich und im zentralen Weddellmeer weiter an, während im westlichen Weddellmeer Anzeichen einer längerfristigen Abkühlung zu erkennen sind. Insgesamt haben sich die Wassermassen am Meridian von Greenwich über die gesamte Wassersäule erwärmt. Der Salzgehalt hat bis 2005 zugenommen und nimmt seitdem im gesamten Bereich wieder ab. Gleichzeitig mit der Erwärmung im Weddellmeer wurde eine Temperaturzunahme in der Tiefe des Einstroms von Zirkumpolaren Tiefenwasser auch weiter nördlich im zirkumpolaren Wassergürtel beobachtet. Im Südatlantik wurde ein Temperaturanstieg im Antarktischen Bodenwasser im Vemakanal gemessen, der darauf hindeutet, dass die Veränderungen in der Antarktis überregionale Auswirkungen haben. Die Erwärmung des Antarktischen Bodenwassers ist inzwischen beckenweit zu erkennen.

Auf dem Weg nach Süden haben wir den Antarktischen Zirkumpolarstrom (ACC) durchquert. Diese gewaltige Meeresströmung bewegt 140 Mio. m^3 Wasser pro Sekunde um die Antarktis herum und stellt damit die Meeresströmung auf der Erde mit dem größten Wassertransport dar. Durch diesen Transport fügt der Antarktische Zirkumpolarstrom die einzelnen Ozeanbecken zu einem globalen System zusammen. Dies ist von Bedeutung, weil im ACC Wärme und gelöste Stoffe, wie z.B. Kohlendioxid, transportiert werden. So kann der Atlantische Ozean vom Wärmeüberschuss des Indischen Ozeans profitieren. Dies führt letztendlich zum warmen Nordatlantik, da diese Wärme aus dem Südlichen Ozean über den Äquator hinweg nach Norden transportiert wird. Auf Grund dieser großräumigen Zusammenhänge sind Transportschwankungen des ACC von großem Interesse und werden mit unterschiedlichen Methoden erfasst. Wir tragen mit unseren PIES dazu bei.

Der weitere Ausbau des HAFOS (Hybrid Antarctic Float Observation System) erfolgte durch die Auslegung von 38 Floats und 9 Schallquellen zur RAFOS-Navigation. Die Floats treiben in 800 oder 1.500 m Tiefe und kommen alle 10 Tage an die Meeres-Oberfläche zurück. Dabei messen sie ein Vertikalprofil von Temperatur und Salzgehalt, das über Satelliten an eine Landstation übermittelt wird. Wenn sie an der Oberfläche sind, wird durch GPS ihre Position bestimmt. Weltweit sind zurzeit etwa 3.250 Floats im Ozean unterwegs und bilden eine wesentliche Komponente des Globalen Ozean-Beobachtungssystems (GOOS). Die Herausforderung an uns ist es, dieses System auch im Eis zu vervollständigen, wo die Floats nicht mehr an die Oberfläche kommen können.

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

Die Wasserproben wurden zur Messung des Gehalts an gelöstem Kohlendioxid (CO_2), anthropogenen und natürlichen Spurenstoffen und an Sauerstoff verwendet. Die Messungen des gelösten CO_2 dienen dazu, die Rolle des Südlichen Ozeans im globalen Kohlenstoffkreislauf zu bestimmen. Darin spielt der Südliche Ozean eine besondere Rolle, da er durch die Aufnahme von CO_2 aus der Atmosphäre als CO_2-Senke zu betrachten ist. Dies erfolgt bei der Zwischen- und Bodenwasserbildung und durch die Primärproduktion des Phytoplanktons. Andererseits aber stellt der Auftrieb von CO_2-reichem Zirkumpolaren Tiefenwasser eine CO_2-Quelle für die Atmosphäre dar. Das Ziel der Chemiker, Physiker und Biologen ist es, dieses Wechselspiel der Prozesse zu quantifizieren, um die Netto-Wirkung zu bestimmen. Die anthropogenen und natürlichen Spurenstoffe erlauben es, den Austausch zwischen Atmosphäre und Ozean und die Ausbreitung der Wassermassen im Ozean zu verfolgen.

Die Messung des im Wasser gelösten Sauerstoffs hatte das Ziel, Aussagen über den Austausch zwischen Atmosphäre und Ozean zu machen. Weiterhin wurden Sensoren erprobt, die Sauerstoffmessungen mit großer Genauigkeit und hoher zeitlicher Stabilität ermöglichen sollen. Dies ist die Voraussetzung, um diese Sensoren unbewacht auf autonomen frei driftenden Floats einsetzen zu können. Auf unserer Reise haben wir 8 Floats mit Sauerstoffsensoren ausgesetzt.

Die Chemiker nahmen Proben zur Messung von “persistent organic pollutants” (POPs), wie polychlorinierte Biphenyle (PCBs) und polybrominierte Diphenylaether (PBDEs), die in der Atmosphäre in abgelegene Gebiete transportiert werden. Es ist das Ziel der Arbeiten, “neue” mögliche POPs (z.B. alternative Entflammungsverzögerer) und verschiedene traditionelle POPs in Bezug auf Transport und Austausch zwischen Atmosphäre und Meerwasser hin zu untersuchen. Dazu erfolgten an Bord Messungen in Luft und Wasser. Die Helikopter wurden genutzt, um auf dem Schelfeis und auf Inseln unberührte Schneeproben zu nehmen, die zur Messung von Schadstoffen verwendet werden sollen.

Im Rahmen des MAPS Projektes wurden quasi-kontinuierlich thermographische Bilddaten erhoben, um Mustererkennungsalgorithmen zur automatisch Detektion von Walen entwickeln zu können. Parallel zur automatischen Erfassung fanden visuelle Beobachtungen statt. Um die Effizienz der Algorithmen bei verschiedenen Umweltbedingungen (Wassertemperatur, Eisbedeckung, Sichtweite) bestimmen zu können, sollen die Autodetektionsdaten mit Walsichtungen des unabhängigen Beobachterteams verglichen werden.

Visuelle Walbeobachtungen wurden auf der Brücke und vom Krähennest ausgeführt und zusätzlich auf einem Gitter mit Hubschrauberflügen, um die Präsenz von Walen und deren Artenverteilung zu erfassen. Dies geschieht nach einem genau festgelegten Verfahren, um die Daten unterschiedlicher Arbeitsgruppen vergleichbar zu machen, und so großräumige Verteilungsmuster erkennen zu können. Besondere Beachtung finden Beobachtung und Dokumentation besonders seltener Tiere oder Ereignisse, wie z.B. eine Gruppe Killerwale, die ein Minke-Wal-Kalb jagen, oder ein Blauwal. Auf unserer Reise wurde nur ein Exemplar dieser selten gewordenen Art gesehen, von der in den dreißiger Jahren noch 30.000 Stück pro Jahr erlegt wurden.

Eine überraschendes Ereignis berichtete die Ozean-Akustik-Gruppe, die bei der Neumayer-Station die akustische Dauerbeobachtungsstation PALAOA mit Hydrophonen unter dem Schelfeis unterhält. Diese Hydrophone zeichnen nicht nur die Geräusche von Walen und Robben auf, sondern auch die von Eisbergen Eisschollen, die zerbrechen oder zusammenstoßen. Die Hochstation war etwa 1,5 km von der Schelfeiskante entfernt. Am 1. Februar erhielten wir von der Neumayer-Station die Nachricht, dass von der Schelfeiskante ein etwa 2.500 m x 800 m großes Stück abgebrochen sei. Nun ist PALAOA nur noch 800 m von der Schelfeiskante entfernt. Weitere Risse im Schelfeis bereiten Grund zur Sorge über die Zukunft von PALAOA.

Die Daten, die während des Krill-Programms gewonnen wurden, werden im Rahmen von CCAMLR (Convention for the Conservation of Antarctic Marine Living Resources) ausgewertet, zu dem das Johann Heinrich von Thünen-Institut einen deutschen Beitrag liefert. Die Ergebnisse der Fänge werden beim Treffen der CCAMLR-Arbeitsgruppe vorgelegt und tragen dazu bei, die Krill-Bestände des Südlichen Ozeans zu überwachen und die Regelung der Krillfischerei zu unterstützen. Die Fänge ergaben eine geringere Krilldichte als im langjährigen Mittel.

Die Untersuchungen zum Erfolg der Eiablage, Überlebensraten und dem Fortpflanzungserfolg sind für die Entwicklung von Vorhersagemodellen zur Entwicklung der Krillbestände von großer Bedeutung. Die Konvention zum Schutz der marinen lebenden Ressourcen der Antarktis wurde 1982 ins Leben gerufen, weil die Sorge bestand, dass die zunehmende Krillfischerei im Südlichen Ozean ernsthafte Auswirkungen auf die Krillbestände und anderes marines Leben, insbesondere auf Vögel, Robben und Fische, die hauptsächlich vom Krill abhängen, haben könnte. Das Ziel der Konvention ist es, das marine Leben im Südlichen Ozean zu schützen.

Biologische Größen wie die Geschlechterverteilung, Altersverteilung und der Reifestatus des Krills werden an jeder Probe bestimmt. Die Verteilung der Krilllarven und der ökologischen Bedingungen werden mit bestimmten Wassermasseneigenschaften in Verbindung gebracht. Auch die Amphipoden-Art *Themisto gaudichaudi* wird untersucht, da sie ein bedeutender Fressfeind des Mesozooplanktons, zu dem der Krill gehört, ist. Salpen (*Salpa thompsoni*) werden mit den Netzfängen gesammelt, um mit Hilfe von DNA-Sequenzierung Geneprofile in Beziehung zur Lebensgeschichte und zu Umweltbedingungen zu setzen.

Die Fänge mit dem Epibenthos-Schlitten hatten das Ziel, die Peracariden-Ordnung Cumacea, sie gehören zu den Krebstieren, zu untersuchen. Die Information über die Cumaceen der Tiefsee werden Ergebnisse der ANDEEP-Expeditionen zur Biodiversität, der Faunenüberlappung verschiedener Tiefseebecken und der Biogeographie dieser Peracariden-Gruppe ergänzen. Eine gewisse Anzahl neuer Arten wird bestimmt und beschrieben werden müssen.

Es hat sich gezeigt, dass Umweltfaktoren wie die anhaltenden Ozean-Versauerung im Zusammenhang mit der sich verändernden atmosphärischen CO_2-Konzentration und saisonale CO_2-Variationen die Struktur und das Wachstum des Phytoplanktons beeinflussen. Um die Phytoplankton-Populationen entlang des Schiffskurses zu charakterisieren, wurden An-Deck-CO_2/Eisen-Störungsexperimente mit natürlichen Phytoplankton-Gemeinschaften ausgeführt. Für die Phytoplankton-Gruppe war dies ein voller Erfolg: Nach 6 Wochen Inkubationszeit wurde ein CO_2-Eisen-Manipulationsexperiment beendet, in dem Artenzusammensetzung, Primärproduktion und Physiologie einer natürlichen Phytoplankton-Gemeinschaft untersucht wurden. Je nachdem, unter welchen Eisenkonzentrationen und CO_2-Bedingungen (vorindustrielles, heutiges oder zukünftiges Szenario) die Algen gewachsen waren, setzten sich in dem Experiment unterschiedliche Phytoplanktonarten durch. Zusätzlich wurde mit hoher räumlicher Auflösung die kleinskalige Verteilung des pCO_2-Wertes im Oberflächenwasser, biologische Sauerstoffsättigung (O_2/Ar) und Dimethylsulfid (DMS) mit Massenspektrometrie bestimmt.

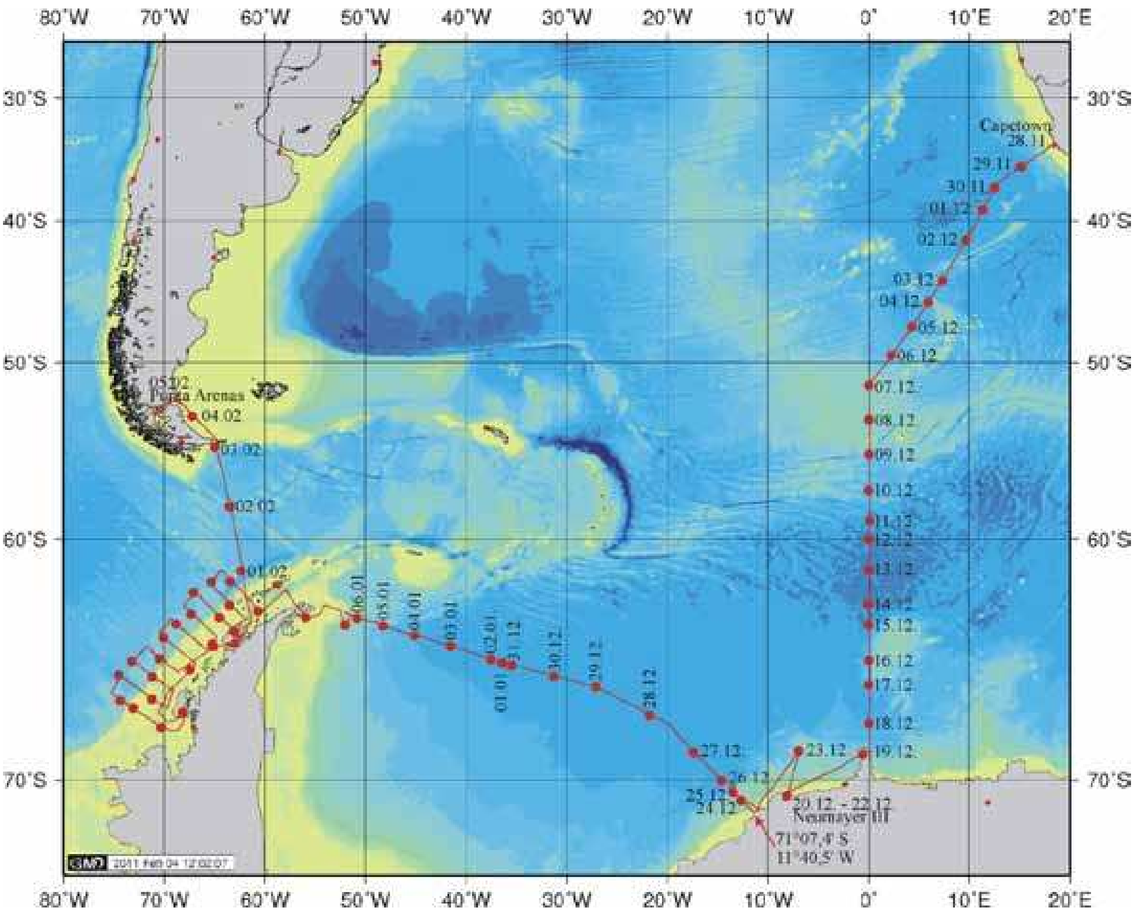

Abb.1.1: Fahrtroute während ANT-XXVII/2 von Kapstadt nach Punta Arenas mit Versorgungsaufenthalten bei der Neumayer und der Rothera Station.

Fig. 1.1: Route of ANT-XXVII/2 from Cape Town towards Punta Arenas with supply at Neumayer and Rothera stations.

SUMMARY AND ITINERARY

R.V. *Polarstern* left on 28 November 2010 at 19:30 LT from Cape Town to the Antarctic. There were 44 crew members and 53 scientific cruise participants on board originating from 12 nations.

First, we headed to Southwest. During the first two days, on 29 and 30 November, the laboratories were set up, instruments unpacked and prepared for operation, instructions on safety and emergency measures were introduced and general directions for life on board were given. The first station for measuring a vertical temperature and salinity profile by means of the CTD probe (Conductivity, Temperature, Depth) started on 30 November at 1.55 UTC. After a calm start of the cruise, the wind had increased and the bright weather had come to an end. The bad weather (poor visibility and white caps) hindered the marine mammal observation programme.

Our course followed a line of moored Pressure Inverted Echo Sounders (PIES) which measure the pressure at the sea bottom and the transit time of a sound signal from the instrument to the sea surface and back. The data are used to derive the water transport and the vertical mean temperature of the Antarctic Circumpolar Current over many years. The instruments were deployed on the sea floor and after the end of the recording period would return on an acoustic command to the surface, where they will be picked up from the ship and deliver the data, which they have recorded. The first two PIES were lost. Problems occurred during the deployment of the second PIES, which returned back to the surface right after reaching the seafloor.

At 46°01'S 5°51'E we met the first strongly weathered iceberg on 4 December. On 7 December we reached at 51°25'S the Greenwich meridian. From then on, our course went along the Greenwich meridian towards the Antarctic continent.

Temperature, salinity, and ocean currents were measured en route. Along the track line floats were deployed and moorings with bottom pressure sensors with inverted echo sounders (PIES) were exchanged. The backbone of the programme were measurements with a CTD probe and water samples which were taken to determine the concentration of dissolved nutrients, oxygen, trace substances, CO_2 parameters, biological properties as well as to obtain water for experiments. An essential part of the work consisted in the recovery and redeployment of moorings. They contain current meters, temperature and conductivity sensors, and sound sources to locate floats, sound recorders and upward looking sonars (ULS) to measure the sea ice thickness. NEMO (Navigating European Marine Observer) and APEX floats were deployed.

During the night from 9 to 10 December we met the first scattered remnants of decayed sea ice fields. During the following day, they became more frequent. Closed fields showed up during the afternoon simultaneously with the first snow. From then on, we crossed open ice fields, which kept off the waves, but did not hamper our progress to the south. However, since it was the time of the most rapid seasonal decay of the winter ice cover the ice conditions changed fast.

On 11 December we reached the first mooring in the current system of Weddell gyre. But mooring AWI-227 did not release in spite that it could be located with Posidonia. According to later observations of imploded floats in moorings which were deeper than 4,000 m, we assume that this was the reason of the complete loss here. Bad visibility and white caps further restricted the visual mammal observing programme. On 12 December in the afternoon we crossed 60°S and from then on were formally in Antarctica.

On our way we had to cross a broad belt of sea ice located between 59° and 65°S. However, the ice consisted mostly in open fields of ice floes which did not really present any obstacle to us, but in contrast were advantageous because they damped the swell and provided a very calm ship in spite of significant winds. In this ice belt the sea ice group started observations and was deposited by the helicopter on the ice. Then, they were able to drill ice cores to determine the air content of the ice. Due to the help of the helicopters this was possible during CTD stations, when the oceanographers measured vertical profiles of water mass properties.

Sea ice presented a particular challenge when to recover moorings. Moorings are autonomous systems, which remain in the ocean for several years to measure a variety of oceanographic properties at a distinct location with high temporal resolution. A mooring consists of the ground weight, a wire, and floats which keep the wire upright in the water column. On the wire instruments are fixed to measure e.g. temperature, salinity current speed and direction, sea ice thickness and underwater sound. All data are recorded internally. After the end of the observation period, the wire is released from the ground weight by means of an acoustic signal from *Polarstern's* Posidonia system and the floats tow the wire with the instruments to the surface. This ascend can be surveyed by the Posidonia system. At the sea surface a satellite transmitter is activated. If we do not spot the mooring with our eyes, the satellite signals help us to detect it. In the ice, either we were lucky and the floats found their way through the floes up to the surface or we had to locate them by acoustic means under the ice and break them free. The ship had to approach the mooring very carefully in order not to crash them between the floes. The last few meters were made using the mammy chair, from which the connection to the ship was achieved by a rope. With very small moorings the chance to find them in the ice is small. Therefore we did not release the mooring MARU 2. However, in open water normally no problems occurred. However, if there was fog which was occasionally the case since we had left the ice, even recovery in open water could be a challenge. Furthermore, with strong winds a great demand on skills was required from the ship's officers to bring the ship very smoothly to the mooring without damaging it.

On the Greenwich meridian, the CTD/water sampler was operated with a station distance of 30 nm. A large and particularly iron free water volume was sampled from the phytoplankton group with a fish which was towed for several hours in a safe distance from the ship to avoid contamination. The water was used for experiments on board which aimed to investigate the influence of the changing CO_2 content of the atmosphere on phytoplankton grows.

During the journey to 51°S and along the Greenwich meridian we obtained 46 stations with the CTD/water sampler. We recovered 7 moorings and 6 PIES and deployed 5 moorings and 13 PIES. We launched 25 NEMO and APEX floats.

Early in the morning of the 20 December we arrived in front of Atka Bight. The ice conditions were favourable and in consequence we could easily find a berth on the northern landing position at the front of the Ekström Ice Shelf. The station team arrived with the Pisten Bullies at the ice shelf front. Finally we found a good location with a height of the ice front of 11 m where *Polarstern* stayed until 22 December evening by means of her thrusters. The unloading of containers began and the fuel pipe was carried on the ice. When the fuel containers had arrived 280.000 l Arctic Diesel and 27.000 l kerosine were pumped onshore. The unloading of 120 t of material and the loading of 50 tons proceeded fast.

The helicopters were active to take snow samples to measure chemical substances far enough from the ship not to be influenced by nearby human activity. The marine mammal observation programme was continued. The acoustic oceanography group was taken to the station to continue from there with skidoos to the PALAOA site on the ice shelf. Whenever visibility allowed, flights were done to the Neumayer-III Station.

One of the scientific cruise participants had to leave us because the person had fallen seriously ill and was not able to continue the cruise. Thanks to the DROMLAN flight network the patient could be flown from Neumayer station via Novolazarevskaya to Cape Town within one night and taken to hospital from where the patient returned to Germany.

On 21 December the South African supply and research vessel *S.A. Agulhas* arrived at the ice shelf edge in a distance of 1.5 nm to *Polarstern*. When the supply work had been achieved, the visit of *Polarstern* was terminated with a farewell party on the ice. At the boundary of the sea ice belt in front of the ice shelf *S.A. Agulhas* carried out oceanographic station work. When passing by both ships greeted each other by blowing their horns. Still in Atka Bight *Polarstern* resumed station work with a CTD station.

After having finished the supply works, we turned north to recover and redeploy mooring AWI-244 and then steamed to the southernmost point of our cruise into the Weddell Sea at 71°06.5' S 11°27'W near Kapp Norvegia. From there we started to work along a transect towards the Antarctic Peninsula. On Christmas Eve, we interrupted station work to enjoy a nice Christmas ceremony.

We met only a few open ice fields on our way and were mostly in open water until we met two ice belts reaching out of the southern Weddell Sea to the Northeast. One from 14° to 23°W and the second from 37° to 42°W. However, the ice extended further to the west as expected. On 3 January 2011 we reached the ice edge at 42°W. With the ice the sunny weather had came to an end. Winds remained weak, but warm air from the north implied poor visibility and sometimes even dense fog. Gradually the rain changed to snowfall. By 7 January, winds increased gradually, however calming down completely when under the shelter of land near the Antarctic Peninsula.

By leaving the sea ice belt, the sampling on ice floes came to an end. As a consequence the sea ice group was busy to analyze the cores which they had drilled by help of the helicopters. They determined the air content of the ice which was a particular challenge, because up to now, there is no established technique available and in consequence had to be developed.

The work on the Weddell Sea section proceeded fast because of mainly calm weather with only open ice fields to cross. The station distance in the central Weddell Sea ranged from 40 to 50 nm. In the Weddell Sea proper, we achieved 56 CTD/water sampler stations. We recovered 9 moorings and deployed 8 new ones. We launched 10 NEMO floats. The helicopter flights for whale observations were continued.

On 8 January 2011, after reaching the shelf of the Antarctic Peninsula near Joinville Island, we turned south and passed by Paulet and Rosamel Island to enter the Antarctic Sound. From there, we steamed to the central Bransfield Strait, where the mainly biological part of our cruise began with a haul with the epibenthos sledge. On 9 January, we started the station grid west of the Antarctic Peninsula near Trinity Island in direction towards the South Shetland Islands. On 10 parallel sections perpendicular to the coast hauls with the Rectangular Midwater Trawl (RMT) and casts with CTD/ water sampler occurred at stations of 20 nm distance. Starting between the South Shetland Islands passing by Deception and Snow Island the track went northwest towards the open ocean. After 160 nm the northwesterly corner was reached, where the epibenthos sledge was deployed in addition to the standard station. About 50 nm further to southwest the next section directed towards land began on which we passed Smith and Low Island. In the night from 12 to 13 January we reached the landside end of the section near Hoseason Island and turned to southwest to begin the third section. However, during the 13 January wind and waves had increased to a point that the safe deployment of the RMT was not possible any more. As it became obvious that a fast improvement of the weather could not be expected, we decided to do stations in the Gerlache Strait which were planned to be done later during the cruise. It was hoped that - protected by the mountains - the use of the RMT should be possible. We entered the Gerlache Strait between Brabant and Anvers Island. The assumption to be protected from the wind by the mountains was confirmed and work could be continued. The visibility was sufficient to transform this detour into a delightful event. In the Gerlache Strait we proceeded to the northeast to carry out a second station. On the way, a short visit with the helicopter to the Chilean station Gabriel Gonzales Videla was possible.

After having completed stations 142 and 143, the weather improved and we left the Gerlache Strait and started on 14 January the third section from Anvers Island to the northwest. On the 15 January we reached the off shore end of the section where we again deployed the epibenthos sledge. From there, we went for the fourth section which we terminated again in sight of Anvers Island on 17 January.

With the exception of the one storm on 13 January we were spoiled by the weather in this area. When we arrived we were received with calm weather and sunshine. We had optimal conditions for the helicopter flights which was not only of advantage for the whale observers but as well for the chemists who could fly to Low Island and collect 0.25 m^3 of snow for later analysis. After the 13 January it was windy wise calm again however the visibility changed significantly. At times dense fog slowed down our progress and whale observation flights could not occur. Over all the weather was more favorable as expected, however, and the intense low pressure systems were only far off in the Pacific.

Until 20 January the sixth section on the krill grid was completed. Week winds and frequent sun shine made work easy. Then we interrupted the krill survey and reached Marguerite Bay and the British Rothera Station on Adelaide Island in the night to 21 January to where we had to take aviation fuel. During the day *Polarstern* had to stay with the bow towards the wharf, because she has too much draught to go alongside. A pipe was laid by which 140,000 litres of kerosine were pumped on shore. Depending on their work schedule cruise participants and crew had the possibility to get onshore by boat. At the station we were received warm-heartedly like old friends. In the evening we left again after a joyful farewell party on deck to express our gratitude for the kind hospitality granted.

On the island the air chemists used the helicopter to collect snow samples to measure pollutants. The whale observation programme was continued on further survey lines with the helicopters. The marine acoustics group used the occasion to dip a hydrophone into the water away from the noisy ship to observe marine mammal vocalizations. They could not obtain a record from the elephant seal for which they set off, but many other noises as for example from melting ice.

On 22 January the period of good weather had come to an end and we had to cope with less favourable conditions. We had to interrupt the krill programme because there were too much wind and waves to operate the RMT. On 24 January the wind and swell had calmed down and station work was continued.

On 27 January a rare catch occurred at station 196 when in the cod-end of the RMT an extreme high concentration of krill larvae of 334,000 individuals per 1,000 m^3 of filtered water was found. This was the second highest concentration which was observed since 1980.

The krill grid was finalized after 10 sections on 30 January. We steamed through Bismark Strait towards Gerlache Strait where the last station with the epibenthos sledge should occur. But it had to be cancelled because the bottom topography was too rough. Therefore only the RMT and the CTD/water sampler system were applied.

At the entrance into the Gerlache Strait we passed by the Goudier Island on which a British summer station is located. It is the former “Base A“ which was established in 1944 in the context of the Operation Tabarin and is maintained today by the Antarctic Heritage Trust. Again, we experienced an extreme friendly reception.

After steaming through Gerlache Strait, we crossed Drake Passage. We left the Antarctic on 1 February at 17:30 LT, when we crossed 60°S towards the north. Then, we did the two last stations 205 and 206 with launching two Argo floats and run two CTD profiles for sensor calibration. Research was finished on 2 February on 10:18 LT at 58°20’S 63°30.4‘W. After steaming through the Lemaire Strait and Magellan Strait we reached the Mardones Pier in Punta Arenas, Chile, on Saturday, 5 February 2011 at 8:00, where the cruise ended.

We had been at sea for 68 days and made 8,479 nm. At 195 stations we achieved 188 CTD/water sampling profiles, 82 hauls with the RMT and 6 with the epibenthos sledge. We recovered 13 moorings and deployed 13 new ones. We launched 38 floats. The helicopters operated 176 hours. The whale observers could monitor over a distance of about 15,200 km. The en-route measurements of chemical and physical parameters and the whale observations from the ship, visual or with the thermal sensor completed the abundant data set which will keep us busy for the next months and even years.

The cruise track is displayed in Figure 1.1.

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

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

On our way south we had crossed the Antarctic Circumpolar Current (ACC). This gigantic ocean current moves 140 Mio m^3 water per second around Antarctica and is the ocean current with the largest water transport on earth. By its transport, the ACC forms out of individual ocean basins one global system. This is of importance since the ACC transports heat and dissolved substances, such as carbon dioxide. By that means the Atlantic Ocean can profit from the heat collected in the Indian Ocean. This leads to the relative heat excess of the North Atlantic since the heat is transported across the equator from the Southern Ocean to the north. For this reason it makes sense to measure the transport fluctuations of the ACC in order to understand the global climate system. We contribute to these measurements with our PIESs.

In the context of the HAFOS (Hybrid Antarctic Float Observation System) we had deployed 38 Argo floats and 8 sound sources for RAFOS navigation during the cruise. The floats drift in 800 or 1,500 m depths and return every 10 days to the sea surface. On the way, they measure vertical profiles of temperature and salinity. The data is transmitted via satellite to land. When they are at the surface, their position is determined by GPS. At present worldwide about 3,250 floats are active and form the major component of the Global Ocean Observing System (GOOS). It is our challenge to extend the system into the sea ice areas where the floats are not able to reach the surface any more.

The water samples were used to measure the content of dissolved carbon dioxide (CO_2), anthropogenic and natural trace substances, oxygen and biological properties. The measurements of dissolved CO_2 are used to determine the role of the Southern Ocean in the global carbon cycle. The Southern Ocean is of particular interest. Due to the uptake of CO_2 from the atmosphere during intermediate and bottom water formation as well as by primary production of phytoplankton, the Southern Ocean acts as a CO_2 sink for the atmosphere. On the other hand, the upwelling of CO_2 rich Circumpolar Deep Water presents a CO_2 source for the atmosphere. It is the aim of the chemists, physicists, and biologists to quantify the interaction of these processes in order to estimate the net result. The anthropogenic and natural trace substances provide the possibility to estimate the exchanges between atmosphere and ocean and to follow the spreading of the water masses within the ocean.

Oxygen concentrations were measured in order to draw conclusions on atmosphere-ocean exchange and to develop, test, and improve sensors, to measure oxygen with high accuracy and long term stability. This is the precondition to use these sensors uncontrolled on autonomous freely drifting floats. On our cruise, we deployed 8 of such floats which were equipped with oxygen sensors.

The chemists study persistent organic pollutants (POPs), such as polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs) which are being transported in the atmosphere into remote areas. The aim of the project is to determine “new” possible POPs (e.g. alternative flame retardants) and several legacy POPs with respect to their transport and exchange between the atmosphere and seawater.

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

The visual marine mammal observations were carried out by helicopter flights along a well defined grid to determine the presence and the species distribution. The observations followed a clearly defined protocol, to assure that data from different groups are compatible and large scale pattern can be derived. There was particular excitement, when very rare species or special events were observed, e.g. when a group of killer whales was chasing an Antarctic minke whale calf or a blue whale was encountered. During this cruise, only one specimen of this rare species was detected. In the thirties of last century 30,000 of them were hunted in one season.

A great surprise was offered by the ocean acoustics group which maintains the permanent PALAOA observatory with hydrophones under the ice shelf. Those hydrophones do not only record noises from marine mammals, but as well from icebergs or ice floes which break and collide. The acoustic station was located in a distance of about 1.5 km from the ice shelf front. On 1 February we were informed by the staff of the Neumayer station that a piece of 2,500 m x 800 m broke off the ice shelf four days ago. Now, PALAOA has only a distance of about 800 m from the shelf ice front. Further cracks in the ice shelf raise concern on the future of PALAOA.

The data obtained during the krill survey will be analyzed in the context of the CCAMLR (Convention for the Conservation of Antarctic Marine Living Resources) to which the Johann Heinrich von Thünen-Institut provides a German contribution. The results of the catches will be submitted to the CCAMLR working group meetings to support the monitoring of the krill stocks in the Southern Ocean and the management of the krill fishery. The observed krill density was smaller than the long term average.

Studies on the spawning success, survival rates and recruitment success are essential to develop prediction models for the development of the krill stocks. The Convention on the Conservation of Antarctic Marine Living Resources came into force in 1982, as part of the Antarctic Treaty System. It was established mainly in response to concerns that an increase in krill catches in the Southern Ocean could have a serious impact on populations of krill and other marine life; particularly on birds, seals and fish, which mainly depend on krill for food. The aim of the Convention is to conserve marine life of the Southern Ocean.

Biological parameters such as sex ratio, age composition and maturity stage development of the krill were determined from each sample. The krill larvae distribution and ecology were correlated with particular water masses properties. The amphipod *Themisto gaudichaudi* was studied as an important mesozooplankton predator. Salps (*Salpa thompsoni*) were collected from the catches to carry out transcriptome analysis by whole-genome RNA sequencing to characterize gene expression profiles in relation to life history processes and environmental conditions.

The catches with the epibenthos sledge were aimed at the study of the pericardia order Cumacea (Crustacea). The information about the cumaceans from the deep sea completes the results from the ANDEEP expeditions about the biodiversity, faunal overlap and biogeography of this peracaridean group. A number of new species will have to be identified and described.

Environmental factors like changing atmospheric CO_2 concentrations and the ongoing ocean acidification as well as to seasonal changes in CO_2 were found to also exert control on both phytoplankton structure and growth. To characterize phytoplankton populations along the cruise track on-deck CO_2/iron perturbation experiments with natural phytoplankton communities were performed. After 6 weeks of incubation time it was possible to finalize a CO_2-iron-manipulation experiment in which species composition, primary production and physiology of natural phytoplankton communities under different CO_2 conditions (preindustrial, today's values or future scenarios) and iron concentrations were investigated. Depending on the CO_2 and iron conditions, different phytoplankton species were able to dominate the community. These preliminary findings hint to other interesting results of the samples yet to analyze. The goal of further biochemical work was to map, with high spatial resolution, the fine-scale distribution of surface water pCO_2, biological oxygen saturation (O_2/Ar) and dimethylsulfide (DMS) using ship-board mass spectrometry.

2. WEATHER CONDITIONS

Klaus Buldt, Manfred Gebauer
Deutscher Wetterdienst

Polarstern left Cape Town south-westwards in order to reach the Greenwich meridian. From here the ship steamed southwards towards the German Antarctic Station Neumayer III. During this time the average temperature decreased from values near 16 °C below freezing point (Fig 2.1) according to latitude. The high pressure influence decreased and the first troughs of the frontal atmospheric area reached us south of 40°S. It lasted up to 60°S. At the northern edge of cyclones passing through intermediately stormy westerly winds started to influence us. For the most part of the time the wind blew from westerly directions with average wind force 5 to 6 (Fig. 2.3, 2.4).

On 3 December the following weather was typical for the weather in the latitude band between 40° and 60°S. The trough of a gale low approached from the west. Deepening it moved eastwards on 50°S (Fig. 2.5). In front of the warm front the wind shifted to north and increased up to 7 Bft, and the visibility deteriorated rapidly. The cold front followed very fast accompanied by some rain. Afterwards there blew a stormy westerly wind with 8 Bft and showers, but otherwise good visibility. At the rear of the low the following ridge of high pressure turned the wind direction to southwest (wind direction i.e. direction, from where the wind blows). Finally the wind calmed down and shifted to northwest.

Further gale lows followed and predominantly it was cloudy (Fig. 2.2). Neumayer Station was reached on 20 December accompanied by calm weather, although frequent patches of fog complicated the working process.

Leaving Neumayer Station the second part of the cruise through the Weddell Sea started aiming for the northern point of the Antarctic Peninsula. Large areas were crossed in partly dense, partly loosed ice fields. We were not affected by intensive gale lows, only mostly secondary lows passed the ship as it was on the 3 January (Fig. 2.6). In front of the low the wind shifted to northerly directions, at the rear to southerly directions. But mostly the centre of the low was far in the north, easterly directions dominated, as the distribution of wind directions indicate (Fig. 2.7). The average wind force was 5 to 6 Bft (Fig. 2.8), but due to the ice fields waves could not develop significantly high. Despite the absence of intensive cyclones it was mostly cloudy with a high amount of quite low clouds, also fog, which was caused by low temperatures, thus the dew point was quickly reached inducing condensation (Fig. 2.10). Temperatures of -3 °C around the Atka Bay rose to freezing point in the area of Antarctic Sound (Fig. 2.9). At the end of temporary high pressure influence some lows passed through north of the Antarctic Peninsula. They made flight conditions worse. The Antarctic Sound was reached after passing some fog patches on 8 January 2011.

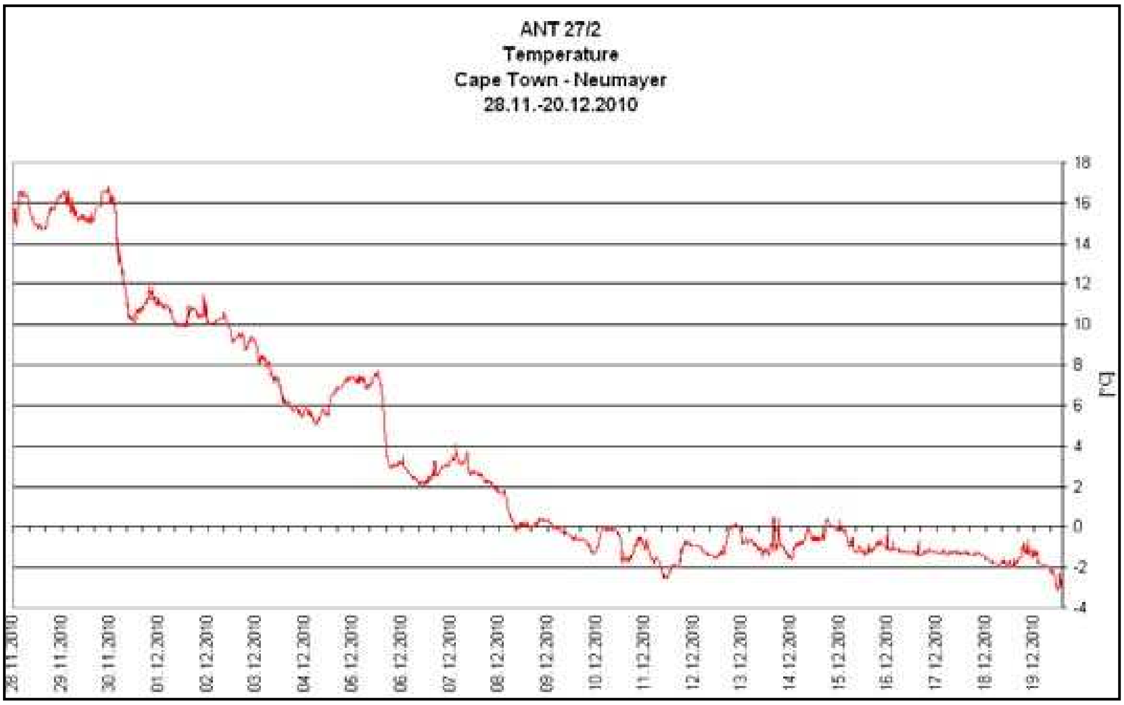

Fig. 2.1: Distribution of air temperature from Cape Town to Neumayer Station

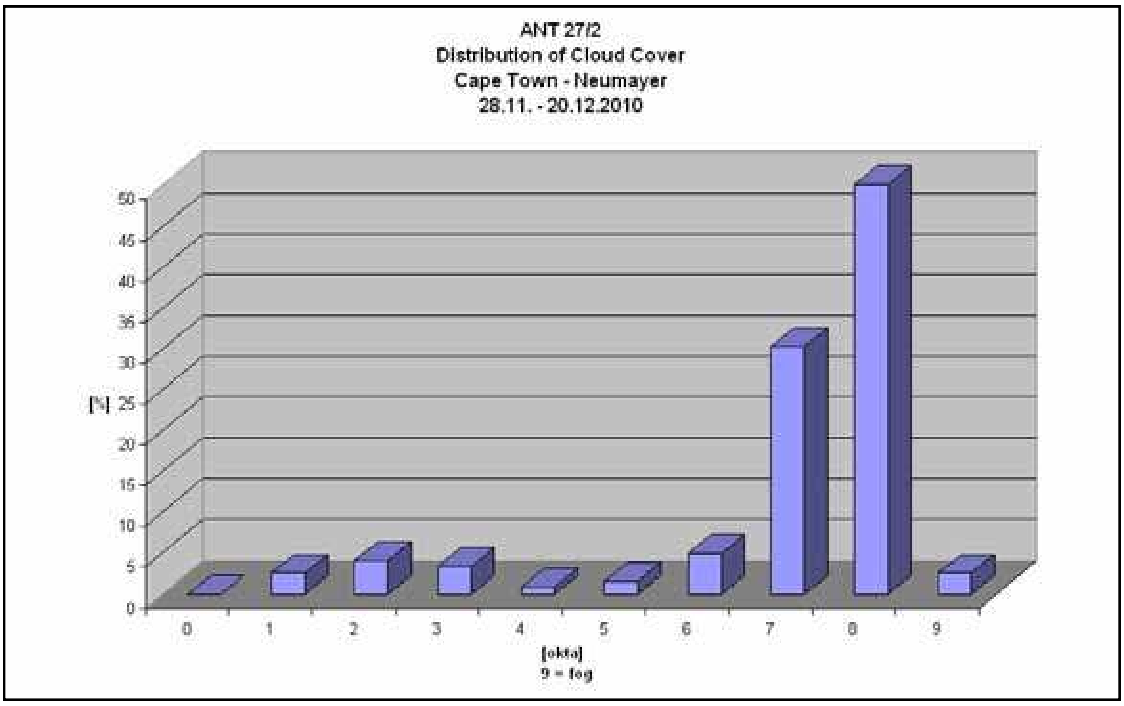

Fig. 2.2: Distribution of cloud cover from Cape Town to Neumayer Station

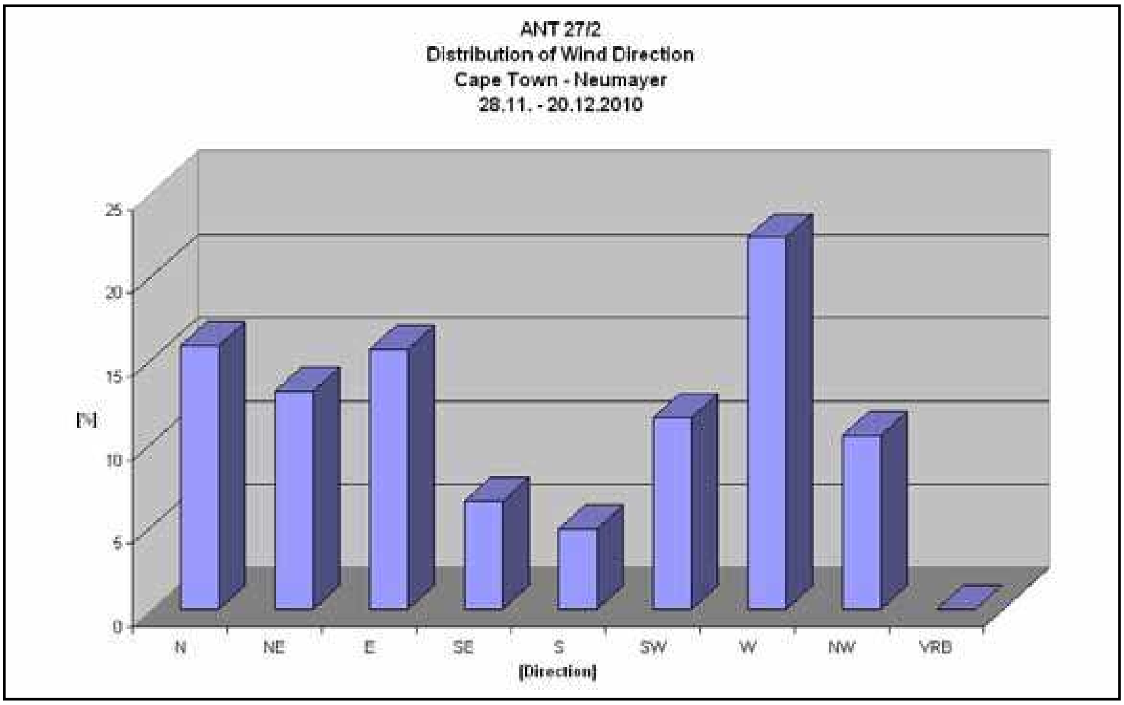

Fig. 2.3: Wind direction from Cape Town to Neumayer Station

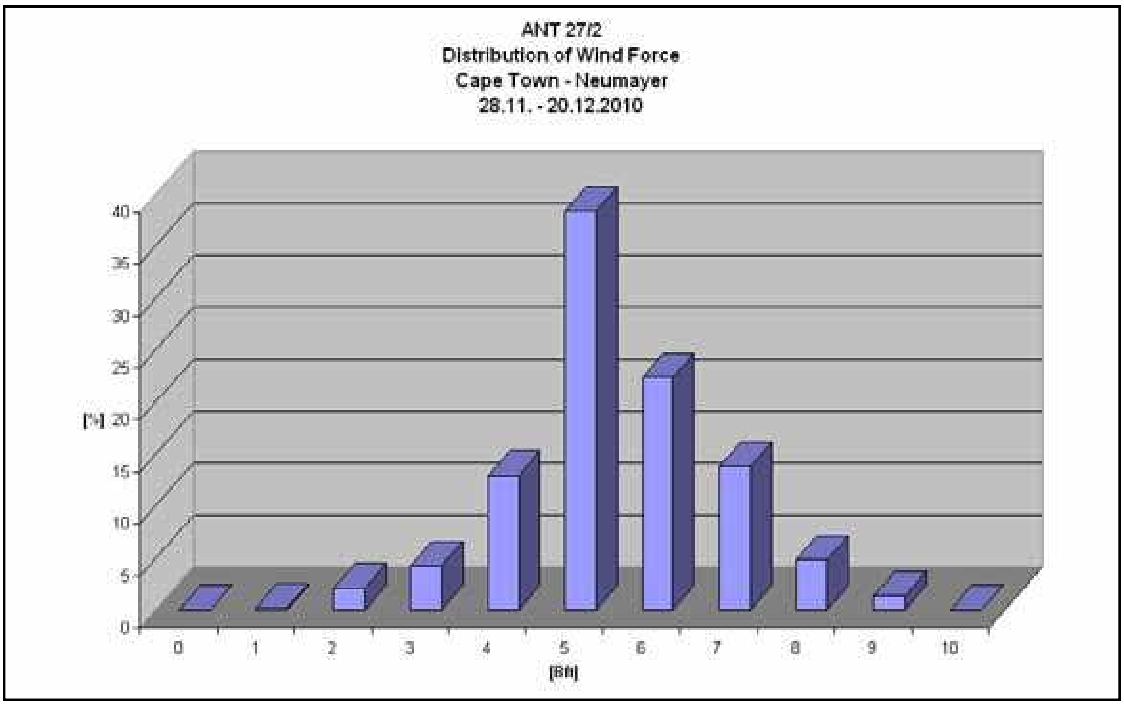

Fig. 2.4: Wind force from Cape Town to Neumayer Station

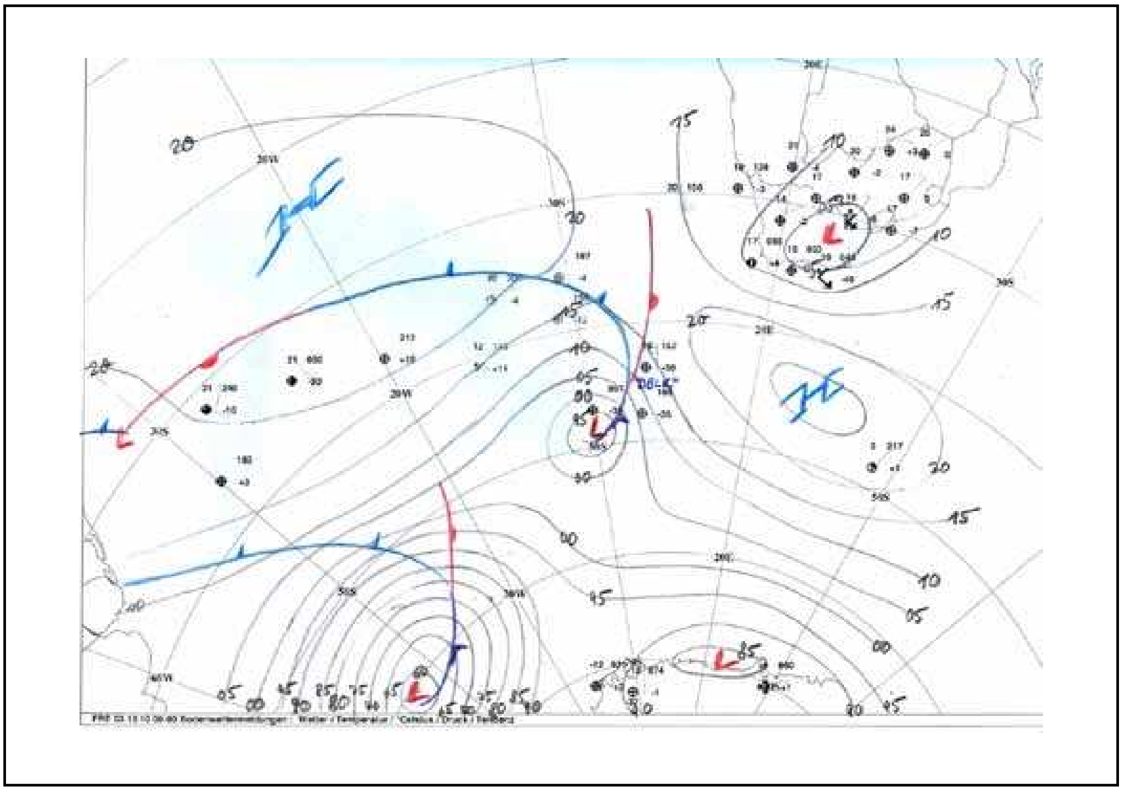

Fig. 2.5: A typical weather situation during the transect from Cape Town to Neumayer Station

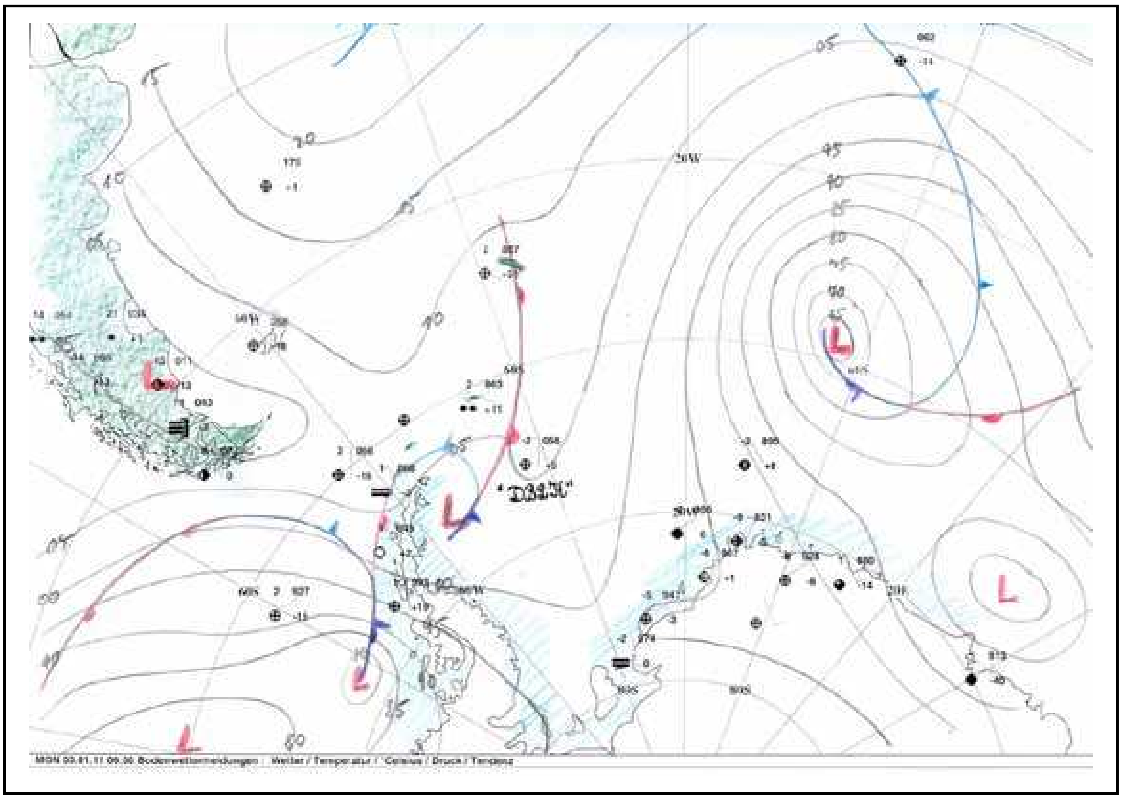

Fig. 2.6: A typical weather situation during the transect in the Weddell Sea

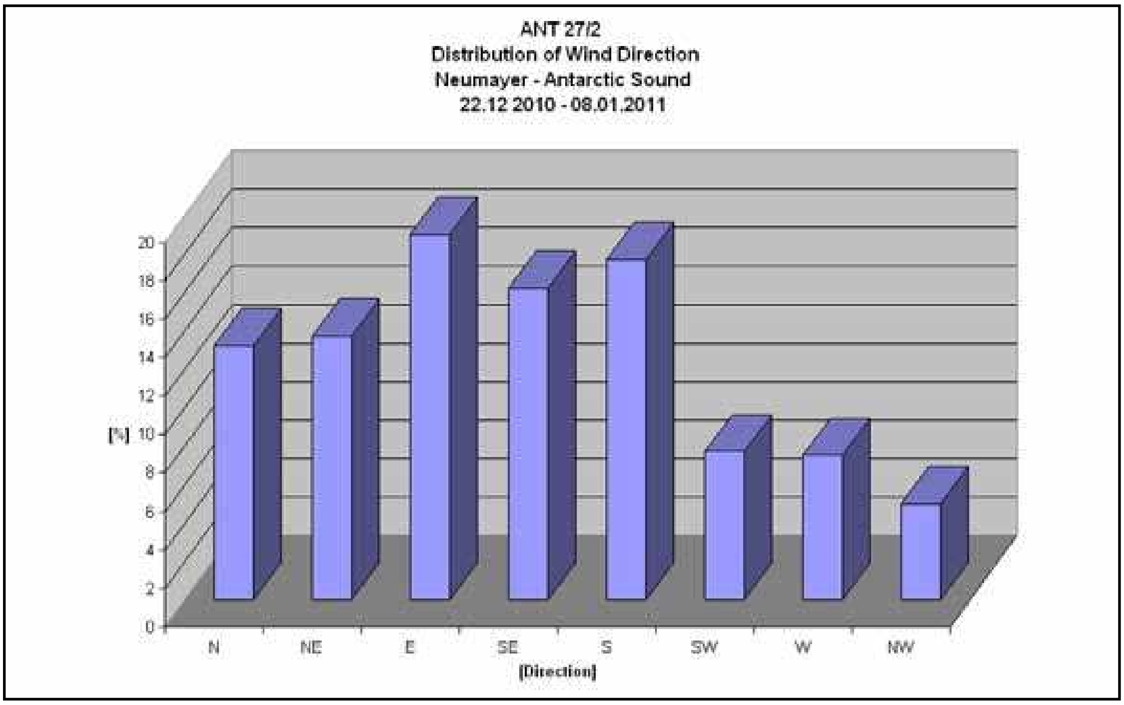

Fig. 2.7: Wind direction in the Weddell Sea

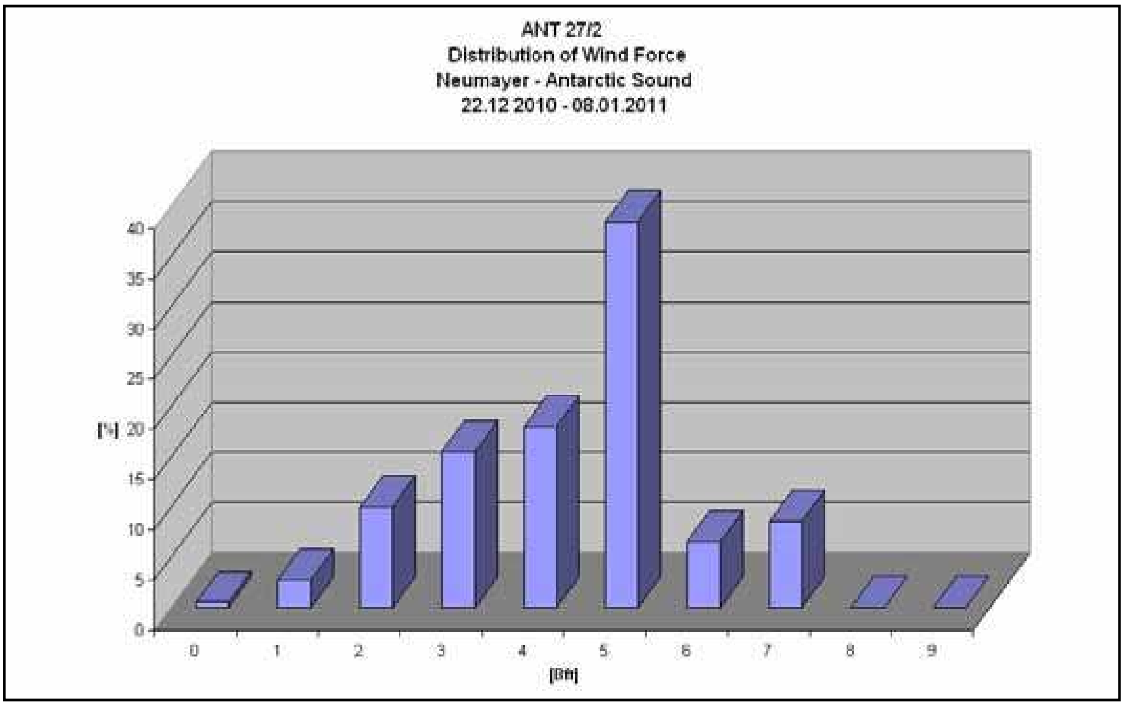

Fig. 2.8: Wind force in the Weddell Sea

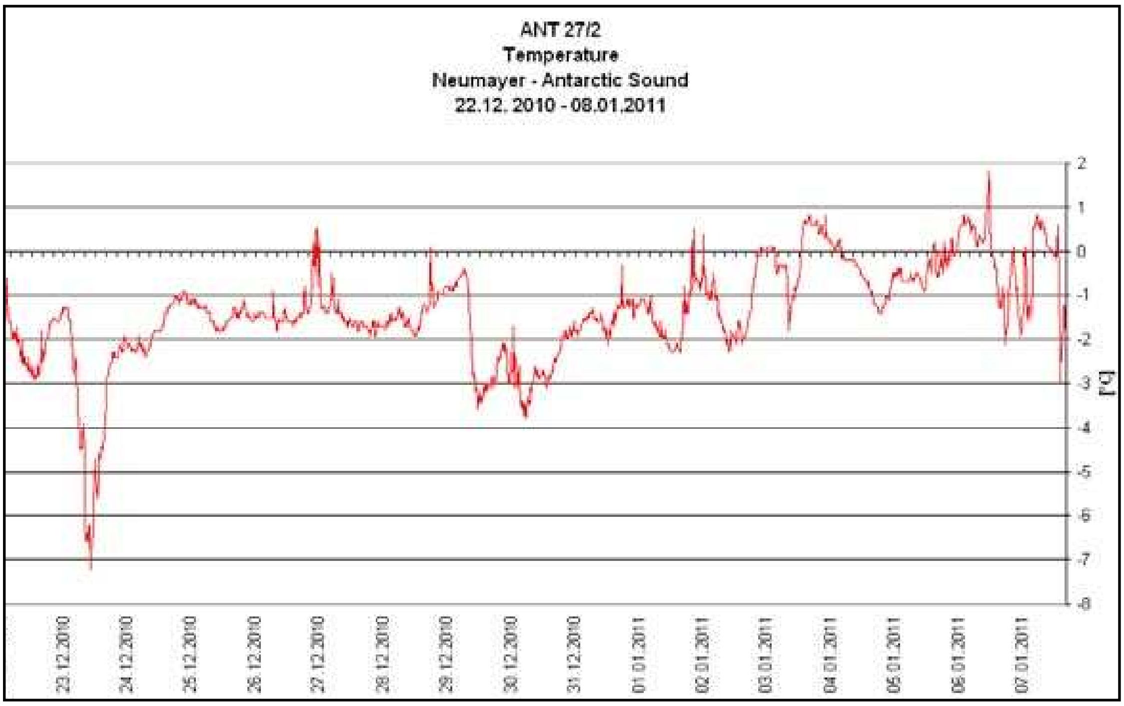

Fig. 2.9: Distribution of air temperature in the Weddell Sea

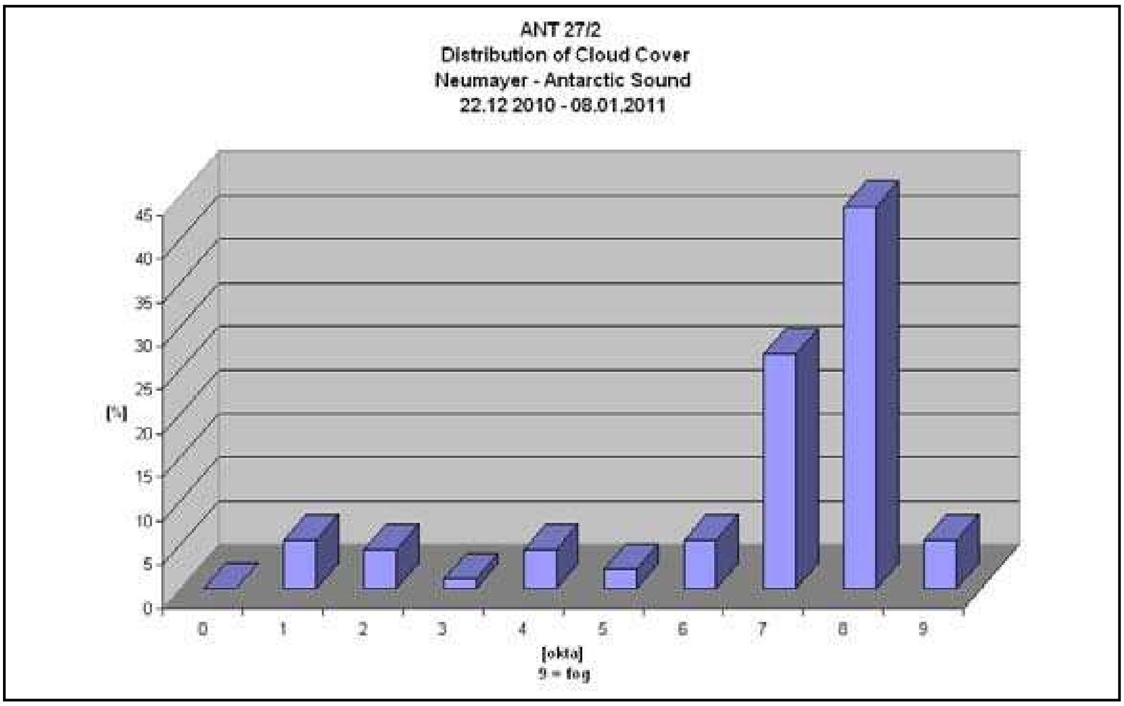

Fig. 2.10: Distribution of cloud cover in the Weddell Sea

From that time on work was done west of the Antarctic Peninsula as the third part of the cruise. During the 12 January a gale low moved to the north-western part of the

Antarctic Peninsula. A stormy north-easterly wind developed. Temporary the work was continued in Gerlache Strait, until the low weakened. Rothera Station was reached on the 21 January and left in the evening. From west a very strong and extensive gale low approached along 60°S latitude. When its warm front reached the ship, the wind blew with 8 to 9 Bft from northeast during the night on the 23 January (Fig. 2.11). Soon the visibility deteriorated and the wave height reached more than 4 m due to the long fetch along the west coast of the Antarctic Peninsula. Slowly this low moved on to east and waves and swell heights decreased, and the visibility improved. The following ridge of high pressure induced a southerly fresh wind. Atmospheric instability and an upper trough induced some snow showers, otherwise the visibility was good. Then weather conditions were fairly good during the work west of the Antarctic Peninsula, except when Gerlache Strait was passed. Finally the ship was heading for the Drake Passage and the ship was influenced by strong north-westerly and westerly winds, sometimes with gale wind force.

The average wind force during the time west of the Antarctic Peninsula and the way to Punta Arenas was 5 to 6 Bft (Fig. 2.13), the prevailing wind directions were northeast to east (Fig. 2.12), the accompanying temperatures were mostly between freezing point and 1 °C (Fig. 2.14). Very often it was cloudy due to cyclonal activity with some intermediate spots of sunshine (Fig. 2.15).

Punta Arenas was reached on the 5 February 2011.

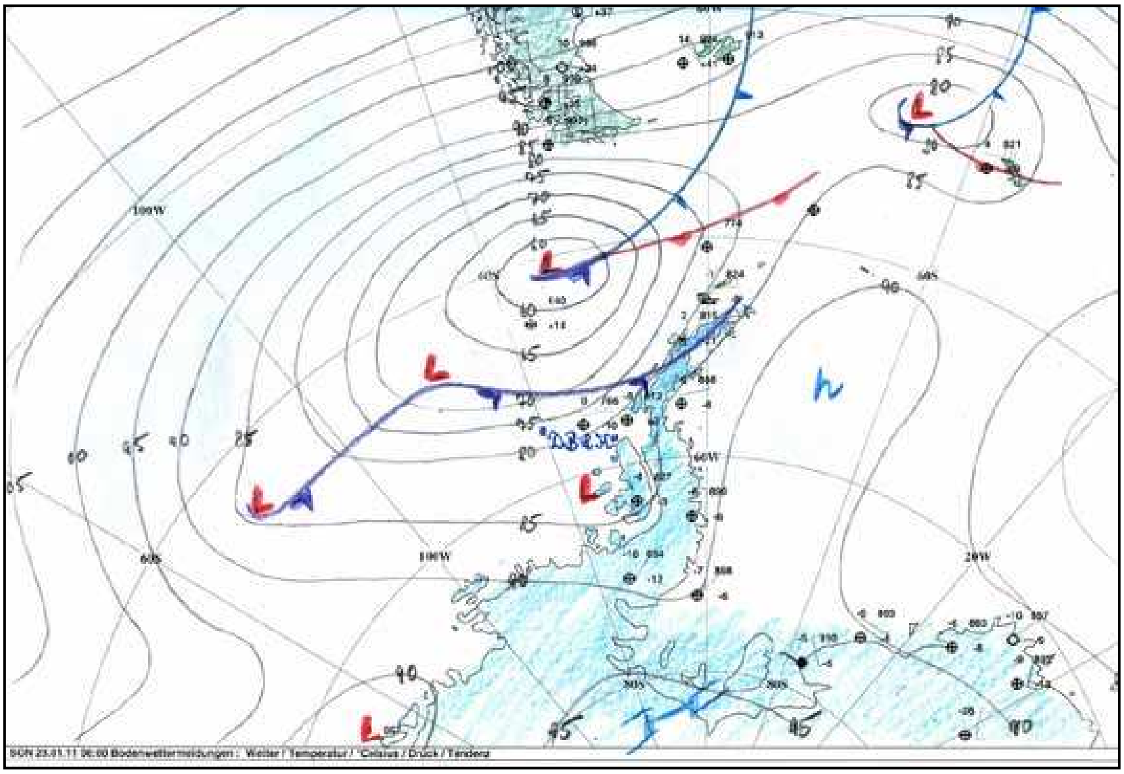

Fig. 2.11: A typical weather situation during the krill survey west of the Antarctic Peninsula

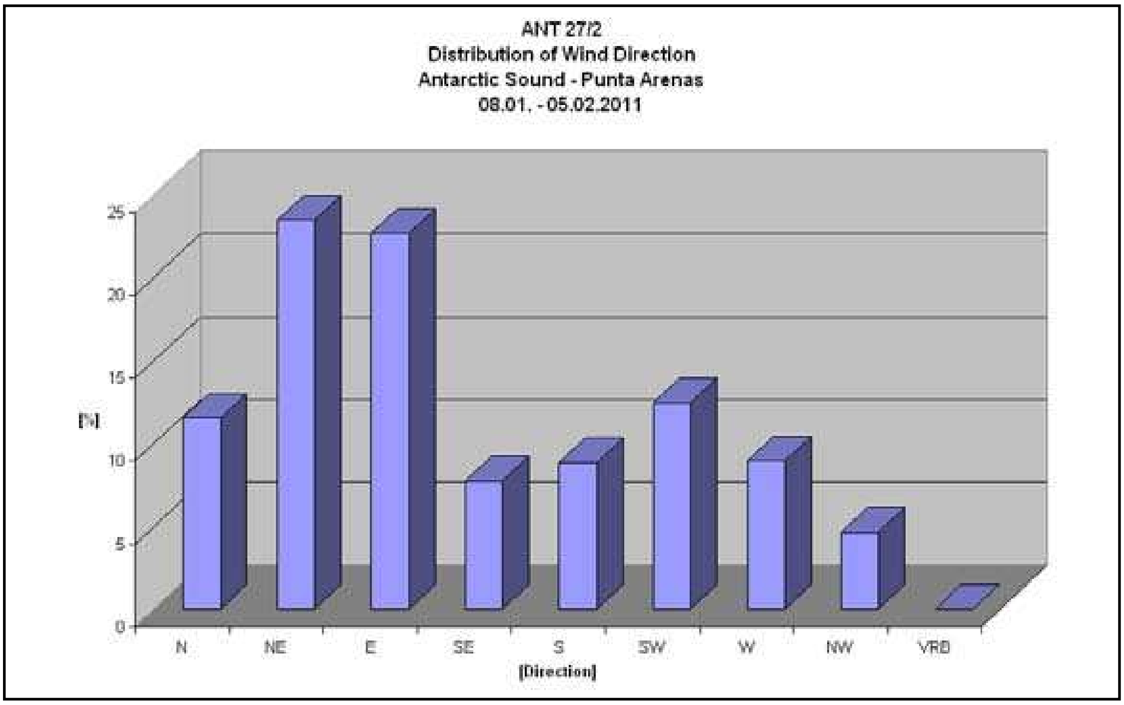

Fig. 2.12: Wind direction during the krill survey west of the Antarctic Peninsula

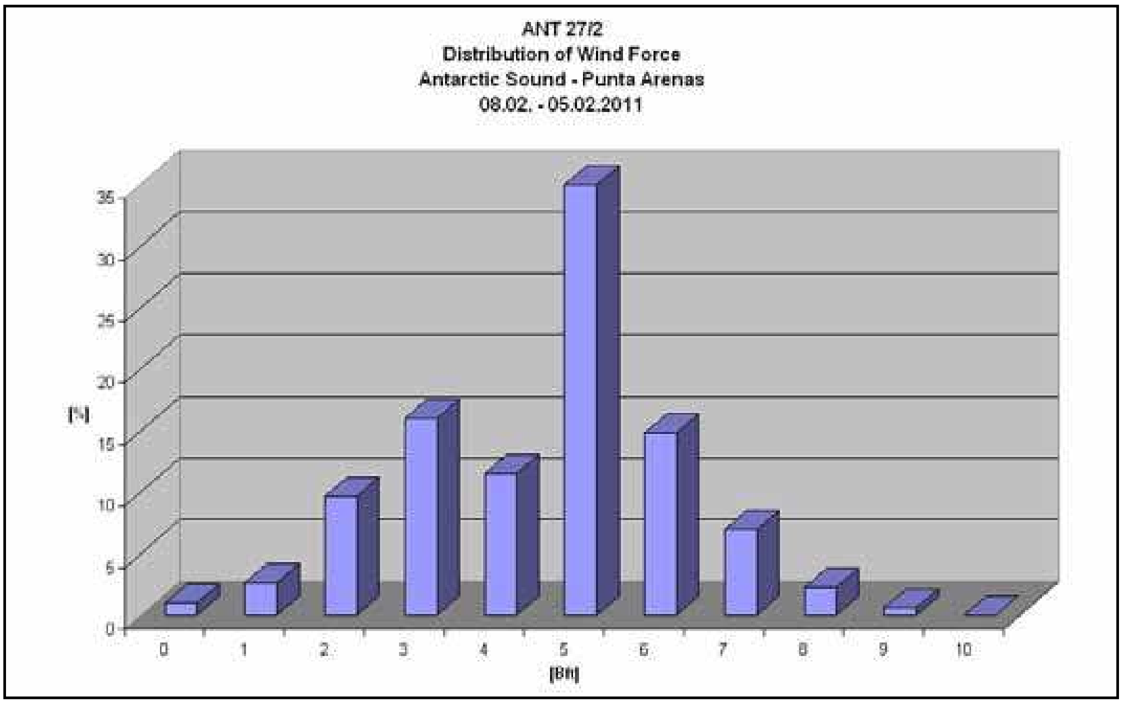

Fig. 2.13: Wind force during the krill survey west of the Antarctic Peninsula

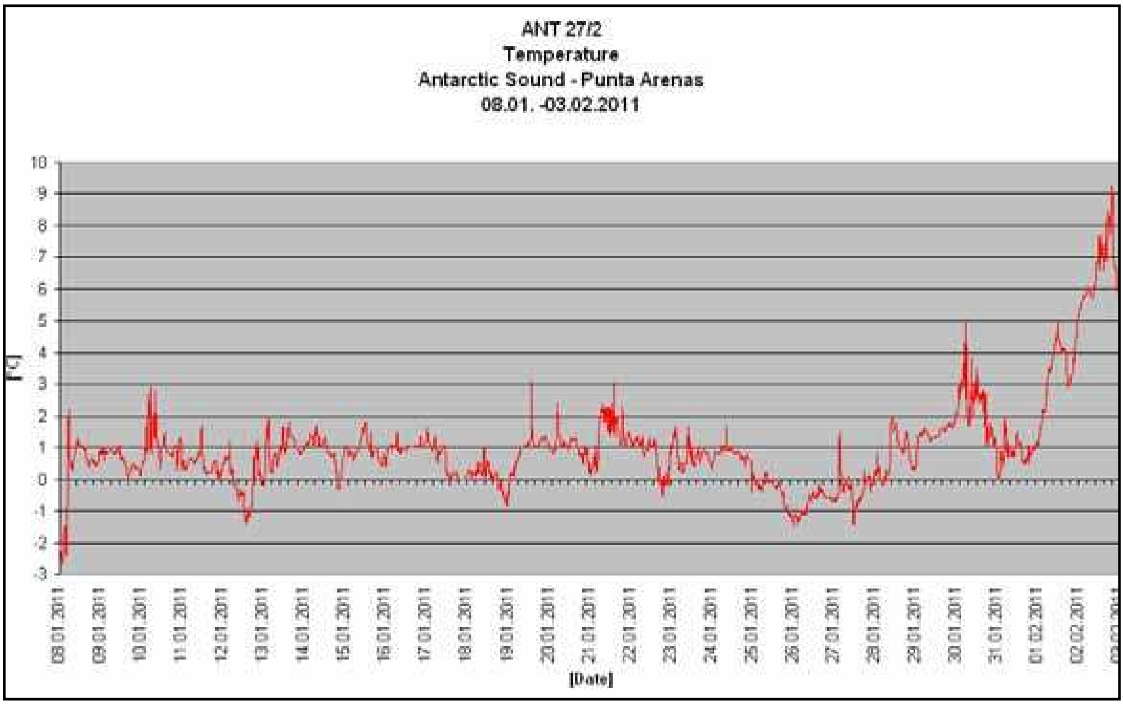

Fig. 2.14: Distribution of air temperature during the krill survey west of the Antarctic Peninsula

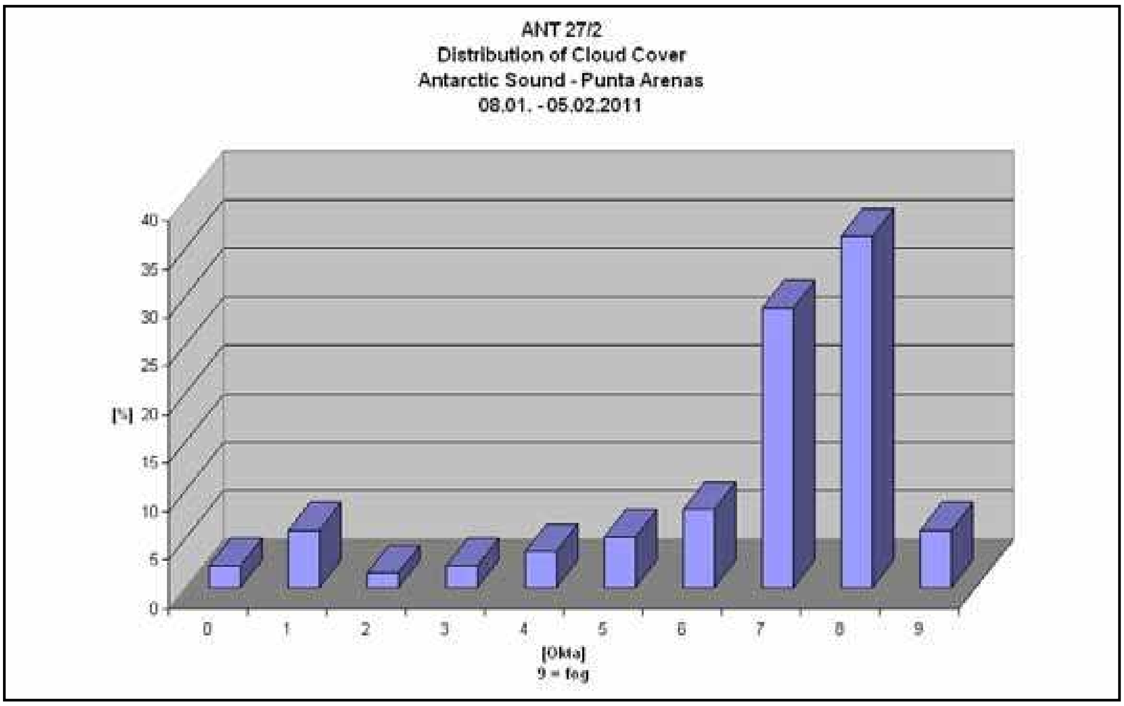

Fig. 2.15: Distribution of cloud cover during the krill survey west of the Antarctic Peninsula

3. OCEANOGRAPHY

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

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Objectives

The densest bottom waters of the global oceans originate in the Southern Ocean. Production and export of these dense waters constitute a vital component of the global climate system. The formation of dense water in polar areas is controlled by the delicate balance between supply of fresh water through precipitation and melt of continental and sea ice and the extraction of freshwater by sea ice formation and evaporation. The influence of Southern Ocean waters can be traced far into the northern hemisphere. As deep and bottom waters, they represent the deepest layer of the global overturning circulation. The Antarctic Circumpolar Current (ACC), the world´s most powerful current system, transports about 140 Sv (10^6 m^3 s^{-1}) of water at all depths. It connects the three ocean basins and forms an isolating water ring around the Antarctic continent. South of the ACC, in the subpolar region, warm and salty water masses are carried in the subpolar gyres to the continental margins of Antarctica. The most prominent are the Weddell and Ross gyres. In the subpolar gyres, water mass modification occurs through ocean-ice-atmosphere interactions and mixing with adjacent water masses. The ACC is dynamically linked to meridional circulation cells, formed by southward ascending flow in intermediate depth feeding into northward flow above and below. In the deep cell water sinking near the continental water spreads to the adjacent ocean basins, in the shallow cell the northward flow occurs in the near surface layers. Dense waters are produced at several sites near the continental margins of Antarctica. Quantitatively the most important region for dense water formation may well be the Weddell Sea. However, other areas provide significant contributions as well.

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

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

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

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

To achieve further progress significant steps occurred in the development of appropriate technology and logistics. Oceanic properties are measured under the sea ice which required the development of under-ice acoustic ranging and data transmitting systems. It is the aim of the HAFOS (Hybrid Antarctic Float Observation System) to establish a set of observations platforms in the Atlantic sector of the Southern Ocean to implement such a comprehensive observation system. To construct from the achievable observations a comprehensive circumpolar view, model assimilations have to be done which require the development of appropriate models.

The WECCON project (*Weddell Sea convection control*) continues work which had occurred during the CASO project (*Climate of Antarctica and the Southern Ocean*) of the International Polar Year 2007/2008. It aims to investigate processes which occur in the Atlantic Sector of the Southern Ocean in cooperation with the Bjerknes Centre for Climate Research in Bergen, Norway and the British Antarctic Survey (BAS). In the framework of iAnZone, a programme associated to SCOR (*Scientific Committee of Oceanographic Research*) and its SASSI project (*Synoptic Antarctic Shelf Slope Interactions Study)* observation occurred in the area of Maud Rise and the Antarctic slope front area. The PIES deployments along the GoodHope/Greenwich section further contribute to the DFG special research programme "Massentransporte". The cruise occurred in the context of the PACES programme of the Hermann von Helmholtz Association of German Research Centres (HGF). It is a contribution to the *Climate Variability and Predictability* (CLIVAR) and the *Climate and Cryosphere* (CliC) projects of the *World Climate Research Programm*e (WCRP) and *Scientific Committee of Antarctic Research* (SCAR). The ULSs are a contribution to the *Antarctic Sea Ice Thickness Project* (AnSITP). The deployment of floats occurs in the framework of the international *Argo* programme which contributes to the *Global Ocean Observing System (*GOOS). The work represents a further step towards a *Southern Ocean Observing System* (SOOS) by building up further the *Hybrid Antarctic/Arctic Float Observing System* (HAFOS).

Work at sea

The *Polarstern* cruise ANT-XXVII/2 complemented the efforts to obtain *in-situ* observations in the Atlantic sector of the Southern Ocean. The backbone of the observations consist of the CTD/water sampler system (chapter 3.1.1) providing vertical profiles of temperature, salinity and a variety of further parameters as well as the water samples required for further analysis to determine a variety of water mass properties or laboratory work.

Water samples were taken to control the conductivity sensors (see chapter 3.1.1). A particular focus was given to oxygen measurements (see chapter 3.1.2), to measurement of trace gases (CFCs, SF6; helium isotopes, neon, oxygen isotopes see chapter 3.2), radiocarbon sampling (see chapter 3.3), nutrients (see chapter 3.4), carbon dioxide parameters (see chapter 4.1), POPS (see chapter 4.2) and phytoplankton and biogenic gases observations (see chapters 5.6 and 5.7). The water samples will be compiled in a bottle file.

Time series stations with moored instruments provide measurements of water mass properties in the deep and the surface layers and of ice thickness. For this purpose moorings with current meters, temperature and salinity sensors as well as upward looking sonar were recovered and redeployed (see chapter 3.1.3). Pressure inverted echo sounders were installed in the ACC (see chapter 3.1.4). The work with floats and sound sources is summarised in chapter 3.1.5. En-route measurements are described in chapter 3.1.6.

3.1.1 The CTD/water sampler observations

During the cruise a total number of 188 CTD/water/sampler profiles were carried out (Fig. 3.1.1).

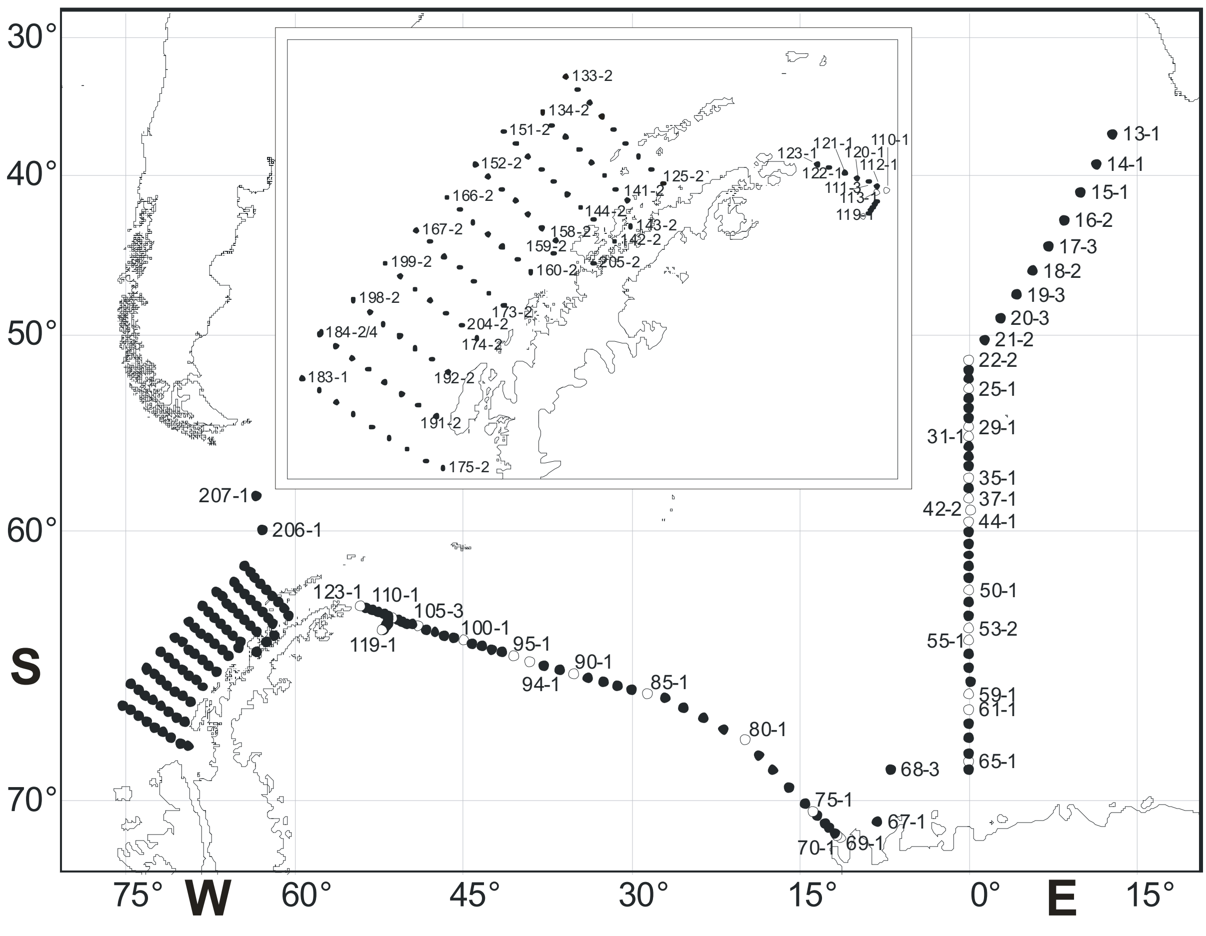


Fig. 3.1.1: CTD stations. Numbers are the stations numbers as given in the station list.

The CTD/water sampler consists of a SBE911plus CTD system combined with a carousel water sampler type SBE32 for 24 samplers and with 12 liter volume each. The CTD was equipped with double sensors for temperature (SBE3plus) and conductivity

(SBE4C). These sensors were calibrated before the cruise and will be returned to Seabird Electronics right after the cruise for calibration purpose. The sensor pairs indicated a small difference in the order of 0.0005 in temperature and 0.003 in conductivity. For the preliminary results the secondary sensor pair was used because it seems to be the most precise one; see paragraph *Salinometer*. There is an indication of weak pressure dependence for one of the temperature sensors and also for one of the conductivity sensors. The post-cruise calibration will provide final correction criteria as well as the complete analysis of the measured salinity samples; see paragraph *Salinometer*. Nevertheless the sensor drift is very small and high quality data could be expected for this cruise. The CTD was additionally equipped with an Benthos/ DataSonics altimeter type PSA 916D which makes it possible to lower the CTD near to the sea floor – depending on the sea state the profile ends 5 m above the bottom. Further on a Wet Labs Eco Fluorometer was used and for investigating the stability of oxygen sensors four sensors of different types and manufactures were installed too; see section 3.1.2. The remaining free input port was used for testing purpose of a new motion sensor (SUMO).

The use of so many external sensors caused a problem with the sensor which used the second half auxiliary port which was used by the altimeter. The first detected bottom echo caused a number of spikes in the oxygen – here the SBE43. After a short period the signal recovers and still allows resolving the structure of the bottom layer. The spikes were edited manually in the pre-processing state.

A software package which was developed at AWI was used to run the SBEDataProcessing procedures automatically, apply header information direct from the DShip-Electronic Station Book, do a preliminary de-spiking and data validation and create an import file to the OceanDataView visualization software. By this procedure e.g. sections from all measured parameters could be published right at the end of a profile.

Salinometer

Salinity samples were taken once a day to check the conductivity sensors of the CTD. The samples were taken in homogeneous layers from shallow, mid and full depth to identify possible pressure dependency. But for the final evaluation the post-calibration of the CTD sensors were needed.

The salinity samples were measured with an Optimare Precision Salinometer (OPS) which was used the first time during *Polarstern* cruise ARK-XXV/1 (Fig. 3.1.2). In spite of the experiences made during that cruise an essential part of the salinity measurements was concentrated to understanding the various influences of e.g. the type of salinity bottles, the rinsing of the bottle, or of the stratification inside the sampler during the up-cast. These investigations are needed because the precision of OPS is in the order of 1/1000. For this purpose about 270 OPS measurements were made. 215 OPS measurements were made to verify the conductivity sensors of the CTD. The water samples were measured in reference to Standard Water batch no. P152; K15 = 0.99981, production date: 2010-05-05.

Fig. 3.1.2: Optimare Precision Salinometer (OPS)

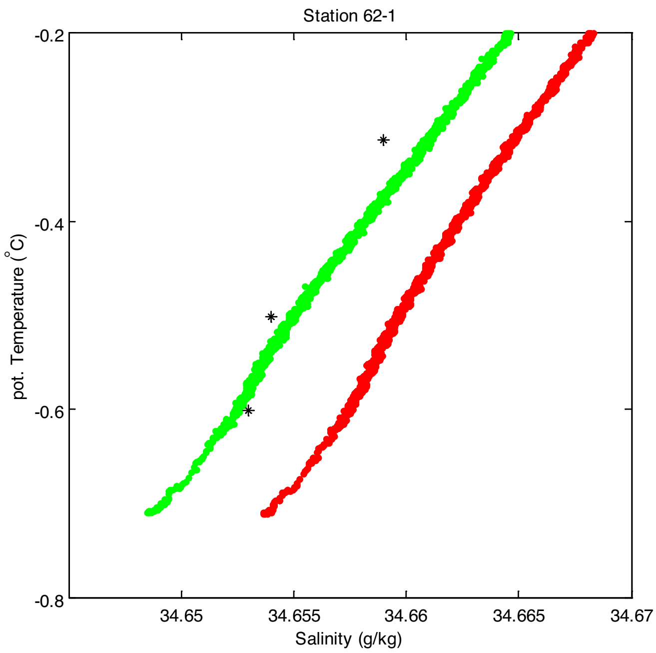


Fig. 3.1.3: Comparison of the T/S properties of the deep part of the profile measured by the two sensor pairs installed on the CTD during ANT-XXVII/2 at station 82

Conductivity and temperature sensors were calibrated before the cruise but the difference between salinity was relatively high; about 0.003 g/kg (Fig. 3.1.3). To work with preliminary data during the cruise, it is needed to decide which sensor pair has the smallest error. Instead of needing a statistic from hundreds of measured salinity samples, the accuracy of the OPS is suitable to use measurements from one single profile only. This is demonstrated as an example shown in Fig. 3.1.3. Here the secondary sensor pair could be identified as the sensor pair to be used for preliminary analysis.

SUbmersible Motion Observer (SUMO)

A prototype of the newly developed submersible motion observer (SUMO) was tested. It was be mounted to the rosette and connected to the CTD via the auxiliary sensor channels not in use actually. The instruments is able to measure and observe in real time a variety of parameters, e.g. twist of the cable, angular velocity, heading of the rosette, combined tilt of the rosette, etc. while the comprehensive and more detailed data were stored and will be processed after the stations. One to four channels were used to transmit the desired information to the operator on board for improved knowledge of the state of rosette and CTD, avoidance of critical situations and saving of ship and station time. The final goals were the proof of functionality under real *in-situ* conditions, the determination of the best parameters to send to the operator for easiest and most efficient work and the measurement of the complete state of the rosette for validation of its model of the mechanical behaviour. The instrument was used during part of the stations and delivered data which are used after the cruise to analyse the performance of the instrument and of the wire. The comparatively calm conditions resulted in little stress for the wire.

Data

The data of the CTD profiles and the bottle files will be transferred to the PANGAEA data base after final post-processing on shore.

3.1.2 Dissolved oxygen measurements

Objectives

The main objective of the dissolved oxygen programme is to continue the high-quality oxygen measurements along the repeat transects of the Greenwich meridian and through the Weddell Sea. This region is a key area for the formation of deep water within the global circulation system and any changes in source waters will spread throughout the world oceans. A precise estimate of the oxygen inventory not only gives valuable information about the air-sea gas exchange of this region. Dissolved oxygen is also considered as the ocean's biogeochemical "canary bird" for global climate change and is sensitively affected, e.g., by heat flux and temperature anomalies. However, the Weddell region is highly variable both on annual and decadal time scales and a single snapshot alone is not sufficient to capture the dynamics. The measurements during this cruise provide the initial state of the oxygen distribution for 8 Argo-O_2 floats (see section on Argo in the Southern Ocean). They add to the approximately 200 active Argo floats worldwide that possess an additional oxygen sensor, thus providing regular data on an important biogeochemical parameter from an autonomous observation system. The floats used here are equipped with an ice detection algorithm, a memory for under-ice profiles and can be tracked acoustically via RAFOS. Thus they will provide a year-round picture of the biogeochemical features, while ship-based cruises concentrate only on the summer season and scarce data is available for winter time and under-ice conditions.

The *in-situ* measurements are supplemented by an extensive evaluation of four different types of oxygen sensors. Their performance will be assessed regarding the quality of their calibration and their stability. However, the focus lies on the response characteristics and behavior in profiling applications as they are attached to the ships CTD. Oxygen sensors are widely used and have been commercially available for some decades. Still, they should be complemented by Winkler measurements at some point during their field deployment to verify the data and correct for possible drifting or offset. This cruise provides a critical review of state-of-the-art sensors in unfavorable conditions (i.e., low temperatures, high profiling speed, strong oxygen gradients, as well as subtle changes in deeper layers) to give a realistic assessment of their performance. This is of particular interest for autonomous operation like on the Argo-O_2 floats and essential to interpret the data afterwards. The findings shall be used to improve a physicochemical model of the working principle of the sensors as well, which will provide a tool to compensate some of their intrinsic drawbacks by adequate post-processing.

Work at sea

Winkler analysis of CTD rosette water samples

During the course of the cruise 2,296 discrete water samples from 122 CTD stations were analyzed towards their oxygen content using the standard Winkler method. The endpoint was determined visually with starch as indicator and KIO_3 used for standardization of the thiosulfate solutions. A map of the locations is shown in figure 3.1.4. The precision of the titration was at 0.3 μmol/l. The accuracy was checked by air saturated samples of seawater at constant ambient pressure and temperature (personal communication Karel Bakker, NIOZ, Texel) and showed good agreement (within 1%) with the iodate standard.

Oxygen sensor evaluation in profiling application

A total of 4 different dissolved oxygen sensors were attached to the CTD unit. A Seabird SBE43 is installed as standard sensor. Three auxiliary input channels were occupied by an Aanderaa optode model 3830 and a fast-response Aanderaa optode model 4330F as well as a JFE Alec Co., Ltd. RINKO III sensor. Only the phase channel was recorded for the auxiliary sensors and the temperature data of the CTD used for the calculation. The Aanderaa optodes were mounted on a digital to analog converter (3966C) to fit to the 0-5 V input of the CTD unit and set to an internal sampling rate of 5 s. For the SBE43 a set of factory calibration coefficients from 30.04.2010 was available. The two Aanderaa optodes were calibrated by a newly designed laboratory setup at IFM-GEOMAR in Kiel just before the cruise in October 2010. A second laboratory calibration will be performed after the cruise. No previous calibration coefficients were available for the RINKO sensor. The Winkler bottle data is used as reference to the sensor data.

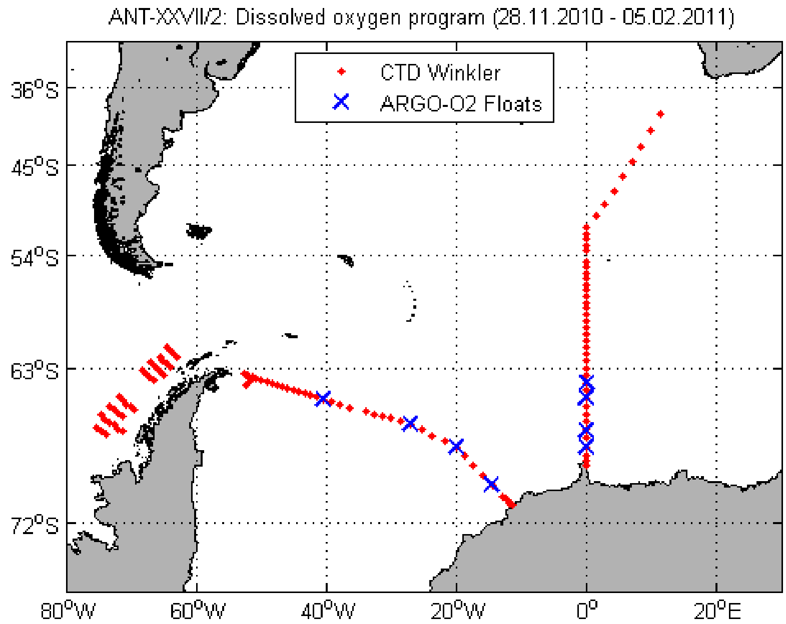


Fig. 3.1.4: Map of CTD stations with Winkler sampling (red dots) and deployment sites of Argo-Oxygen floats (blue cross)

Deployment of Argo floats

Eight Argo floats each equipped with an Aanderaa optode model 3830 were deployed along the Greenwich meridian and the Weddell Sea transect. The optodes were calibrated in the laboratory at IFM-GEOMAR in August and September 2010 before being mounted to the floats. The calibration will be verified by the CTD oxygen profile measured at the deployment location. The latter were chosen so as to follow the course of the Weddell gyre into the Weddell Sea with a good spatial coverage (see figure 3.1.4) in order to provide valuable year-round data about this circulation system. They are equipped with an ice detection algorithm and a memory for under-ice profiles that will be sent by satellite when the float reaches open water again. The position of these profiles can be assessed by acoustic tracking via RAFOS and 10 moored sound sources. For details, see section 3.1.5 (float serial numbers N126 – N133).

Preliminary and expected results

The densely distributed Winkler data provides a valuable source for detailed analysis of the sensor performance. The Aanderaa optodes are known to possess a reversible pressure effect which is not covered by the laboratory calibration. For the 3830 model with regular sensor membrane this was found to amount to 3.2 % per 1000 dbar whereas for the thinner fast-response membrane of the 4330F model a linear correction of 3.6 % per 1000 dbar was applied. Preliminary analysis shows that there is an offset of 6 or 7 μmol/l, respectively, between the laboratory calibration and the field data for the Aanderaa optodes 3830 and 4330F. However, this offset remains constant throughout the cruise. The calibration coefficients of the Seabird SBE43 sensor lead to an initial offset of approx. 8 µmol/l which doubles until the end of the cruise. A similar drift of ca. 10 µmol/l is observed for the RINKO III sensor. Apart from the calibration stability the response time of the sensor is the second important feature in profiling applications. The data obtained will be used to evaluate the systematic error induced by different/ slow response characteristics. This is especially pronounced in strong gradients at the bottom of the mixed layer or close to the bottom. The comparison of the profiles will be used to validate laboratory experiments on the different response behavior and to improve a physicochemical model to compensate the induced errors.

Moreover, the cruise data set the initial stage for the oxygen distribution for the 8 Argo-O_2 floats deployed. It will be the basis for inventory estimates and to assess trends in this key region for deep water formation. Further analysis and comparison with historical data (mostly collected with *Polarstern*) will give further insight into the dominant processes of water mass formation, mixing and biogeochemistry and recent changes in this region.

Data

Both sensor data and Winkler data will be transferred to the PANGAEA data base after final post-processing on shore.

3.1.3 Moorings

The ship borne surveys are imbedded in the time series measurements with moorings and floats to quantify seasonal variability on transfer processes and to avoid the aliasing effect on longer term observations. Moorings were recovered and redeployed. The details of the moored instruments are summarized in tables 3.1.1 to 3.1.4. Figure 3.1.5 shows the locations of moorings and PIES (see paragraph 3.1.4) which have been deployed during the cruise. See the paragraph 3.1.5 concerning the instruments for tracking the floats (sound sources) or for the underwater acoustics (various acoustic recorders).

Mooring AWI227-10 was lost. It was located with *Posidonia* and both of the double releasers were released. *Posidonia* showed a constant transponder depth, which clearly indicates that the mooring did not ascend. Later four moorings were recovered with imploded glass floatation which was placed at similar depth level. Therefore it is most likely that this has happened also in AWI227-10, which also explains the weak signal from the transponder when the instruments are lying at the ground.

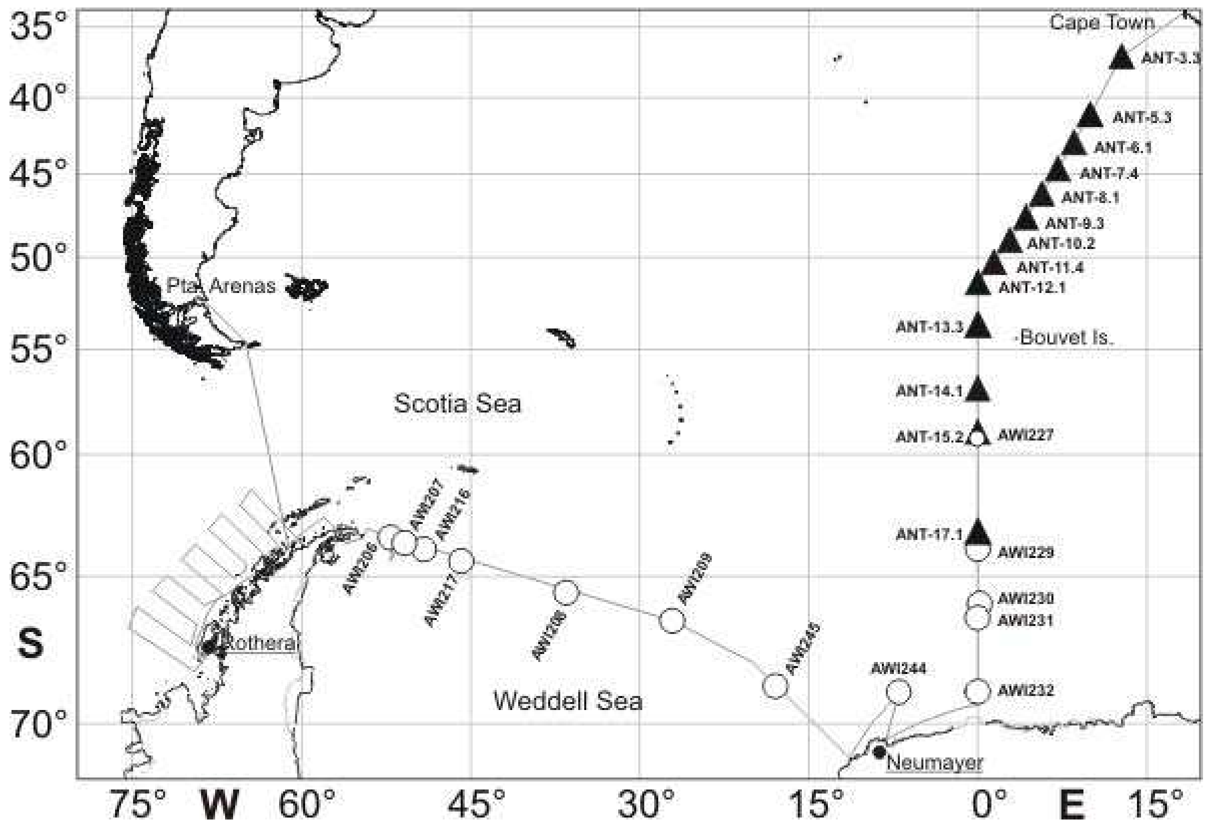


Fig. 3.1.5: Route of ANT-XXVII/2 with moorings. Black triangles indicated the locations of PIES deployments. Circles indicated the locations of re-deployed mooring locations.

The moorings were located with the Posidonia system. There are two antenna arrays which could be used. One antenna is permanently installed in the box keel behind a window. The second one must be installed through the moon pool (mobile antenna) which needs about 45 minutes for installation. After installation, it is not possible to maneuver in ice. But mobile antenna provides more accurate positions since the window has a negative influence on the accuracy and also on the number of detected replies. Nevertheless the permanent antenna array is of great advantage for the mooring recovery. It shows that the mooring is still at its position when starting the recovery. After sending the release code it confirms a successful release by displaying the depth of the rising release. It also indicates the sector in which the top floatation will surface. In areas with closed ice coverage the mobile antenna was used. Having a precise position the mooring could be released on time when leads were drifting over the mooring location. Deployed moorings were tracked with Posidonia to determine the time when the anchor has reached the sea floor. During the most deployments the „window-array“ was used and therefore not the position displayed by Posidonia, but the ships position when the anchor was dropped was taken as final mooring position. For more detail on the performance of Posidonia see Appendix A5.

Table 3.1.1: Moorings recovered on the Greenwich meridian

Mooring	Latitude Longitude	Water Depth (m)	Date Time 1. Record last Record	Instrument Type	Serial Number	Instru-ment Depth (m)	Nr. of Days recorded
AWI232-9	68° 59.74' S	3419	11.03.2008	ULS	57	150	+(1)
	00° 00.17' E		14:00	AURAL	085	216	+(2)
			19.12.2010	ADCP	6240	450	(3)
			02:00	AVT	9782	750	1012
				RCM 11	144	1800	1012
				SBE37	2086	3300	1012
				RCM 11	486	3300	1012
AWI231-8	66° 30.68' S	4546	07.03.2008	ULS	56	150	(4)
	00° 01.81' W		22:00	SBE37	1236	200	1014
			17.12.2010	SBE37	449	300	1014
			04:00	SBE37	2088	400	1014
				ADCP	825	450	
				SBE37	2089	500	1014
				SBE37	2090	600	1014
				SBE37Pu	1237	700	1014
				AVTP	10928	700	911 (5)
				SOSO	30	850	+(6)
				AVT	9180	1800	1014
				SBE37	237	4500	1014
				AVT	9186	4500	1014
AWI230-6	66° 01.13' S	3577	08.03.2008	AURAL	086	200	+(2)
	00° 04.77' E		16:00	AVTP	3517	200	1014
			16.12.2010	SBE37Pu	1229	200	1014
			12:00	SBE37	2091	300	1014
				SBE37	2092	400	1014
				SBE37	2093	500	1014
				SBE37	2094	600	1014
				SBE37Pu	2237	700	1014
				RCM 11	295	700	1014
				AVTP	9188	1600	1014
				SBE37	2099	3400	1014
				RCM 11	504	3400	1014
MARU#2	64° 05.07' S	5194	14.12.2008	PAM	2	5144	(7)
	00° 05.24' W		10:00				
AWI229-8	63° 58.03' S	5195	28.02.2008	ULS	64	150	+(2)
	00° 03.10' W		22:00	SBE 37	2098	200	1020
			15.12.2010	SBE37	2096	300	1020
			04:00	ADCP	5373	350	+(2)
				SBE16	2416	400	1020
				SBE37	2095	500	1020
				SBE37	2100	600	1020
				SBE37Pu	2396	700	1020

Mooring	Latitude Longitude	Water Depth (m)	Date Time 1. Record last Record	Instrument Type	Serial Number	Instru-ment Depth (m)	Nr. of Days recorded
				AVTP	10925	704	1020
				SOSO	29	850	+(6)
				AVT	9390	2000	1020
				SBE37	2101	5150	1020
				AVT	10499	5150	1020
MARU#1	59° 10.28' S	4838	12.12.2008	PAM	1	4798	+(2)
	00° 00.39' E		18:00				
AWI227-10	59° 04.10'S	4630	25.02.2008	SBE37P10	1565	4580	(8)
	00° 04.88' W		14:00				

Table 3.1.2: Moorings recovered along transect from Kapp Norvegia towards Joinville Island

Mooring	Latitude Longitude	Water Depth (m)	Date Time 1. Record last Record	Instru-ment Type	Serial No.	Instr. Depth (m)	Nr. of Days recorded
AWI-244-1	68° 59.70' S	2927	13.03.2008	SOSO	23	850	+(6)
	06° 56.70' W		16:00				
AWI245-1	69° 03.68' S	4466	15.03.2008	SOSO	24	850	+(6)
	17° 25.89' W		16:00				
AWI209-5	66° 36.89' S	4864	18.03.2008	SBE 16	2415	300	1015
	27° 07.08' W		22:00	SOSO	34	800	+(6)
			29.12.2010	SBE37P	220	4800	1015
			08:00	SBE37	230	4850	1015
AWI208-5	65° 36.85' S	4770	21.03.2008	ULS	62	150	+(2)
	36° 24.43' W		16:00	ADCP	3813	300	+(2)
				SBE16	1979	300	1015
				SBE37	435	4680	1015
				SBE37	2234	4730	1015
AWI242-1	65° 34.51' S	4715	30.01.2007	SOSO	27	830	+(6)
	37° 07.33' W		05:00	SBE37	221	4708	1203 (5)
			18.05.2010				
			03:15				
AWI217-3	64° 23.63' S	4456	24.03.2008	SOSO	32	850	+(6)
	45° 52.38' W		14:00	SBE37	250	4150	1015
			03.01.2011	SBE37	240	4350	(9)
			18:00	RCM 11	296	4351	1015 (5)
AWI216-3	63° 54.03' S	3516	26.03.2008	SBE37	2392	3350	1014
	49° 04.68' W		16:00	SBE37	2393	3400	1014
			05.01.2011	SBE37	439	3450	1014

Mooring	Latitude Longitude	Water Depth (m)	Date Time 1. Record last Record	Instru-ment Type	Serial No.	Instr. Depth (m)	Nr. of Days recorded
			12:00	RCM 11	298	3451	630 (5)
AWI207-7	63° 42.74' S	2500	27.03.2008	ULS	60	150	+(2)
	50° 50.55' W		22:00	AVTP	10872	250	1014
			06.01.2011	SBE 16	2414	251	(4)
			08:00	AVT	10503	750	1014
				SOSO	36	850	+(6)
				SBE37	2297	2200	1014
				AVT	10530	2300	1014
				SBE37	436	2490	(10)
				RCM 11	619	2490	629 (5)
AWI206-6	63° 28.77' S	950	28.03.2008	ULS	61	150	+(2)
	52° 05.77' W		18:00	AVTP	9206	250	1014
			06.01.2011	SBE37	1228	500	1014
			18:00	AVT	9201	501	1014
				SBE16	2422	700	1014
				SBE37	438	900	1014
				RCM 11	508	901	

Table 3.1.3: Moorings deployed on the Greenwich meridian

Mooring	Latitude Longitude	Water Depth (m)	Date Time (at Depth)	Instru-ment Type	Serial Number	Instrument Depth (m)
AWI232-10	69° 00.11' S	3370	19.12.2010	ULS	69	150
	00° 00.11' W		10:20	AVTP	8400	250
				AVT	9219	750
				PAM	1003	1250
				RCM 11	212	1800
				POD	403	2000
				SBE37	441	3300
				RCM 11	216	3300
AWI231-9	66° 30.71' S	4524	17.12.2010	ULS	68	150
	00° 01.54' W		12:00	AVTP	8367	200
				SBE37	249	200
				SBE37	232	250
				SBE37	233	300
				SBE37	235	350
				SBE37	236	400
				SBE37	1230	450
				SBE37	238	500
				SBE37	239	550
				SBE37	2388	600
				SBE37	437	650
				SBE37	1232	700

Mooring	Latitude Longitude	Water Depth (m)	Date Time (at Depth)	Instru-ment Type	Serial Number	Instrument Depth (m)
				RCM 11	145	700
				SOSO	29	850
				PAM	1002	1000
				AVT	9212	1800
				SBE37	440	4500
				RCM 11	146	4500
AWI230-7	66° 01.90' S	3540	16.12.2010	AVTP	10539	200
	00° 03.25' E		20:00	SBE37	8125	200
				SBE37	227	300
				SBE37	246	400
				SBE37	228	500
				SBE37	229	600
				SBE37	247	700
				RCM 11	102	700
				PAM	1001	1000
				AVTP	9211	1600
				SBE37	231	3500
				RCM 11	133	3500
AWI229-9	63° 59.56' S	5170	15.12.2010	ULS	67	150
	00° 002.65' W		16:28	AVTP	10926	200
				SBE37	2719	200
				SBE37	241	250
				SBE37	215	300
				SBE16	216	350
				SBE37	218	400
				SBE37	2720	450
				SBE37	224	500
				SBE37	225	550
				SBE37	226	600
				SBE37	2382	650
				SBE37	2722	700
				AVTP	8037	704
				SOSO	17	850
				PAM	1000	1000
				RCM 11	501	2000
				SBE37	2383	5150
				RCM 11	134	5150
AWI227-11	59° 03.02'S	4600	11.12.2010	PAM	0002	1000
	00° 06.63' W		18:28	SBE16	630	4540

Table 3.1.4: Moorings to be deployed along transect from Kapp Norvegia towards Joinville Island

Mooring	Latitude Longitude	Water Depth (m)	Date Time (at Depth)	Instrument Type	Serial Number	Instrument Depth (m)
AWI244-2	69° 00.30' S	2900	23.12.2010	SOSO	02	700
	06° 58.89' W		10:27	SOSO	30	800
				PAM	1005	900
AWI245-2	69° 03.52' S	4740	27.12.2010	SOSO	24	800
	17° 23.05' W		11:00	PAM	1004	1000
AWI209-6	66° 36.70' S	4830	29.12.2010	PAM	086	200
	27° 07.31' W		15:15	SBE37	1233	300
				SOSO	23	800
				SBE37	1603	4775
				SBE37	442	4825
AWI208-6	65° 37.06' S	4740	01.01.2011	ULS	66	150
	36° 25.28' W		17:49	SBE37	1234	300
				SOSO	29/34	800
				SBE37	1606	4680
				SBE37	444	4730
AWI217-4	64° 23.88' S	4416	04.01.2011	SOSO	28/27	810
	45° 51.95' W		17:57	SBE37	1564	4320
				SBE37	2087	4370
				RCM 11	217	4372
AWI216-4	63° 53.66' S	3500	05.01.2011	SBE37	2395	3300
	49° 05.20' W		15:57	SBE37	448	3400
				SBE37	2611	3450
				RCM 11	219	3451
AWI207-8	63° 43.20' S	2500	06.01.2011	ULS	63	150
	50° 49.54' W		12:26	RCM 11	294	250
				SBE37	1235	251
				AVT	8405	750
				SOSO	32	850
				POD	845	2100
				SBE37	2235	2100
				SBE37	1605	2200
				RCM 11	297	2300
				SBE37	1607	2490
				RCM 11	311	2490
AWI206-7	63° 28.93' S	950	06.01.2011	ULS	65	150
	52° 05.87' W		20:52	AVTP	8417	250

Mooring	Latitude Longitude	Water Depth (m)	Date Time (at Depth)	Instrument Type	Serial Number	Instrument Depth (m)
				SBE37	2723	500
				RCM 11	312	501
				SBE16	2418	700
				POD	844	750
				SBE37	2097	900
				PAM	1006	910
				RCM 11	313	912

Abbreviations:

ADCP	RD-Instruments, Self Contained Acoustic Doppler Current Profiler
AURAL	AURAL-Underwater Acoustic Recorder
AVTCP	Aanderaa Current Meter with Temperature-, Conductivity- and Pressure Sensor
AVTP	Aanderaa Current Meter with Temperature- and Pressure Sensor
AVT	Aanderaa Current Meter with Temperature Sensor
PAM	Passive Acoustic Monitor (Type: AURAL or SONOVAULT)
POD	Porpoise Detector
SBE37	SeaBird Electronics, Type: MicroCat, to measure Temperature and Conductivity
SOSO	Sound Source for SOFAR-Drifter
ULS	Upward looking sonar from Christian Michelsen Research Inc. to measure the ice draft

Remarks:

+ indicates a successful result

(1) Full memory but upload failed

(2) Instrument has worked successfully but data are not processed now

(3) No data recorded; unknown failure

(4) Flooded instrument

(5) Recording stopped due to full memory or low power

(6) Instrument has worked successfully

(7) Not recovered

(8) Mooring not surfaced

(9) Measurements failed

(10) Lost during the recovery

Two moorings were released from helicopter several miles ahead of *Polarstern's* track to be out off the ships noise, because the releases could not be operated by Posidonia.

Except of AWI227-10 all other moorings were recovered and the deployment was done without any problem too. Specially to be mentioned is the recovery of a sound source mooring which was deployed January 2007 by the British Antarctic Survey.

Aanderaa current meters and Seabird CT- or CTD-recorders were completely processed on board. In spite of the long period the instruments contained data of good quality. Only four deployed instruments failed. See details in tables 3.1.1 and 3.1.2.

On 6 moorings upward looking sonars (ULS) were mounted. Scratches on several instruments indicated that they have been hit by icebergs. The encounters were not powerful enough that the moorings displaced. However one of the instruments was dropped to a depth that water intruded and damaged the lithium batteries what in consequence implied the destruction of the instrument and the loss of the data. From the remaining instruments the full data rate is to be expected.

Data

The data from the moored instruments will be transferred to the PANGAEA data base after final post-processing on shore.

Preliminary results

Despite the fact that the data requires comprehensive processing and calibration work, the quality of our instruments is so high, that a first look on the preliminary data from the hydrographic survey suggests some preliminary conclusions.

The temperature and salinity distributions of the sections along the Greenwich meridian (Fig. 3.1.6) and across the Weddell Sea from Kapp Norvegia to Joinville Island (Fig. 3.1.7) present the dominating water masses. At the surface Antarctic Surface Water (ASSW) suggests the onset of summer warming. Below the Winter Water (WW) is visible as a temperature minimum layer. The Circumpolar Deep Water (CDW) below it, in the Weddell Sea called Warm Deep Water (WDW), becomes obvious as temperature and salinity maxima. The inflow from the east is evidenced by the horizontal maximum on the southern side of the transect along the Greenwich meridian (Fig. 3.1.6), the eastern and the western side of the Weddell transect (Fig. 3.1.7) and finally the northern side of the Greenwich section (Fig. 3.1.6). The temperature maximum is clearly decreasing along the flow of the Weddell gyre suggesting interaction with the adjacent water masses. At the bottom the water masses with a potential temperature below -0.7°C belong to the Weddell Sea Bottom Water (WSBW). It fills the basins but is as well found on the western slope. Enclosed between WDW and WSBW, the most voluminous water mass consists of Weddell Sea Deep Water (WSDW). This water mass originates to some part by a mixture of WDW and WSDW, but is formed as well directly when the shelf water descends along the slope and mixes with the adjacent water masses. WSDW is leaving the Weddell Sea and forms the basis of the Antarctic Bottom Water of the World Ocean.

The comparison with transects from earlier cruises indicated that the cooling of the Warm Deep Water which was observed since the mid 90ties has come to a halt and that since 2005 warming is ongoing. Together with the observation of an earlier warming until the mid 90ties this suggests that decadal fluctuations dominate the variability. The salinity follows as well to a decadal pattern with freshening since 2005. In the ongoing analyses, we will compare the atmospheric forcing during the last decades to better understand the forcing mechanism of the fluctuations. The temperature of the Weddell Sea Bottom Water increased further at the Greenwich meridian and the central Weddell Basin. This observation provides evidence that the temperature and salinity changes affect the whole water column resulting in a net warming and freshening of the water column. In the western Weddell Sea the bottom water is more likely to cool and freshen raising the question how the bottom water at the slope and in the basin are connected. The different time histories suggest the interaction of different source areas.

The descending motions in the Southern Ocean are part of the world wide oceanic overturning circulation. They affect the role of the ocean in climate change and biogeochemical cycles. Our measurements raise the question as to whether the deep reaching, descending motion of the overturning is reduced or changing to a different regional distribution related to different process.

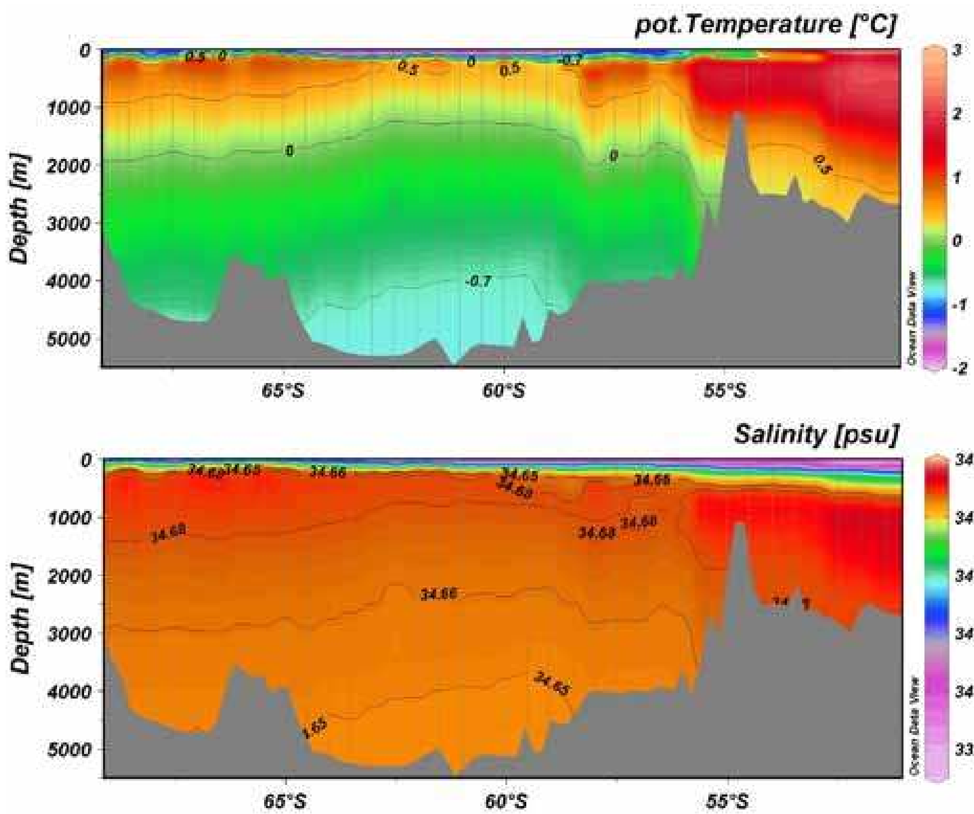


Fig. 3.1.6: Section of potential temperature (top) and salinity (bottom) along the Greenwich meridian

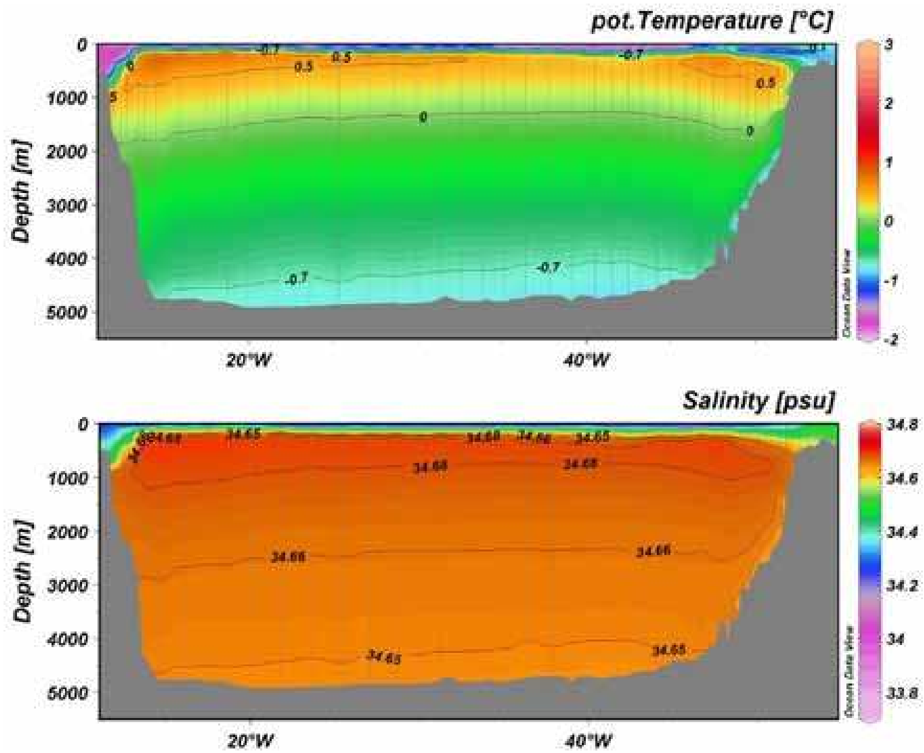
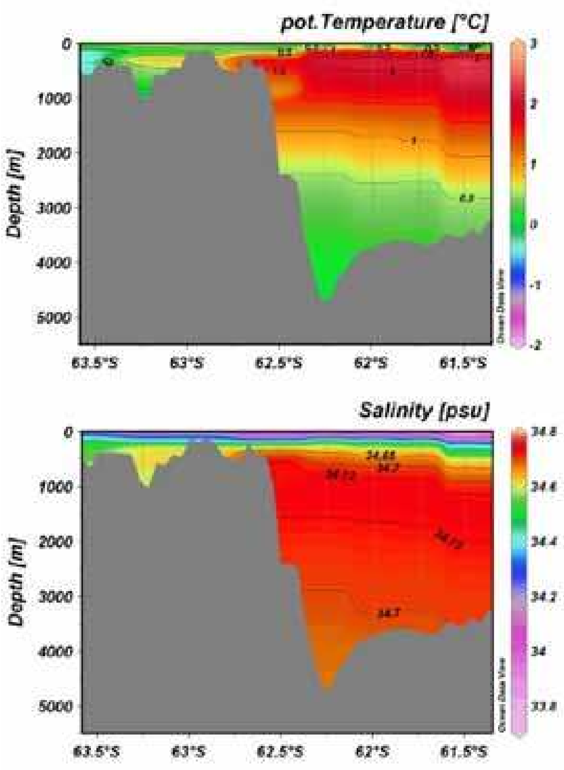
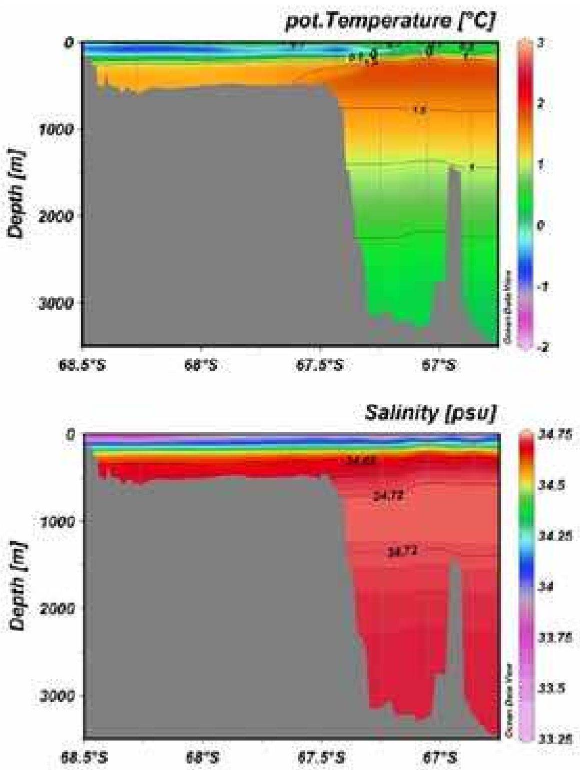


Fig. 3.1.7: Section of potential temperature (top) and salinity (bottom) across the Weddell Sea from Kapp Norvegia to Joinville Island

The data obtained during the krill survey west of the Antarctic Pensinsula are presented as transects and maps. The northeastern (Fig. 3.1.8) and the southwestern (Fig. 3.1.9) most temperature and salinity sections are presented as examples. The horizontal distributions of the sea surface temperature (Fig. 3.1.10) and salinity (Fig.3.1.11) show the transition from the near shore to the offshore regimes which are separated by the Polar front. The fluorescence near the sea surface is presented in figure 3.1.12 and the intensity of the temperature maximum of the Circumpolar Deep Water in figure 3.1.13.





Left: Fig. 3.1.8: Section of potential temperature (top) and salinity (bottom) of the north-eastern section of the RMT grid (station 125 to 133)

Right: Fig. 3.1.9: Sections of potential temperature (top) and salinity (bottom) of the south-western section of the RMT grid (station 175 to 183)

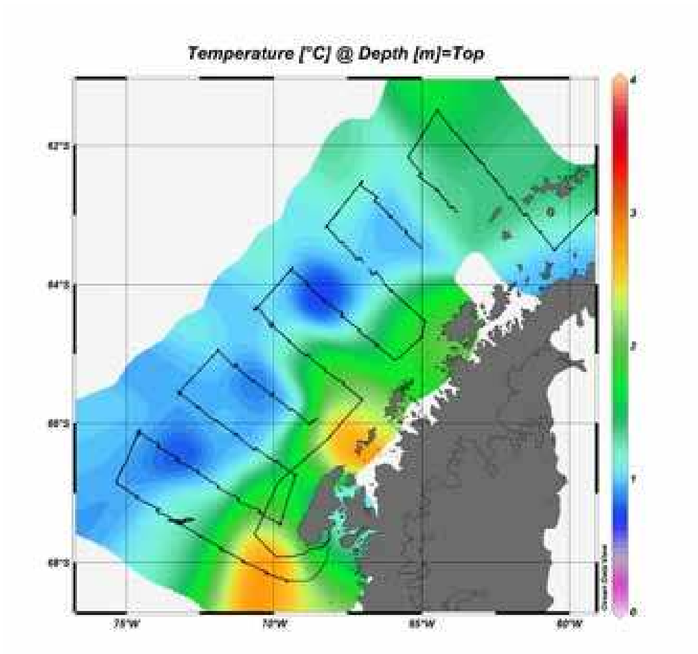


Fig. 3.1.10: Map of the sea surface temperature of the RMT grid from the underway measurements (SBE21 thermosalinograph)

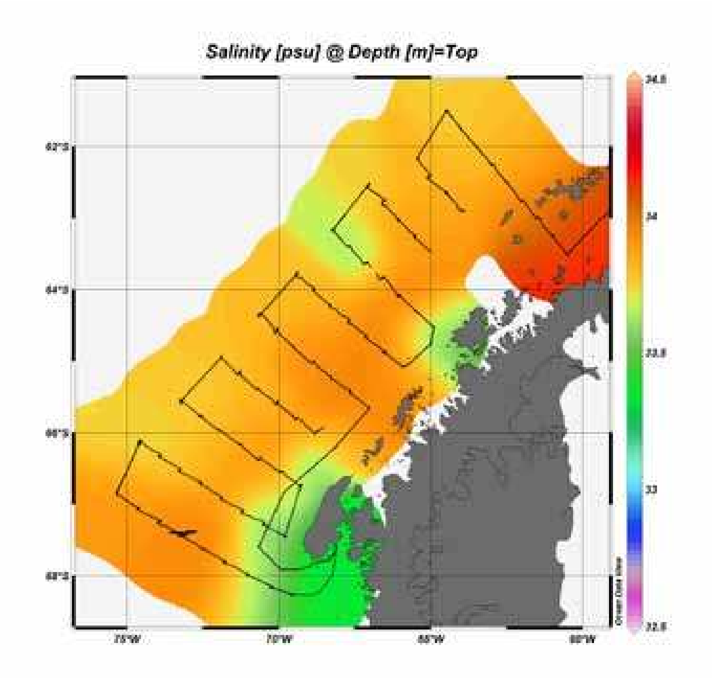


Fig. 3.1.11: Map of the surface salinity of the RMT grid from the underway measurements (SBE21 thermosalinograph)

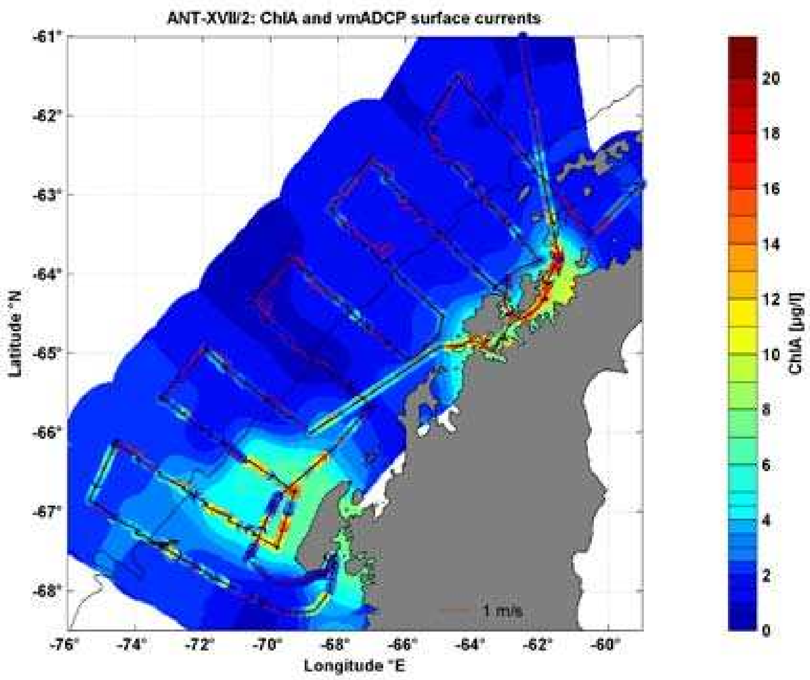


Fig. 3.1.12: Map of the surface fluorometer record of the RMT grid from the underway measurements („ferry-box“). Current vectors obtained as vertical averages over the 35-75 m records from the ADCP are indicated as red arrows along the transects.

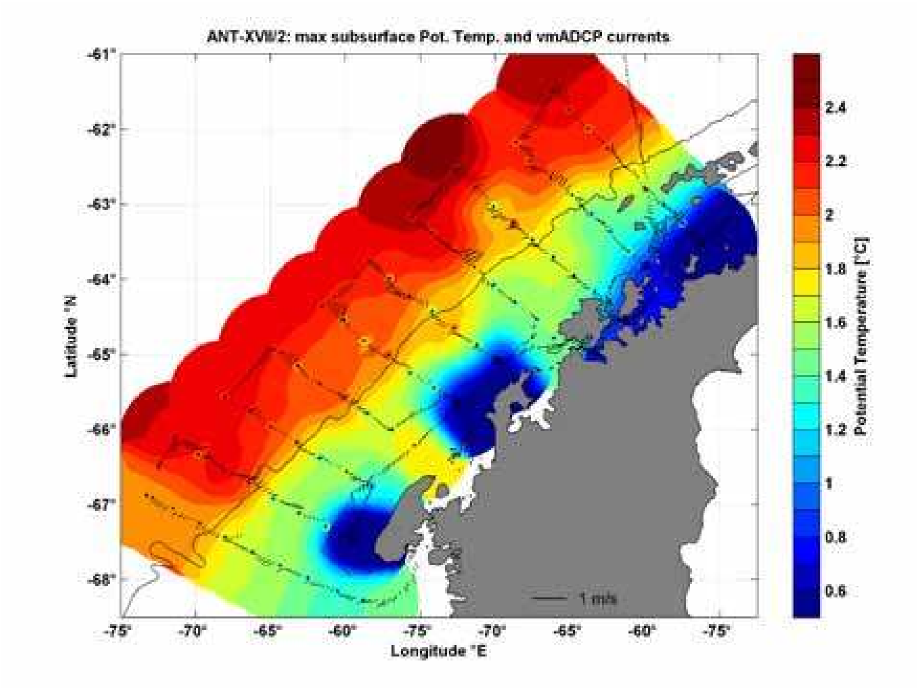


Fig. 3.1.13: Map of the potential temperature maximum of the RMT grid. Current vectors obtained as vertical averages over the 35-75 m records from the ADCP are indicated as black arrows along the transects.

3.1.4 Transport variations of the Antarctic Circumpolar Current

Objectives

Pressure Inverted Echo Sounders (PIES) deliver bottom pressure, bottom temperature and travel times of sound signals from the bottom to the sea-surface, effectively providing a measure of average temperature of the water column and sea surface height (SSH). C-PIES additionally provide local current speed 50 m above the bottom by an acoustic DCS current meter. These data are used to evaluate variations of both barotropic and baroclinic geostrophic transport of the Antarctic Circumpolar Current (ACC) as part of the AWI programme to observe the decadal variability of the ACC. The PIES are placed along the GoodHope section between South Africa and Antarctica (Fig. 3.1.14), which in large parts coincides with ground track # 133 of the Jason (previously TOPEX/ Poseidon) satellite mission to allow direct comparison with altimetry SSH. PIES-to-PIES distances are chosen to resolve the major oceanic fronts of this region.

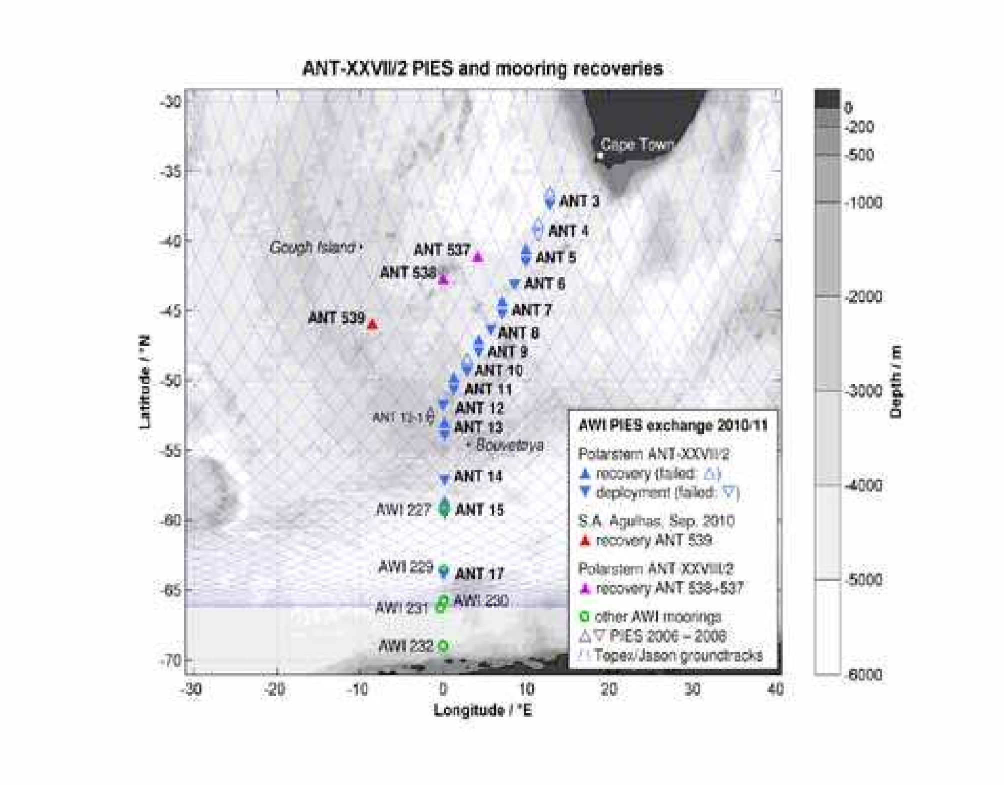


Fig. 3.1.14: Location of PIES recoveries/deployments during ANT-XXVII/2.

In addition, the same PIES data is used in the context of the GRACE satellite mission (Gravity Recovery and Climate Experiment) to validate monthly mean ocean bottom pressure anomalies as derived from the GRACE geoid variations. As the typical length scale inherent to GRACE data is about 1000 km, the broad spatial coverage of the GoodHope PIES array (spanning nearly 2,000 km) is well suited to determine the accuracy of the GRACE measurements in this region. To achieve a 2-dimensional coverage of coherent large scale Ocean Bottom Pressure signals detected by GRACE, 3 additional PIES complement the array to the northwest (Fig. 3.1.14).

Work at sea

Overview

While the first PIES on the GoodHope/Greenwich section were deployed in 2002, the configuration before ANT-XXVII/2 involved 9 PIES deployed in 2008 from *R/V G.O. Sars* (AKES Leg 2) and *Polarstern* (ANT-XXIV/3 and ANT-XXV/2) (Fig. 3.1.14). On ANT-XXVII/2, these 9 PIES were scheduled for recovery and data download, with 9 replacement deployments at the same locations, plus additional 5 new deployments to improve spatial resolution in the frontal zones of the ACC, and extended southward coverage closing the gap to the current meter/CTD mooring array further south along the prime meridian (Fig. 3.1.14).

A single PIES deployed 2006 northwest of the main section (Fig. 3.1.14) for GRACE validation was successfully recovered by *R/V S.A. Agulhas* in September 2010 (Gough Island relief cruise 2010), and picked up by *Polarstern* in Cape Town at the beginning of this cruise. Two other PIES on the northwestern “GRACE extension” (Fig. 3.1.14) far away from any regular cruise tracks are planned for final recovery by *Polarstern* ANT-XXVIII/2 in December 2011.

Tab. 3.1.5: PIES recoveries by *S.A. Agulhas* and *Polarstern* in Sep-Dec 2010. All times in UTC, all depths uncorrected deepwater echo sounder depths (DWS) calculated with c_s = 1500 m/s.

Mooring ID Station book (deployment)	**Deployment date/ time [UTC]**	**Deployment position (GPS) Depth (DWS)**	**Final position (best estimate from Posidonia)**	**PIES SN DCS SN Posidonia SN**	**PIES Auto-release date, REL code**	**Remarks**
ANT3-3 PS77/013-3	30.11.2010 06:31	37° 5.84' S 12° 45.23' E 4904 m	*37° 05.80‘ S* *12° 45.48‘ E* *5000 m @07:40*	PIES #058 no DCS ET861 #637	31-Mar-2017 12:00 UTC **REL: 58**	Posidonia uncertain, GPS depl. position better
ANT4-2 PS77/014-3	01.12.2010 10:13	39° 12.71' S 11° 19.57' E 5139 m	39° 12.81' S 11° 19.88' E 4438 m @ 11:32	PIES #069 no DCS ET861 #469	01-Apr-2017 12:00 UTC **REL: 5**	Releaser failed, recovered at 13:14 **Deployment failed**
ANT5-3 PS77/015-3	02.12.2010 08:05	41° 9.77' S 9° 55.31' E 4624 m	41° 9.74' S 9° 55.34' E 4601 m @09:29	C-PIES #182 no DCS ET861 #469	02-Apr-2017 12:00 UTC **REL: 54**	C-PIES, but without DCS
ANT6-1 PS77/016-1	02.12.2010 22:17	42° 58.80' S 8° 30.15' E 3930 m	42° 58.76‘ S 08° 30.00‘ E 3871 m @01:00	PIES #069 no DCS ET861 #384	01-Apr-2017 12:00 UTC **REL: 5**	
ANT7-4 PS77/017-2	03.12.2010 18:37	44° 39.73' S 7° 5.15' E 4593 m	44° 39.65‘ S 07° 05.25‘ E 4500 m @22:20	C-PIES #181 DCS #750 ET861 #639	03-Apr-2017 12:00 UTC **REL: 53**	
ANT8-1 PS77/018-1	04.12.2010 14:55	46° 12.97' S 5° 40.23' E 4786 m	46° 12.95' S 5° 40.17' E 4760 m @17:40	C-PIES #183 DCS #751 ET861 #616	04-Apr-2017 12:00 UTC **REL: 55**	
ANT9-3 PS77/019-2	05.12.2010 10:20	47° 39.87' S 4° 15.22' E 4541 m	no reception	C-PIES #251 DCS #26 ET861 #602	05-Apr-2017 12:00 UTC **REL: 59**	vmADCP current 0.25 kn to NE
ANT10-2 PS77/020-2	06.12.2010 03:58	49° 0.77' S 2° 50.05' E 4056 m	no reception	C-PIES #250 DCS #31 ET861 #617	06-Apr-2017 12:00 UTC **REL: 58**	vmADCP current 0.25 kn to E
ANT11-4 PS77/021-3	07.12.2010 00:13	50° 15.45' S 1° 25.18' E 3901 m	50° 15.33' S 1° 25.00' E 3846 m @ 01:22	C-PIES #249 DCS #24 ET861 #385	07-Apr-2017 12:00 UTC **REL: 57**	
ANT12-1 PS77/022-1	07.12.2010 10:52	51° 25.15' S 0° 0.24' E 2713 m	51° 25.23' S 0° 0.42' E 2654 m @ 11:41	PIES #062 no DCS ET861 #612	08-Apr-2017 12:00 UTC **REL: 62**	
ANT13-3 PS77/026-2	08.12.2010 11:23	53° 31.22' S 0° 0.13' E 2642 m	53° 31.20' S 0° 0.23' E 2585 m @ 12:09	C-PIES #252 DCS #32 ET861 #391	09-Apr-2017 12:00 UTC **REL: 60**	
ANT14-1 PS77/034-1	10.12.2010 04:15	56° 55.71' S 0° 0.01' W 3673 m	56° 55.60' S 0° 0.10' W 3582 m @ 06:15	PIES #191 no DCS ET861 #638	10-Apr-2017 12:00 UTC **REL: 63**	
ANT15-2 PS77/042-2	11.12.2010 18:51	59° 2.37' S 0° 5.29' E 4647 m	59° 2.39' S 0° 5.52' E 4590 m @ 20:30	PIES #189 no DCS ET861 #614	11-Apr-2017 12:00 UTC **REL: 61**	near AWI-227
ANT17-1 PS77/053-1	14.12.2010 23:45	64° 0.70' S 0° 2.72' W 5201 m	no reception	PIES #125 no DCS ET861 #601	12-Apr-2017 12:00 UTC **REL: 61**	vmADCP current 0.15 kn to SW

PIES recoveries

During ANT-XXVII/2, 6 of 9 PIES were recovered successfully (plus 1 PIES by S.A. Agulhas), whereas 3 PIES could not be recovered (Table 3.1.5).

All PIES were acoustically released by a mobile EG&G 8011A deck unit connected to a hydrophone lowered over the side of the vessel. Release commands were repeated 6-7 times with 2 minutes spacing to ensure that the PIES is not blocked during its own measurement schedule, and to re-trigger release execution after possible resets. Due to the high underwater noise level of *Polarstern*, acknowledge pings of the PIES were never detected with the exception of the shallowest position ANT15-1. In all but the first PIES ANT3-2, an iXSEA ET861 Transponder aided the underwater location of the moorings by the ship's Posidonia device (albeit with significant scatter in position estimates; see Technical Report (Posidonia) in Appendix 5). After ascending to the surface with about 0.8 m/s, the PIES were located by VHF direction finder, visually spotted, and taken on board with a kedge anchor thrown across the floating line between PIES and Posidonia transponder.

The southernmost PIES ANT15-1 surfaced in loose sea ice, but could be recovered without problems.

At ANT3-2, ANT4-1 and ANT10-1, the PIES did not surface. Acoustic replies from either PIES or Posidonia were not detected; no VHF signals were received either. After 1 hr 30 min waiting time, the PIES were released again. At ANT4-1, an additional helicopter search was terminated without any results. After 6 hours *Polarstern* departed from the station sites; the PIES are most likely lost.

PIES deployments

At all 9 positions on the GoodHope section, new or refurbished PIES were redeployed, plus 5 new deployments for improved spatial resolution of the main frontal zones of the ACC (Table 3.1.6). All PIES were firmly seated in a steel stand, and deployed free-falling. The steel stand ensures a stable position on the ground important for accurate pressure records. 50 m above the PIES, an ET861 Posidonia transponder, and an acoustic current meter (in some cases) for underwater location and local current measurements are attached to a floating line.

All but one deployment were successful in the sense that the PIES remained at the seafloor; it could not be verified, if the instrument is operating correctly was because of the underwater noise level of *Polarstern* which prevents the detection of any pings transmitted by the PIES. At ANT4-2, Posidonia detected the PIES ascending to the surface immediately after hitting the sea floor; it was taken on board and not deployed again in order to reliably solve the apparent mechanical problems of the release. For all following deployments (ANT5 to ANT17), the mooring design was modified ensuring that the PIES release is not over-stressed (see below).

The two optional PIES in the Weddell Sea included in the cruise plan were not deployed as the 3 lost and several significantly damaged PIES reduced the number of intact spare instruments to just one.

Tab. 3.1.6: PIES deployments by *Polarstern* in December 2010. All positions except ANT15 and ANT17 are at Topex/Jason crossovers. The Posidonia positions are best estimates based on analysis of all 10 second fixes for scattering artefacts and consistency with launch position and vmADCP current speed and direction. They may differ slightly from the positions noted in the bridge protocol which are based on an ad-hoc analysis of the Posidonia readings. vmADCP (vessel-mounted Acoustic Doppler Current Profiler) current speeds averaged from 100 – 200 m depth give a rough estimate of possible mooring displacement during deployment are stated where no Posidonia signals were received.

Mooring ID Station book (deployment)	**Deployment date/time [UTC]**	**Deployment position (GPS) Depth (DWS)**	**Final position (best estimate from Posidonia)**	**PIES SN DCS SN Posidonia SN**	**PIES Auto-release date, REL code**	**Remarks**
ANT3-3 PS77/013-3	30.11.2010 06:31	37° 5.84' S 12° 45.23' E 4904 m	*37° 05.80‘ S 12° 45.48‘ E 5000 m @07:40*	PIES #058 no DCS ET861 #637	31-Mar-2017 12:00 UTC **REL: 58**	Posidonia uncertain, GPS depl. position better
ANT4-2 PS77/014-3	01.12.2010 10:13	39° 12.71' S 11° 19.57' E 5139 m	39° 12.81' S 11° 19.88' E 4438 m @ 11:32	PIES #069 no DCS ET861 #469	01-Apr-2017 12:00 UTC **REL: 5**	Releaser failed, recovered at 13:14 **Deployment failed**
ANT5-3 PS77/015-3	02.12.2010 08:05	41° 9.77' S 9° 55.31' E 4624 m	41° 9.74' S 9° 55.34' E 4601 m @09:29	C-PIES #182 no DCS ET861 #469	02-Apr-2017 12:00 UTC **REL: 54**	C-PIES, but without DCS
ANT6-1 PS77/016-1	02.12.2010 22:17	42° 58.80' S 8° 30.15' E 3930 m	42° 58.76‘ S 08° 30.00‘ E 3871 m @01:00	PIES #069 no DCS ET861 #384	01-Apr-2017 12:00 UTC **REL: 5**	
ANT7-4 PS77/017-2	03.12.2010 18:37	44° 39.73' S 7° 5.15' E 4593 m	44° 39.65‘ S 07° 05.25‘ E 4500 m @22:20	C-PIES #181 DCS #750 ET861 #639	03-Apr-2017 12:00 UTC **REL: 53**	
ANT8-1 PS77/018-1	04.12.2010 14:55	46° 12.97' S 5° 40.23' E 4786 m	46° 12.95' S 5° 40.17' E 4760 m @17:40	C-PIES #183 DCS #751 ET861 #616	04-Apr-2017 12:00 UTC **REL: 55**	
ANT9-3 PS77/019-2	05.12.2010 10:20	47° 39.87' S 4° 15.22' E 4541 m	no reception	C-PIES #251 DCS #26 ET861 #602	05-Apr-2017 12:00 UTC **REL: 59**	vmADCP current 0.25 kn to NE
ANT10-2 PS77/020-2	06.12.2010 03:58	49° 0.77' S 2° 50.05' E 4056 m	no reception	C-PIES #250 DCS #31 ET861 #617	06-Apr-2017 12:00 UTC **REL: 58**	vmADCP current 0.25 kn to E
ANT11-4 PS77/021-3	07.12.2010 00:13	50° 15.45' S 1° 25.18' E 3901 m	50° 15.33' S 1° 25.00' E 3846 m @ 01:22	C-PIES #249 DCS #24 ET861 #385	07-Apr-2017 12:00 UTC **REL: 57**	
ANT12-1 PS77/022-1	07.12.2010 10:52	51° 25.15' S 0° 0.24' E 2713 m	51° 25.23' S 0° 0.42' E 2654 m @ 11:41	PIES #062 no DCS ET861 #612	08-Apr-2017 12:00 UTC **REL: 62**	
ANT13-3 PS77/026-2	08.12.2010 11:23	53° 31.22' S 0° 0.13' E 2642 m	53° 31.20' S 0° 0.23' E 2585 m @ 12:09	C-PIES #252 DCS #32 ET861 #391	09-Apr-2017 12:00 UTC **REL: 60**	
ANT14-1 PS77/034-1	10.12.2010 04:15	56° 55.71' S 0° 0.01' W 3673 m	56° 55.60' S 0° 0.10' W 3582 m @ 06:15	PIES #191 no DCS ET861 #638	10-Apr-2017 12:00 UTC **REL: 63**	
ANT15-2 PS77/042-2	11.12.2010 18:51	59° 2.37' S 0° 5.29' E 4647 m	59° 2.39' S 0° 5.52' E 4590 m @ 20:30	PIES #189 no DCS ET861 #614	11-Apr-2017 12:00 UTC **REL: 61**	near AWI-227
ANT17-1 PS77/053-1	14.12.2010 23:45	64° 0.70' S 0° 2.72' W 5201 m	no reception	PIES #125 no DCS ET861 #601	12-Apr-2017 12:00 UTC **REL: 61**	vmADCP current 0.15 kn to SW

Technical remarks on PIES recoveries and deployments

The reasons for the three unsuccessful recoveries are unclear. Hardware, firmware, battery, VHF/flashlight module, or leakage problems are not known to affect these particular PIES, but cannot be excluded. However, it appears unlikely that the Posidonia transponder at ANT4-2 and ANT10-1 failed concurrently, which suggests that the PIES have left their position unnoticed. Although PIES have been deployed by AWI in the ACC since 2002 with a largely similar mooring design, some critical issues were identified based on the experiences of this cruise:

- Over-stressing of the releaser anode wire during deployment: At ANT3-3, a loose wire connection was noted prior to deployment; the release was exchanged. However, a similar production error may have occurred in previous years. Further, when the stand hits the ground with higher speeds, the wire may be pulled out of the release pin supporting the 40 kg anchor weight (this occurred at ANT4-2). Without prolonged Posidonia control (not done in 2008) the re-ascent of the PIES would go unnoticed, as the VHF module is triggered only by a release command, and not an accidental drop of the anchor weight.
- Corrosion: the anchor weight might be lost if two welds corroded, freeing the PIES when it is not secured with an additional safety line to the stand. This scenario applies to ANT4-1 and ANT10-1 only. PopUp data from ANT10-1 which suddenly end at 30-Dec-2009 might suggest that this PIES dropped its anchor end of 2009.
- Stand tipped over: In case of steep bottom topography or strong currents, the stand may have landed on its side. Data from ANT5-2 suggest that such a scenario is possible (Fig. 3.1.15).

All PIES deployed during ANT-XXVII/2 have an additional safety line securing it directly to the stand. Beginning with deployment ANT5-3, all release anode wires were stress-tested, and the PIES attached with a short Kevlar wire directly to a fixed cross bar instead of a freely hanging anchor weight, reducing the peak load when the stand lands on the sea floor. The overall weight of the stand and anchor weight assembly was reduced by about 30 kg to 92 kg (for C-PIES with Aanderaa DCS current meter, Posidonia and 17” float, buoyancy 10+17+28 kg) or 64 kg (PIES + Posidonia only, buoyancy 10+17 kg). This weight reduction effected a slower descent (0.95 m/s instead of 1.25 m/s, as observed by Posidonia). For further details, refer to Technical Report (PIES) in the Appendix 6.

Preliminary results

Assessment of data quality

Most of the 7 PIES recovered by *S.A. Agulhas* and *Polarstern* operated flawlessly over the entire deployment period of 2 – 4 years (with ANT539-1 being the longest AWI PIES deployment so far). Pressure accuracy and drift is within accepted range of the sensor; also acoustic travel time yields plausible results at most instruments. There are, however, a few exceptions:

At ANT5-2 (Fig. 3.1.15), pressure values exhibit a sudden jump to 0.99 dbar smaller values on 13 October 2008. From this moment, acoustic travel times are rather good, whereas before, only 20 % of all pings recorded a (widely scattered) surface echo. A plausible scenario is that the PIES stand lay on its side until October2008, but was eventually uprighted by the buoyancy pull of the Posidonia transponder, combined with a favourable current direction and speed.

C-PIES #184 at ANT7-3 collected no valid data; resetting and communication on RS232 was impossible. Inspection revealed about 20 cm3 of seawater inside which entered (at least partially) through the equator seal of the PIES. The system battery was dead, with one Lithium cell blown up. The log file showed that the PIES started resetting itself just 20 min after its deployment, likely due to low voltage after a shortcut, and stopped operation shortly later.

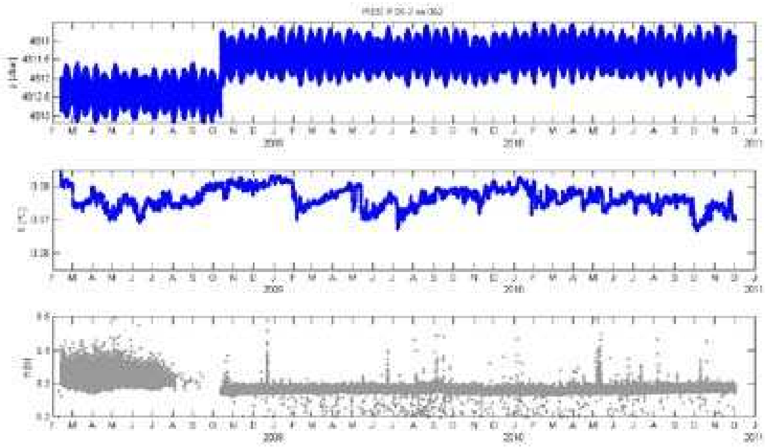


Fig. 3.1.15: Raw pressure, bottom temperature and travel time data from ANT5-2. First part of time series may indicate that the PIES lay on its side. The scattered travel times in this period represent only 20% of all pings; for the remaining 80% the PIES detected no echo.

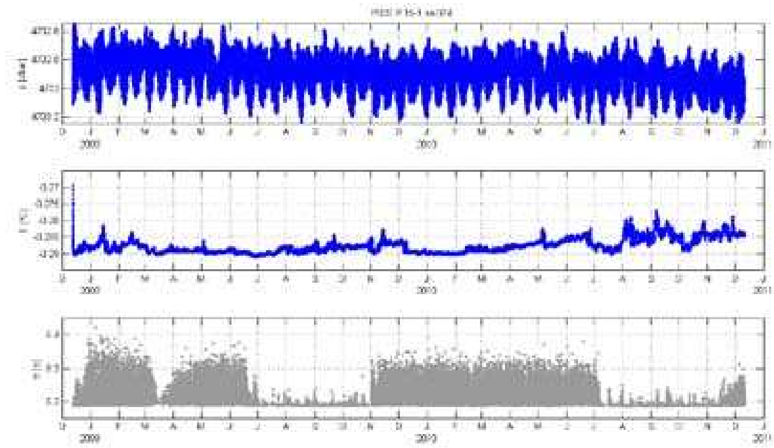


Fig. 3.1.16: Raw pressure, bottom temperature and travel time data from ANT15-1. Scattered travel times may indicate sea ice coverage. Bold lines indicate 7 day low-passed values.

Recovery of ANT10-1 failed. Fortunately a PopUp buoy (receiving data from the PIES via an IrDA link) surfaced as scheduled on 11 April 2010, and transmitted daily averaged pressure and travel time data covering the period from deployment until 30 December 2009, when obviously the PIES died or left the stand.

PIES 113 at ANT9-3 delivered travel times scattered between the actual travel time and the shorter lockout time (not shown). Further inspection is necessary if this is caused by incorrect output level, or electronic problems in the echo detection. The southernmost PIES at ANT15-1 show temporarily more scattered travel times (Fig. 3.1.16). This may be related to sea ice coverage and is to be compared with satellite sea ice data. Nevertheless, even the more scattered portions of ANT9-3 and ANT15-1 travel times contain a sufficient percentage of “real” travel times to facilitate oceanographic data analysis.

ACC temperature and transport variability

The 6 PIES recovered from the GoodHope section cover most of the ACC, resolving the Subantarctic, Polar and Southern ACC Fronts (SAF, PF, and SACCF, respectively). Unfortunately, due to the loss of ANT3-2 and ANT4-1, the Subtropical Front (STF) is not covered (for front positions, see Orsi et al., 1995).

Acoustic travel times depend on sound speed and thus temperature. By assigning OBP/travel time measurements to the known range of temperature/salinity profiles across the ACC (warm = short travel times in the north; method known as Gravest Empirical Mode, GEM; Meinen and Watts, 1998), time series of full T/S profiles are obtained at each PIES position. Preliminary results are shown in Fig. 3.1.17, indicating a consistent seasonal cycle of average upper 2,000 m temperature at 37°S ranging from 7°C to 8°C, and more constant temperatures close to 0°C at 59°S (Fig. 3.1.17 top). Dynamic height anomalies at the northern position are 1.3 m above those at 59°S (c.f. Swart et al., 2008) with a prominent seasonal cycle (Fig. 3.1.17 centre), as does the baroclinic transport (Fig. 3.1.17 bottom). The 1.3 m dynamic height difference is smaller than the 1.7 m SSH slope observed by Jason altimetry (MADT data obtained from Aviso; not shown), which agrees with the fact that a large part of the ACC transport is indeed barotropic.

The barotropic component is inferred from the pressure data of the PIES. All pressure time series were corrected for the sensor drift by an empirical exponential-linear fit. From pressure difference anomalies between the moorings, barotropic transport variability of the ACC can be calculated applying geostrophic balance. Preliminary analysis reveals barotropic transport variations between 37°S (ANT5-2) and 59°S (ANT15-1) of ±40 Sv for 7 day low passed data. On seasonal time scales transport varies by about 20 Sv, with indications of lower values in austral summer, somewhat balancing the increased baroclinic transport in this period.

Further analysis is required to resolve the contributions of the individual fronts to the overall ACC transport, and its relation to wind stress, Southern Annular Mode (SAM) and climate variability. Absolute barotropic and baroclinic transport time series covering the period from 2002 to 2010 will be obtained by referencing the travel-time derived dynamic height anomalies to satellite altimetry and PIES-observed ocean bottom pressure.

The OBP records are also to be used in validation of GRACE gravity field estimates. Previous studies (Macrander et al., 2010) suggest that in the predominantly barotropic Southern Ocean, GRACE indeed captures about 80% of the actual large-scale OBP variability on monthly timescales.

Finally, bottom temperature records may support analysis of local variability and long-term changes in Antarctic Bottom Water properties inferred from repeat hydrography on the Greenwich meridian.

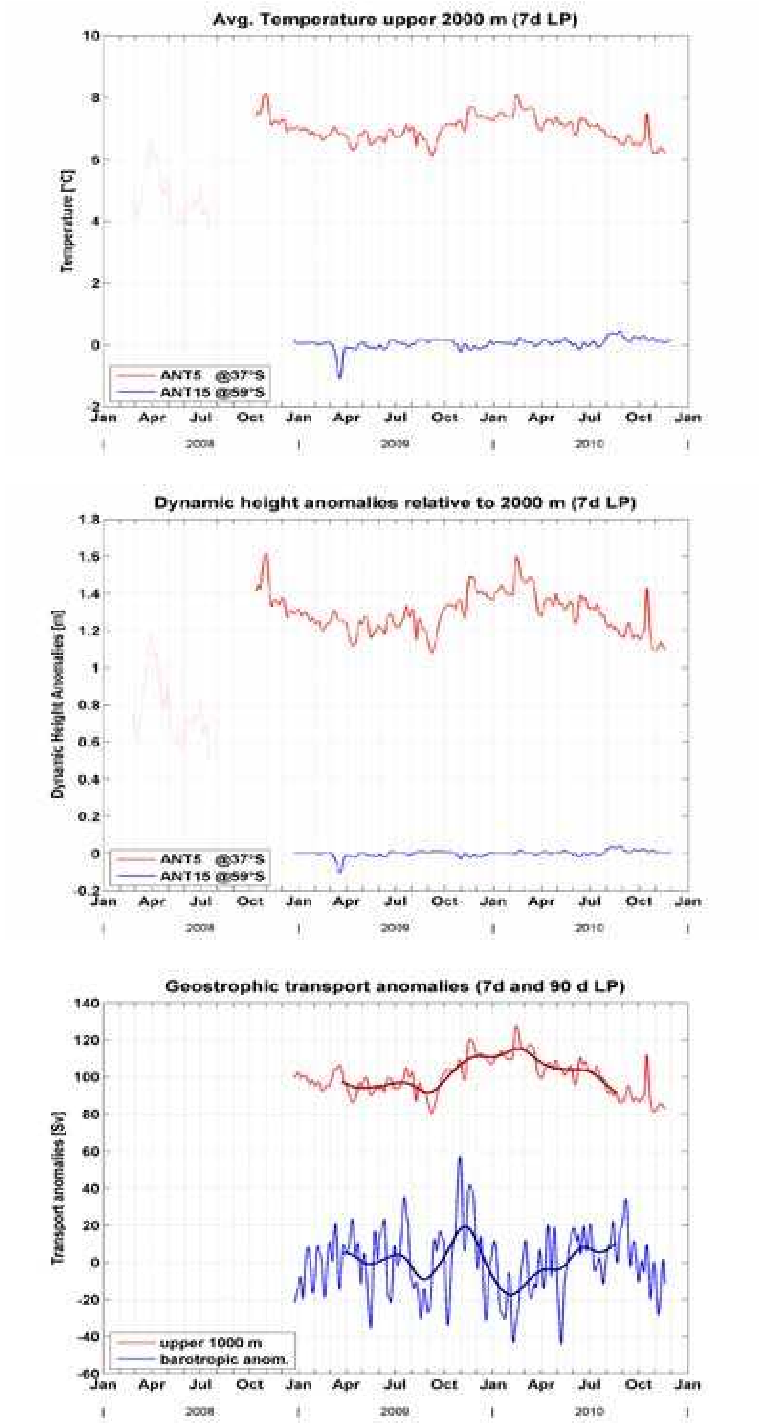


Fig. 3.1.17: 7 day low passed average temperature of upper 2,000 m (top), dynamic height relative to 2,000 m (centre). Red: PIES ANT5-2 at 37°S, blue: PIES ANT15-1 at 59°S. Bottom: Geostrophic transport anomalies (red: baroclinic, blue: barotropic). Note that for clarity baroclinic transport of upper 1,000 m is shifted by 100 Sv. Bold lines denote 90 day low passed values.

Long-term data storage and access

All PIES data are to be error checked, pressure drift corrected and validated with adjacent CTD profiles taken during deployment and recovery. The data are accessible by contacting Andreas Macrander or Olaf Boebel at AWI, and will be made available in the Pangaea database at AWI within one year of this cruise.

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3.1.5 Argo in the Southern Ocean

Objectives

The international Argo-project maintains order of 3,000 profiling floats distributed throughout the world ocean, to establish a real-time operational data stream of mid- and upper (< 2,000m) ocean temperature and salinity profiles. In addition, the array provides the mid-depth oceanic circulation pattern. During the past years, the AWI pushed technological developments to extend the operational range of Argo floats into seasonally ice-covered regions. To this end and with additional support by the EU projects MERSEA and EURO-ARGO as well as the BMBF Project German Argo, the NEMO float (Navigating European Marine Observer) has been developed and tested, which is now fully operational (Klatt et al., 2007). NEMO floats are equipped with ISA-2, an ice-sensing algorithm which triggers the abort of a floats' ascent to the sea surface when the presence of sea ice is likely as determined from the existence of a layer of near surface winter water. Nevertheless to be able to (retrospectively) track the floats that actively remained under sea ice, acoustic tracking via RAFOS (Rossby et al., 1986) (Ranging And Fixing Of Sound) is used in by means of an array of 10 moored sound sources.

Work at sea

Deployment of Argo floats

It was planned to deploy 40 Argo Floats of different types and from different manufactures, i.e. 25 NEMO (Navigating European Marine Observer, produced by

Optimare, Germany) and 15 Apex floats (produced by TELEDYNE Webb Research, USA), for details see Table 3.1.7. Two NEMO floats indicated technical problems; a) Nemo 135 (#2 in Table 3.1.7) did not successfully finish the start-up self test; b) the sleeve bladder of NEMO 155 (#5) was not filled properly. Hence both floats were not deployed.

Table 3.1.7: Number and characteristic of the Argo floats deployed during ANT- XXVII/2

#	Planed Quantity (deployed)	Trade Name	Sat. Com.	RA-FOS	Oxygen	Prototype Light-sensor	appropriated
1	8 (8)	NEMO	Iridium	Y	Y		AWI
2	5 (4)	NEMO	Iridium	Y	-	Y	AWI
3	7 (7)	NEMO	Iridium	Y	-	-	AWI
4	2 (2)	NEMO	ARGOS	Y	-	-	BSH
5	3 (2)	NEMO	ARGOS	-	-	-	BSH
6	8 (8)	Apex	ARGOS	-	-	-	BSH
7	7 (7)	Apex	ARGOS	-	-	-	KNMI

NEMO

During ANT-XXVII/2 a remaining number of 23 NEMO floats were deployed, consisting of 19 Iridium floats and four ARGOS floats provided by Bundesamt für Seeschifffahrt und Hydrographie (BSH). All NEMO floats are equipped with an adjustable Ice Sensing Algorithm (ISA-2), set to 1.79°C with a ‘retarded‘ response. However, the later feature has been disabled in order to reduce the possibility of firmware induced defects. Interim data storage (iStore) stores any profiles that could not be transmitted in real time due to ISA aborts and transmits these profiles during ice-free condition. The floats were ballasted to drift at a drift depth of 800 m and will acquire profiles from 2000 m upwards. All float launches were preceded by a CTD cast.

A software bug affected all NEMO Iridium floats – which accidentally brought the floats into sleep conditions – was detected only after the deployment of the second Iridium float. Subsequently, all remaining NEMO Iridium floats (i.e. 17) were successfully updated with new firmware: Version: 15.09.2010; Bugfix-Version: 01.

Apex

In addition 15 Apex floats were deployed, seven have been provided by Koninklijk Nederlands Meteorologisch Instituut (KNMI), eight by Bundesamt für Seeschifffahrt und Hydrographie (BSH). The KNMI (BSH) floats were ballasted to drift at a depth of 1,000 m (1,500 m) and will acquire profiles from 2,000 m upwards. All instruments use ARGOS-system for satellite communications and were launched into the Antarctic Circumpolar Current (see Figure 3.1.18, Table 3.1.8). All Apex float launches were preceded by a CTD cast.

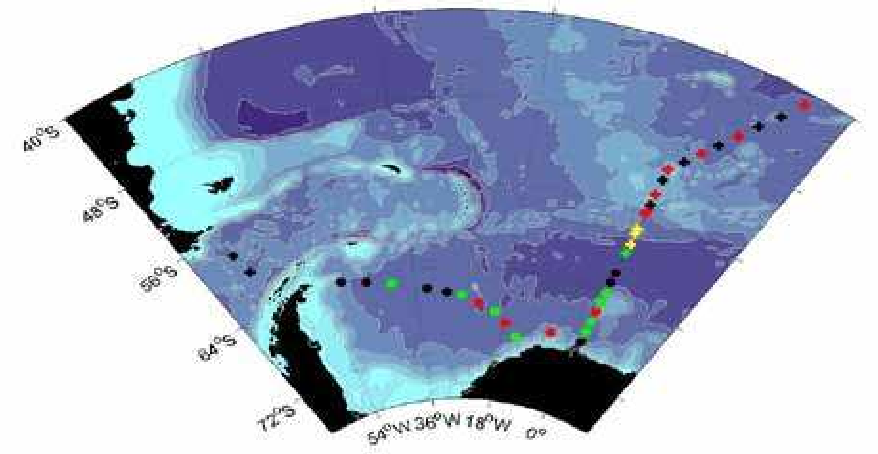

Fig. 3.1.18: Deployment positions of Argo floats. „Pluses“ indicate ARGOS floats, „dots“ Iridium floats(red plus – Apex floats (KNMI), black plus – Apex floats (BSH), yellow plus – NEMO floats (BSH), green plus – NEMO floats with RAFOS (BSH), black dots – NEMO with RAFOS, green dots – NEMO with RAFOS and Oxygen, red dots – NEMO with RAFOS and prototype light sensor).

Table 3.1.8: Deployment of Argo floats

#	Float Serial Number	Internal AWI Notation	Argos Id Dec or Iridium IMEI	Station [PS]	Latitude	Longitude	Date (UTC)	Time (UTC)
01	A5344	NL	102294	77/15	41° 9.73‘ S	9° 55.08‘ E	02.12.10	09:44
02	A5335	BSH	78149	16	42° 58.89‘ S	8° 30.14‘ E	03.12.10	01:28
03	A5336	BSH	78246	17	44° 40.10‘ S	7° 5.95‘ E	03.12.10	22:10
04	A5345	NL	102369	18	46° 13.24‘ S	5° 41.25‘ E	04.12.10	18:42
05	A5337	BSH	78257	19	47° 39.81‘ S	4° 15.32‘ E	05.12.10	14:36
06	A5346	NL	102370	20	49° 1.06‘ S	2° 50.09‘ E	06.12.10	07:19
07	A5338	BSH	78389	21	50° 15.34‘ S	1° 25.02‘ E	07.12.10	01:30
08	A5347	NL	102371	22	51° 25.21‘ S	0° 0.52‘ E	07.12.10	13:31
09	A5339	BSH	79493	24	52° 28.21‘ S	0° 0.12‘ E	08.12.10	00;18
10	A5348	NL	102372	27	54° 0.52‘ S	0° 0.26‘ W	08.12.10	19:59
11	A5340	BSH	79494	29	55° 0.35‘ S	0° 0.07‘ E	09.12.10	05:38
12	A5349	NL	102373	31	55° 30.05‘ S	0° 0.66‘ E	09.12.10	12:42
13	A5350	NL	102374	32	56° 0.02‘ S	0° 0.10‘ E	09.12.10	18:56
14	N151	BSH /141	37393	35	57° 29.53‘ S	0° 0.62‘ W	09.12.10	14:14
15	N153	BSH /142	37395	36	57° 59.67‘ S	0° 0.42‘ E	09.12.10	20:37

#	Float Serial Number	Internal AWI Notation	Argos Id Dec or Iridium IMEI	Station [PS]	Latitude	Longitude	Date (UTC)	Time (UTC)
16	N152	BSH /143	37394	42	59° 1.98‘ S	0° 6.02‘ E	11.12.10	22:24
17	N154	BSH /144	40842	45	60° 0.56‘ S	0° 1.21‘ E	12.12.10	15:29
18	N138	145	3000 340 130 05970	49	61° 57.76‘ S	0° 2.54‘ E	13.12.10	19:43
19	N143	146	3000 340 123 99640	51	62° 59.76‘ S	0° 0.43‘ W	14.12.10	11.07
20	N133	147	3000 340 130 28620	53	63° 59.66‘ S	0° 2.97‘ W	15.12.10	16:41
21	N130	148	3000 340 123 94640	56	65° 1.21‘ S	0° 0.88‘ W	16.12.10	06:11
22	N148	149	3000 340 130 21620	58	66° 0.46‘ S	0° 7.27‘ E	16.12.10	23:05
23	N131	150	3000 340 123 90620	61	67° 0.16‘ S	0° 0.47‘ E	18.12.10	02:35
24	N126	151	3000 340 123 97460	63	68° 0.20‘ S	0° 0.46‘ E	18.12.10	14:42
25	N137	152	3000 340 130 04980	66	69° 0.16‘ S	0° 0.34‘ E	19.12.10	10:27
26	N149	153	3000 340 130 23610	68	69° 0.00‘ S	6° 57.22‘ W	23.12.10	11:56
27	N132	154	3000 340 123 93620	76	70° 5.37‘ S	14° 30.37‘ W	26.12.10	11:24
28	N134	155	3000 340 123 96640	78	69° 3.52‘ S	17° 23.01‘ W	27.12.10	12:02
29	N129	156	3000 340 123 97640	80	68° 0.79‘ S	19° 59.54‘ W	28.12.10	05:08
30	N136	157	3000 340 130 02990	82	67° 19.72‘ S	23° 36.55‘ W	28.12.10	21:03
31	N128	158	3000 340 123 91620	84	66° 37.54‘ S	27° 5.37‘ W	29.12.10	18:34
32	N140	159	3000 340 130 02980	86	66° 18.46‘ S	29° 59.41‘ W	30.12.10	07:54
33	N139	160	3000 340 130 09980	89	65° 54.18‘ S	33° 51.69‘ W	31.12.10	03:05
34	N127	161	3000 340 123 95620	95	65° 5.96‘ S	40° 31.08‘ W	03.01.11	05:10
35	N142	162	3000 340 130 29620	100	64° 30.02‘ S	45° 0.01‘ W	04.01.11	11:40
36	N141	163	3000 340 130 03980	106	63° 52.93‘ S	49° 31.45‘ W	05.01.11	22:36
37	A5341	BSH	79496	206	59° 53.86‘ S	62° 53.41‘ W	02.02.11	00:10
38	A5342	BSH	79497	207	58° 20.56‘ S	63° 28.18‘ W	02.02.11	13:18

Installation of RAFOS Sound sources

The Ranging and Fixing of Sound (RAFOS) technology has been used widely in moderate latitudes to provide high-resolution trajectories of neutrally buoyant floats by means of underwater acoustics. It is based on travel time measurements of a coded sound signal between a moored sound source and the moving float. However, at high latitudes, this technique is expected to work at considerable shorter ranges only.

During ANT-XXVII/2, eight sound sources were recovered and nine were deployed (Tab. 3.1.18 and 3.1.19). The ninth sound source - newly developed and produced by develogic GmbH - was applied for testing purpose only at the location W11 (AWI 244), see Figure 3.1.19.

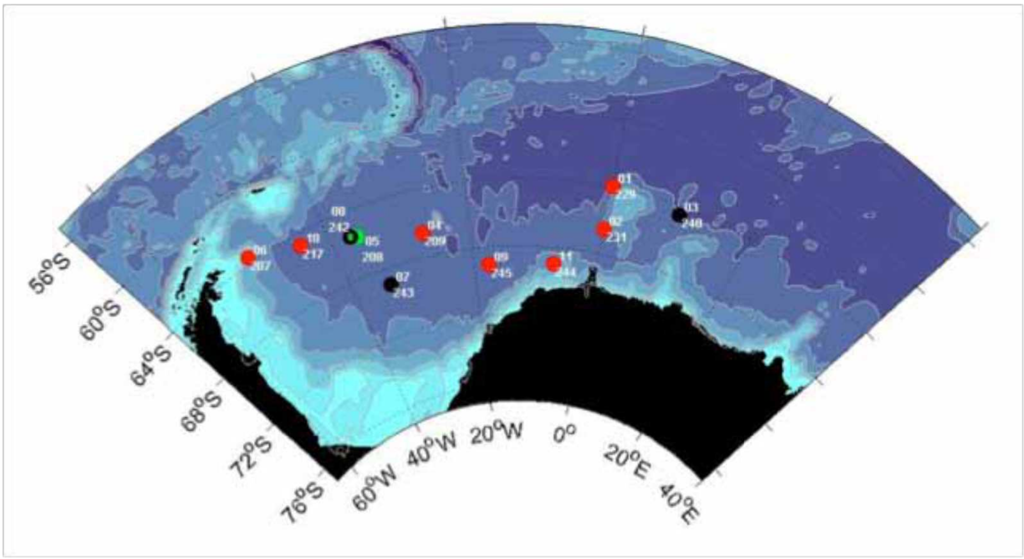

Fig. 3.1.19: Current state of the Weddell Sea RAFOS array. Red dots depict positions where sound sources were deployed or redeployed during ANT XXVII-2, the black circle shows the position of sound source W8, which was only recovered (no redeployment), the green circle shows the position of sound source W5, which was mere deployed (no recover). The black dots represent positions sound sources deployed during earlier cruises.

With the exception of the sound source W6 at AWI-207 all recovered instruments were redeployed during the cruise (see Table 3.1.8). For this purpose the shackles and chains were changed at all sources. The Rossby sources were farther refurbished with new batteries (including the regeneration of vacuum) and the exchange of the electronics of R27 and R34.

No additional maintenance has been applied to Webb sources except the change of the two 9V blocks for communication of W24.

Table 3.1.8: Sound sources recovered

site / mooring **pong time**	**position** **water depth** **recovery date**	**sound source status**
W1d / 229-8 00:30 GPS	63° 58.03'S 00° 03.10'W 5195 m 15 Dec 2010	R29 @ 820m; piggy-back, aluminum resonator RTC 09:40:26 @ GPS 09:49:00 à 514s late general status at recovery: ok
W2d / 231-8 01:00 GPS	66° 30.68'S 00° 01.81'W 4547 m 17 Dec 2010	R30 @ 925m; piggy-back, aluminum resonator RTC 07:38:30 @ GPS 07:42:58 à 268s late general status at recovery: ok
W4b / 209-5 01:30	66° 36.89'S 27° 07.08'W 4860 m 29 Dec 2010	R34 @ 837m; piggy-back, aluminum resonator No time check general status at recovery: resonator ok; electronic defective
W6b / 207-7 01:00	63° 42.74'S 50° 50.55'E 2500 m 06 Jan 2011	R 36 @ 805m; piggy-back, aluminum resonator with electronics R 19 RTC 09:49:17 @ GPS 09:48:00 à 77s early general status at recovery: ok
W8b / 207-7 01:00	63° 42.74'S 50° 50.55'E 2500 m 06 Jan 2011	R 27 @ 825m; piggy-back, aluminum resonator No exact time check due to bat. discharge, approx. RTC 09:14:00 @ GPS 09:00:00 à ~900s early general status at recovery: ok, electronic was changed for further use because of large time offset
W9a / 245-1 01:10 GPS	69° 03.68'S 17° 25.89'W 4766 m 27 Dec 2010	W 24 @ 800m; piggy-back design Bat=+00402dV Vac=+00069 general status at recovery: ok ready for redeployment
W10a / 217-3 00:40 GPS	64° 23.63'S 45° 52.38'W 4456 m 04 Jan 2011	R 32 @ 836m; piggy-back, aluminum resonator RTC 15:08:47 @ GPS 15:08:00 à 47s early Internal Pressure: 1025 hPa (sensor faulty, manual vacuum check ok) general status at recovery: ok
W11a / 244-1 00:40 GPS	68° 59.70'S 06° 56.70'W 2927 m 23 Dec 2010	Webb 23 @ 799 m; piggy-back RTC 08:25:33 @ GPS 08:25:26 à 7s early Bat=+00406dV Vac=+00083 general status at recovery: ok

Table 3.1.9: Sound source moorings deployed during ANT-XXVII/2. Sound source depths are nominal depth according to preliminary mooring protocols.

site / mooring pong time	position water depth deployment date	sound source status
W1e / 229-9 00:40 GPS	63° 59.65'S 00° 02.65'W 5170 m 15 Dec 2011	R 19 @ 807m with electronic 18 (as planed) piggy-back design, aluminum resonator
W2e/ 231-9 01:10 GPS	66° 30.71'S 00° 01.51'W 4517 m 17 Dec 2010	R 29 @ 811m; former position W1 piggy-back design, aluminum resonator
W4c / 209-6 01:00 GPS	66° 36.70S 27° 07.31'W 4860 m 29 Dec 2010	W 23 @ 808m; redeployed W11 piggy-back design, maintenance: replacement of the two 9V blocks, vacuum rene-wed; Bat=+00407dV, Vac=+00049
W5b / 208-6 00:40 GPS	65° 37.04'S 36° 25.28'E 4740 m 01 Jan 2011	R 34 @ 861 m; former position W4 with electronics R 29; piggy-back design
W6 c/ 207-8 01:10 GPS	63° 43.07'S 50° 49.91'W 2500 m 06.01.2011	R 32 @ 807 m; former position W10 piggy-back design
W9b / 245-2 01:10 GPS	69° 03.52'S 17° 23.05'W 4740 m 27 Dec 2010	W 24 @ 808m; immediate redeployment of W9a piggy-back design, aluminum resonator no maintenance applied Bat=+00402dV, Vac=+00069
W10b/ 217-4 00:50 GPS	64° 23.88'S 45° 51.95'W 4416 m 04 Jan 2011	R 27 @ 836m; former W8 with electronics R 28 piggy-back design, aluminum resonator
W11b / 244-2a 00:50 GPS	69° 00.30'S 06° 58.89'W 2950 m 23 Dec 2010	R 30 @ 801m; former position W2 piggy-back design, aluminum resonator
W11b / 244-2b 00:30 GPS	69° 00.30'S 06° 58.89'W 2950 m 23 Dec 2010	Develogic 002 @ 708m; piggy-back design, tune: every 30 days starting at 24 Dec 2010, 20:00 GPS

Preliminary and expected results

The project aimed at two different goals. First, the deployment of 23 NEMO floats and the replacement of eight sound sources are part of a detailed investigation of changes in the hydrographic structure of the Weddell Sea. Second, the deployment of 15 Apex floats into the Antarctic Circumpolar Current was a joint contribution of the Netherlands and Germany to the global Argo project and increased significantly the number of active floats within this region.

References

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Rossby, T., D. Dorson, and J. Fontaine, 1986: The RAFOS-System. Journal of Atmospheric and Oceanic Technology, 3, 672-679

3.1.6 Underway measurements

Thermosalinograph

Because blocking inflow by ice occurred during most of the time when *Polarstern* was operating in ice covered areas two SBE21 thermosalinographs (TSG) were installed. One TSG was placed in the deep box keel. Here the sample was taken from 11 meters depth compared to the bow-thrusters tunnel TSG which is in about 5 m depth.

Sensor specification given by the manufacturer

SBE21; Seabird Electronics

www.seabird.com

	Temperature **SBE38 remote**	**Temperature**	**Conductivity**
Range	-5 to 35 °C	-5 to 35 °C	0 to 70 mS/cm
Accuracy	0.001 °C	0.01 °C	0.001 mS/cm
Resolution	0.0003 °C	0.001 °C	0.0001 mS/cm

Data acquisitions of both TSG were integrated in the DShip system by Werum. Water samples were taken once a day from both TSG's – bow and keel by crew members. These samples were measured with the Optimare Precision Salinometer at least every two weeks to determine the salinity correction and to identify possible sensor faults as soon as possible. By this way the TSG is in good service during the whole cruise.

The final post-processing takes place in Bremerhaven by Fielax and a few weeks after the cruise TSG data can be downloaded from Pangaea database.

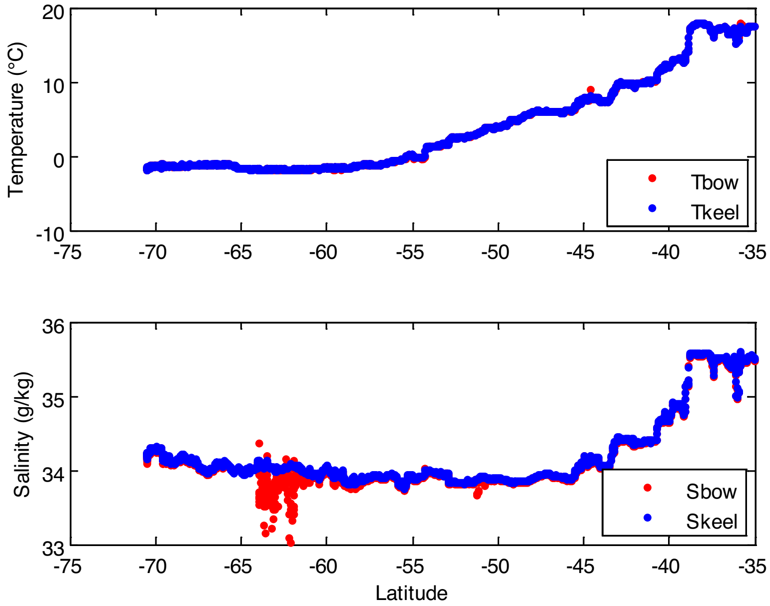

Fig. 3.1.20: Potential temperature and salinity from the underway measurements (SBE21 thermosalinograph; 5 and 11 m depth) along the Greenwich meridian

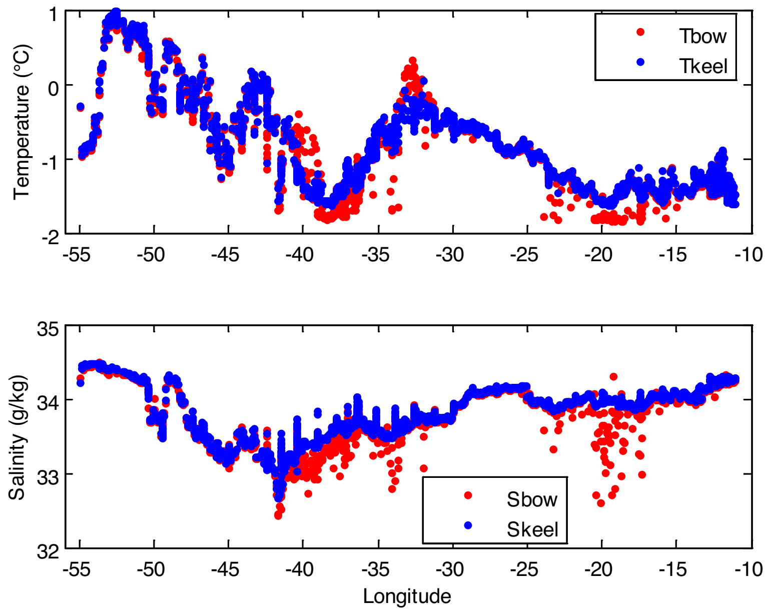

Fig. 3.1.21: Potential temperature and salinity from the underway measurements (SBE21 thermosalinograph; 5 and 11 m depth) from Kapp Norvegia towards Joinville Island

Underway measurements with a vessel mounted 150 kHz-Ocean Surveyor ADCP from RD Instruments and two SBE21 thermosalinographs from Seabird Electronics were conducted along the whole track to supply temperature, salinity and current data at a high spatial resolution (Fig. 3.1.20, and 3.1.21). The thermosalinographs are mounted in 5 m depth in the bow thruster tunnel (TSB) and in 11 m depth in the keel (TSK). Both instruments were controlled by taking water samples each day which were measured on board with the OPTIMARE Precision Salinometer (OPS). The data were corrected after the cruise according to the samples.

Data

The data from the En-route-systems will be transferred to the PANGAEA data base after final post-processing on shore.

3.2 Measurement of trace gases (CFCs, SF6; helium isotopes, neon)

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Objectives

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

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

1. to determine formation rates of WSDW and WSBW in the Weddell Basin and to quantify import and export rates of recently ventilated deep water across the Greenwich meridian;
2. to calculate the C_{ant} inventories in the Weddell Sea, especially in WSDW and WSBW;
3. to distinguish and quantify source water masses involved in the formation of WSBW;
4. to determine entrainment rates and upwelling velocities of mid-depth and subsurface water into the surface layer in the Weddell gyre.

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

Methods

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

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

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

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

Work at sea

During this cruise we used an analytical technique for the simultaneous measurements of the trace gases sulphur hexafluoride (SF6) and the chlorofluorocarbon CFC-12 in water and air. The determination of the two compounds was performed by analysis with gas chromatography with electron capture detection.

We analyzed 1,646 water samples from 98 stations as profiles for CFC-12 and SF6 along the Greenwich meridian, the Weddell Section, and on two sub-sections on the RMT grid at the western Antarctic Peninsula.

Water-samples were collected in 200 ml glass ampoules from 10 l Niskin bottles. 150 ml of this water are transferred to a water purge chamber. After purge of the water, the compounds are trapped on a 1/16” trap, packed with Carboxen 1000 and Porapak-Q. Thermal desorption of the sample gases, held in the trap are flushed onto a Porasil-C and MS5A pre-columns, where SF6 and CFC-12 are separated from nitrous oxide, and any other late eluting compounds. SF6 and CFC-12 are refocused then on a 1/16” Porapak-Q packed trap, to narrow their chromatographic peaks and enhance their detection. After thermal desorption the released gases are separated on a GS Gaspro capillary column (0.32 mm ID x 30 m). SF6 and CFC-12 are then detected by Agilent 6890 N micro-ECD.

Based on the analysis of replicate water samples, we estimate precisions of 0.4 % for SF6 and 0.5% for CFC-12. Overall accuracy, including that off the calibration scale is estimated to be 2% for SF6 and 1.6% for CFC_12. Concentrations of SF6 and CFC_12 in air, seawater samples, and gas standards are reported on SIO 98 scale, and were prepared and calibrated at CMDL, Boulder, Colorado.

480 samples on 46 stations were drawn from the CTD/rosette for stable helium isotopes (^3He, ^4He) and neon along the Greenwich meridian and the Weddell Section. On all of these stations we sampled on the fully available vertical resolution in the upper 300 meters for estimating upwelling velocities and on some stations on the Weddell section full vertical profiles for additional analysis of water mass composition.

The noble gas water samples are stored in gas tight copper tubes. The samples will be analysed later in the IUP Bremen mass spectrometry lab. After gas extraction with ultra vacuum and liquid nitrogen cooling, the samples will be analyzed with a special sector field and quadrupole mass spectrometer system.

Preliminary and Expected Results

The first results and figures for CFC-12 and SF6 below are still preliminary and might be subject to further calibrated and careful quality control.

From the CFC-12 and SF6 along the Greenwich meridian (Fig. 3.2.1 and Fig. 3.2.2) some water masses can be clearly identified. Surface water is highest in these anthropogenic trace gases due to the gas exchange with the atmospheric source. In the northern part old and tracer poor Circumpolar Deep Water penetrates almost down to the Mid Atlantic Ridge. On the slope of the Mid Atlantic Ridge in 4,500 m depth a signature of recently ventilated Weddell Sea Deep Water can be seen. Also on the slope of the Antarctic Continent and near Maud Rise the tracer concentrations are elevated, indicating the inflow of recently ventilated water into the Weddell Sea from an easterly source. However, the centre of this deep boundary current (from previous observations we expect the centre at around 2,500-3,500 m on the slope) might not be fully resolved, since we had to leave the section earlier and missed to sample shallower profiles. The centre of the entire section is poor in tracer due to its slow renewal from deeper waters.

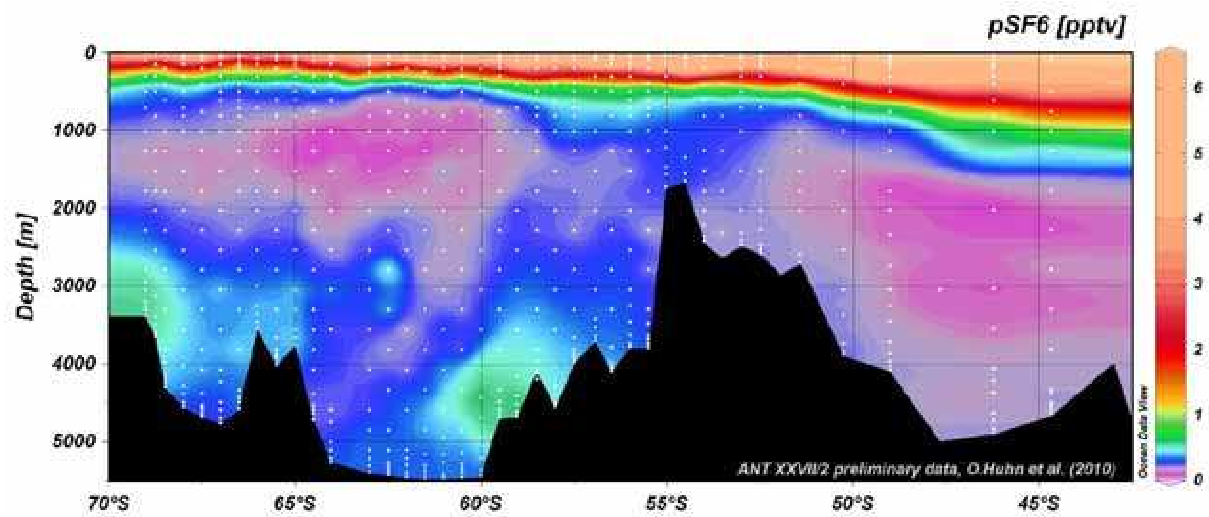

Fig. 3.2.1: Preliminary SF6 partial pressure along the Greenwich meridian section

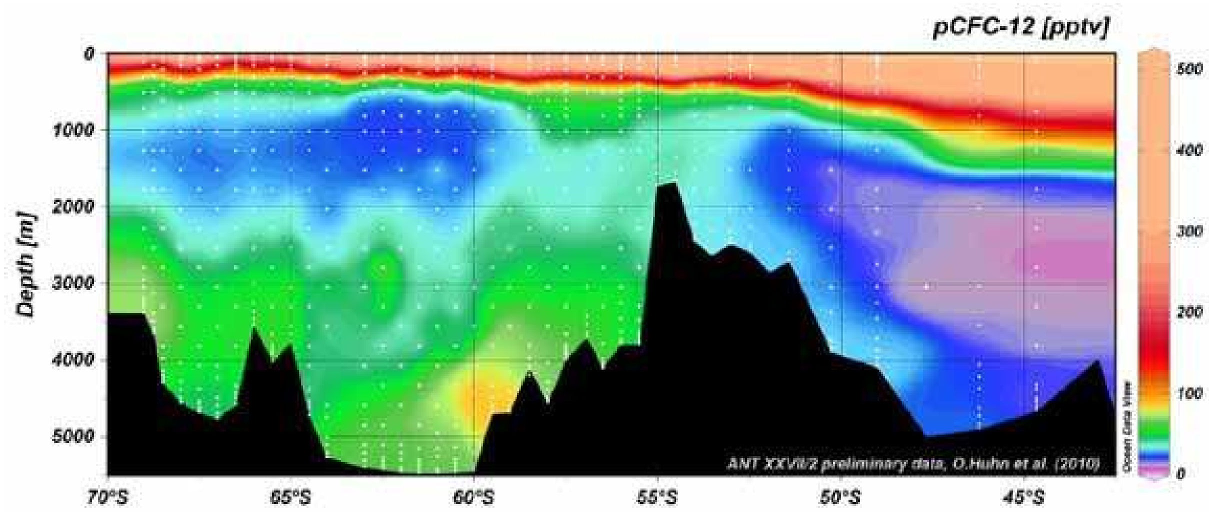

Fig. 3.2.2: Preliminary CFC-12 partial pressure along the Greenwich meridian section

Along the Weddell Sea section (Fig. 3.2.3 and Fig. 3.2.4), in the eastern part, we can identify the same deep boundary current as in the southern part of the Greenwich meridian section in about 3,500 m depths. However, this signal of elevated tracer concentrations, particularly identifiable in SF6, penetrates far into the basin, indicating strong horizontal mixing or branching of that water into the central basin. In the central and western deep basin, confined to the bottom, we see higher concentrations, indicating ventilated Weddell Sea Bottom Water which might has its origin in the southern Weddell Sea. Clearly separated from that, and much higher in concentrations, is the Weddell Sea Bottom Water on the slope of the Antarctic Peninsula. Here, the partial pressure reaches up to 25% of surface water partial pressure. This water is the most likely formed nearby, e.g. at the western Antarctic Peninsula.

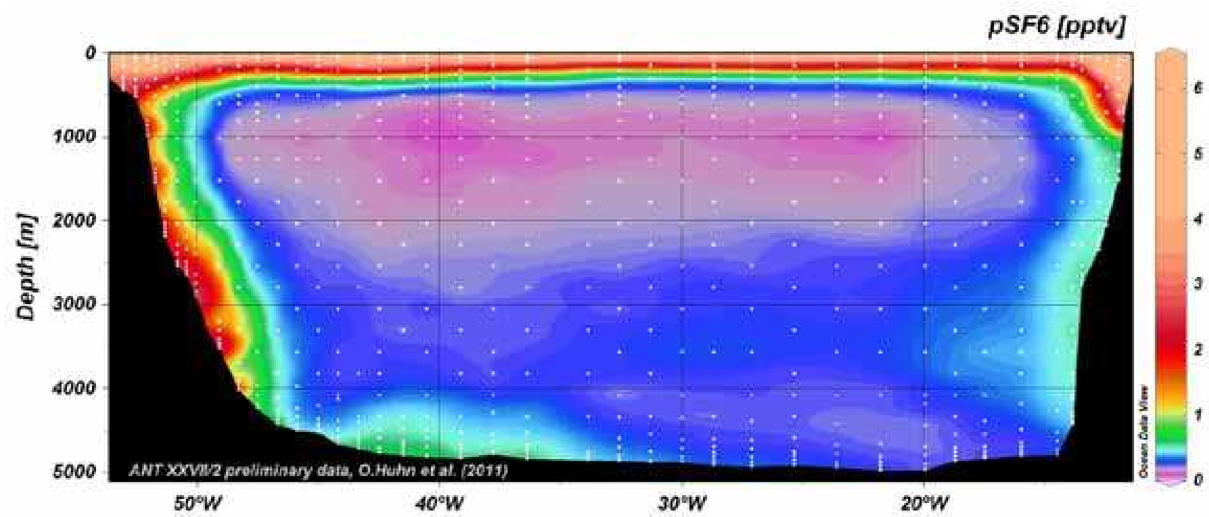

Fig. 3.2 3: Preliminary SF6 partial pressure along the Weddell Sea section

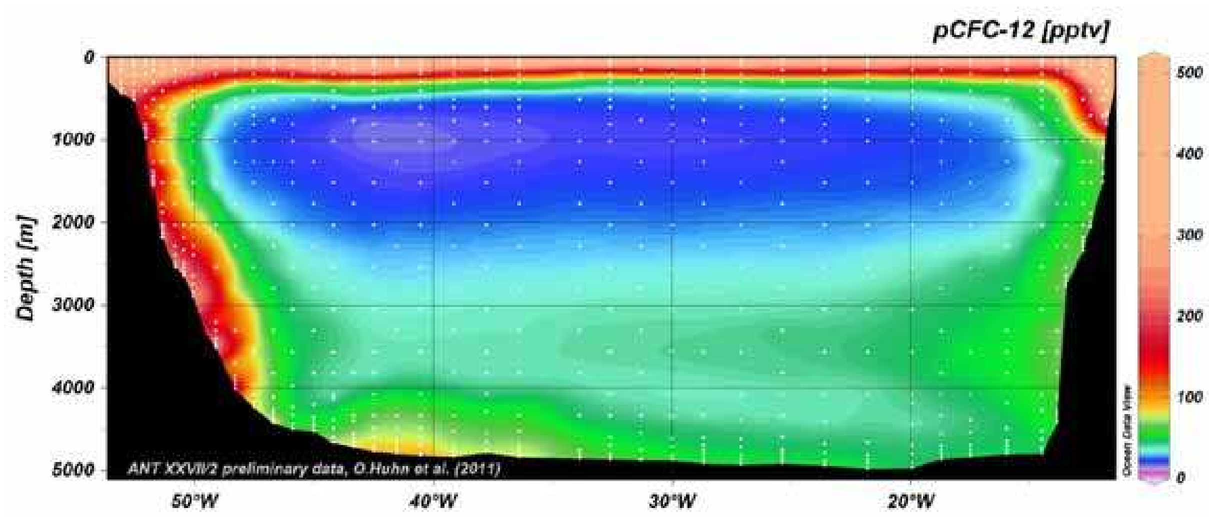

Fig. 3.2.4: Preliminary CFC-12 partial pressure along the Weddell Sea section

These measurements extend our times series of tracer measurements and will allow determining deep and bottom water formation rates and pathways of recently ventilated water masses and a better estimate of transit time distributions to assess the amount of anthropogenic carbon in the Atlantic sector of the Southern Ocean. In comparison with previous measurements they will allow to investigate temporal changes in water mass distribution and formation rates. Particularly the comparison of CFC-12 with the more recently present and steeper in the atmosphere increasing SF6, and hence in the ocean interior, will allow assessing the contribution of advection and horizontal mixing to the transport in the inner ocean.

The helium and neon samples have to be analyzed after arriving in our home lab. The data will be most likely available within summer 2011. From these measurements with the high vertical resolution in the surface near layers we expect to determine entrainment rates and upwelling velocities of deeper water into the surface layer. In addition, the few full profiles from the Weddell Section will allow us to quantify contributions of glacial melt water to recently formed Weddell Sea Bottom Water.

3.3 Radiocarbon sampling in the southern circumpolar current, Weddell Sea and west of the Antarctic Peninsula

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Objectives

Radiocarbon has proven to be a useful chemical tracer for large-scale ventilation and mixing. Naturally occurring radiocarbon is used to study mixing and ventilation processes in deep and abyssal waters. Radiocarbon produced by atmospheric bomb tests in the past is used for similar studies in the upper water column. The change in bomb radiocarbon distribution over the past 10-20 years is proving to be an extremely useful diagnostic for global climate change models. An oceanographic section of radiocarbon in the Weddell Sea was last collected on *Meteor* cruise 11/5 in 1990. We expect to find dramatic changes in the distribution. Near-surface concentrations will have decreased as the bomb transient moves deeper into the water column. Increased concentrations in bottom and deep waters are likely. Those earlier data showed evidence of deep (not bottom) water formation at some locations. We will be particularly interested to see if these features still exist. Additionally, the data from this cruise will be matched up with those collected on the U.S. occupation of the A13.5 line along the Greenwich meridian in the north earlier in 2010, to make a complete section across the southeastern Atlantic.

Work at sea

Full water column sampling for radiocarbon at 14 stations was done along the Greenwich meridian and across the Weddell Sea; stations 35, 50, 61, 66, 77, 81, 91, 94, 97, 100, 105, 110, 120 and 123. These are deep stations except for the last ones near the eastern side of the Antarctic Peninsula, which are supposed to catch the signal of newly formed Weddell Sea Bottom Water and shelf water. Samples of one-half liter of water were taken and approximately the same amount was used for rinsing prior to collection. Each sample was poisoned with 100 μl of a saturated $HgCl_2$ solution and sealed with grease to prevent contamination. The samples will be returned to the National Ocean Sciences Accelerator Mass Spectrometry (NOSAMS) facility at Woods Hole Oceanographic Institution, U.S.A., for analysis. All results will be available within one year after the samples are returned and the final results will be made public immediately. Radiocarbon samples were collected from the same Rosette bottles sampled for Total CO_2 and total alkalinity analysis. This is required because alkalinity is used to separate the bomb ^{14}C signal from the natural component.

West of the Antarctic Peninsula the radiocarbon samples were collected at a number of stations furthest offshore, which are part of transects that run across the wide shelf into the deeper basin. Additionally, two stations in the Drake Passage were sampled. Mostly smaller sampling bottles were used (250 ml), tightened by a screw cap and parafilm inside and around the cap. Those samples will be returned to the Centrum voor Isotopen Onderzoek (CIO; Centre for Isotope Research) in Groningen, the Netherlands, for later analysis of ^{14}C and CO_2 system variables. At some stations CO_2 system variables were measured on board by the CO_2 group of NIOZ/AWI. Also 4 samples were taken in this area for inter-comparison between both ^{14}C laboratories.

Preliminary (expected) results

Only water sampling for future analysis in the home laboratories has been done on board. Therefore, results will only become available.

3.4 Oxygen Isotope sampling in the Weddell Sea Bottom Water off the Antarctic Peninsula

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[2] University of East Anglia
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Objectives

Weddell Sea Bottom Water is formed from high saline shelf water and Ice shelf Water with variable contributions from different regions. Oxygen isotopes have proven to be a useful tracer for the contribution of melt water from the ice shelves. To distinguish between the different sources is facilitated by the concentration of oxygen isotopes.

Work at sea

Samples were taken at 13 stations on the Weddell Sea section.

Preliminary (expected) results

Only water sampling for future analysis in the home laboratories has been done on board. Therefore, results will only become available.

3.5 Nutrients distribution in the Weddell Sea and adjacent areas

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[1] Royal Netherlands Institute for Sea Research (NIOZ), Laboratory for sea-water analysis
[2] Royal Netherlands Institute for Sea Research
[3] Alfred-Wegener-Institut

Objectives

The major nutrients phosphate, nitrate and silicate are necessary for photosynthesis. In contrast to most other oceanic regions, in the Southern Ocean they are generally abundant in the surface layer because of additional limiting factors, such as iron or deep mixing. Nutrient concentrations have been used to estimate the net community production and export production in the Weddell Sea (Hoppema et al., 2002; 2007). The behavior of nutrients reflects biogeochemical processes on seasonal to (inter-)annual scales. They are also necessary in carbon cycle investigations: Using back-calculating techniques for anthropogenic carbon, the biologically mediated changes in the carbon concentration is estimated from nutrient increases. A specific objective at cruise ANT-XXVII/2 will be to investigate robustly the inter-annual variability at two transects along the Greenwich meridian and across the Weddell Sea. Data from previous cruises with *Polarstern* along the same transects are available for 1996, 1998, 2005 and 2008 as measured by the same laboratory with the same standards having been used. Nutrient data measured by other labs can additionally be compared with, although with restrictions due to different standardization procedures. That this step is not trivial was convincingly shown by the CARINA project (Tanhua et al., 2010). Nutrient data will also be used in carbon cycle work at this cruise.

Work at sea

Sample water was obtained from the rosette sampler from all depths. All samples were collected in polypropylene bottles of 125 ml directly after the trace gases, oxygen and TCO_2 sampling. In the lab container the nutrient samples were transferred in 5 ml polyethylene vials, covered with parafilm against evaporation, and placed in the sampler after rinsing three times. All analyses were done within 11 hours on the auto-analyzer, preferably three stations at a time in one run. Calibration standards were diluted from stock solutions of the different nutrients in 0.2 μm filtered low nutrient seawater (LNSW) and were freshly prepared every day. The LNSW is surface seawater depleted of most nutrients; it is also used as baseline water for the analysis between the samples. Each run of the system had a correlation coefficient of at least 0.9999 for 10 calibration points, but typical 1.0000 for linear chemistry. The samples were measured from the lowest to the highest concentration in order to keep carry-over effects as small as possible, i.e. from surface to deep waters.

Prior to analysis, all samples and standards were brought to lab temperature of 22°C in about two hours; concentrations were recorded in μmol per liter at this temperature. During every run a daily freshly diluted mixed nutrient standard, containing silicate, phosphate and nitrate (a so-called nutrient cocktail), was measured in triplicate. Additionally, a natural sterilized Reference Material Nutrient Sample (JRM Kanso, Japan) containing known concentrations of silicate, phosphate, nitrate and nitrite in Pacific Ocean water, was analyzed in triplicate every run. The cocktail and the JRM were both used to monitor the performance of the analyzer. Finally, the JRM was used to adjust all data to the level of the known concentrations of the JRM by means of a correction factor. The final data set is thus referenced to the same JRM values, which makes data internationally comparable and consistent. From every station the deepest sample bottle was sub-sampled for nutrients in duplicate, the duplicate sample-vials were all stored dark at 4 °C, and measured again in the next run with the upcoming stations, this being for statistical purposes.

More than 3,000 samples were analyzed for phosphate, silicate, nitrate and nitrite in total, of which 2,635 at CTD stations. Some 300 samples were analyzed in support of the biological work of Trimborn et al. Analyses were typically processed within three hours after sampling. There were about 12,000 analyses processed on a Technicon

TRAACS 800 Auto-analyzer.

As to the chemistry of the nutrient determinations (Grasshoff et al., 1983):

Silicate reacts with ammonium molybdate to a yellow complex, after reduction with ascorbic acid; the obtained blue silica-molybdenum complex is measured at 800 nm. Oxalic acid is added to prevent formation of the blue phosphate-molybdenum.

Phosphate reacts with ammonium molybdate at pH 1.0, and potassium antimonyl-tartrate is used as an inhibitor. The yellow phosphate-molybdenum complex is reduced by ascorbic acid and measured at 880 nm.

Nitrate plus nitrite (NOx) is mixed with an imidazol buffer at pH 7.5 and reduced by a copperized cadmium column to nitrite. The nitrite is diazotated with sulphanylamide and naphtylethylene-diamine to a pink colored complex and measured at 550 nm.

Nitrate is calculated by subtracting the nitrite value of the nitrite channel from the NOx value.

Nitrite is diazotated with sulphanylamide and naphtylethylene-diamine to a pink colored complex and measured at 550 nm.

Preliminary (expected) results

In table below, the statistics of analysis of 24 bottles at one depth level (1,500 m) taken at station 68 is shown. Samples were analyzed in one run, followed by 9 replicates from one bottle. Overall statistics computed against Japanese Reference Material, followed by statistics using the in-house diluted cocktail98 over all runs:

CTD068-3	PO_4	Si	NO_3	NO_2
UNIT	µmol/L	µmol/L	µmol/L	µmol/L
Average	2.325	122.81	33.91	0.010
Stand dev	0.0040	0.1841	0.0539	0.0008
CV %	0.17	0.15	0.16	8.31
CTD 068-3 9 replicates in one bottle				
Average	2.342	123.00	33.85	0.011
Stand dev	0.0051	0.0793	0.0474	0.0011
CV %	0.22	0.06	0.14	10.71
JapanRM				
Average	3.090	137.48	43.65	0.03
Stand dev	0.0191	0.344	0.135	0.003
CV %	0.62	0.25	0.31	11.02
Cocktail98				
Average	2.453	121.83	35.01	
Stand dev	0.0146	0.475	0.117	
CV %	0.60	0.39	0.34	

The coefficient of variation (CV) of the duplicate samples (all bottle 1 of rosette) in-between runs after correction with RMNS during the Weddell Sea transect:

Phosphate: 0.009 µM C.V. 0.40 % at average concentration of 2.26 µM

Silicate: 0.297 µM C.V. 0.27 % at average concentration of 110.9 µM

Nitrate: 0.105 µM C.V. 0.32 % at average concentration of 32.80 µM

Modifications during the cruise

During the transect along the Greenwich meridian the peak shape for phosphate and silicate was not satisfying. After implementing several changes in the flow setup, the precision improved by 50% for both channels. For phosphate and silicate the flow speed was reduced thus getting longer reaction times which in turn made it possible to reduce the flow length by taking out glassware, i.e., reduce the amount of coils thus reducing the dispersion of the system. For Si the backpressure after the pumps was reduced, which resulted in a smoother running flow. For nitrate an extra coil was placed for optimal linearity.

In the deep waters, levels of nitrite are very low (< 0.015 µM), but a calibration line of 0 to 0.50 µM has to be used because of the high surface layer values. After the cruise it will be possible to correct the baseline settings for every run to its initial setting and use only the first and second calibrants in the low range of 0-0.10 µM for recalculation.

Data Quality

From the statistics it is clear that analysis from one single bottle in replicates gives the highest reproducibility. Approximately the same "noise" is obtained if the sampling from rosette bottles (all closed at 1,500 m) is done in different polypropylene bottles. It can be concluded that the Niskin bottles are 100% tight.

Monitoring the Japanese Reference Material and our in-house Lab reference (cocktail98), the JRM shows slightly more consistent data considering the precision (CV %). It is suggested that through diluting the in-house cocktail98 by means of an electronic pipette and a calibrated flask, a small error of 0.15% maximum is introduced.

All data was normalized to the JRM batch AZ, resulting in a comparable data set. The overall statistics for in-between runs is better than 0.01 µM for phosphate, 0.3 µM for silicate, and 0.11 µM for nitrate and 0.005 µM for nitrite, this being the average standard deviations of 52 differences between duplicates from the rosette bottle 1 measured in two different runs.

After finalization of the data processing, the data will be submitted to data centers, as has been done with all data of previous cruises with *Polarstern*. The usual data center for carbon research is the Carbon Dioxide Information and Analysis Center (CDIAC; Boulder, U.S.A.) together with CCHDO. Since nutrient data are used in close combination with the carbon data, they will also be submitted to this data center. In the past, data have also been transferred to Pangaea, which shall also be done with the carbon and nutrient data of cruise ANT-XXVII/2. They should be public within two years after the end of the cruise.

Section data

A section across the Weddell Sea is shown for preliminary silicate data in units µmol l-1 (Fig. 3.4.1). This section has been sampled also in previous years starting in 1996, which allows a rigorous comparison for investigating inter-annual variability. The comparison is particularly useful as in all those years the same standard solutions were used for setting the accuracy of the data. The features of the silicate distribution include low values in the surface layer as compared to the deep waters; however, the surface layer values are high compared to those in other oceanic regions. In the west Si in the surface is lower due to extensive algal blooms. At about 1,000-1,500 m a silicate maximum is found all across the basin. This maximum occurs deeper than the maximum of phosphate and nitrate. All along the continental slope of the Antarctic Peninsula in the west, the low-silicate signal of the newly formed Weddell Sea Bottom Water is clearly distinguishable. In the deepest part of the basin, the silicate distribution exhibits many features. Since newly formed bottom water is characterized by low silicate values (as shown on the continental slope in the west), any elevated concentrations point to enrichment, either within the bottom layer or from the seafloor. The highest silicate values of the entire section are found in the east at the base of the continental slope, which makes that a hotspot of enrichment. This is known from previous occupations of the section indeed (Hoppema et al., 1998). At 45-47°W increased Si values are found as well, which is a downstream remnant of the high-Si water from the east being transferred around the basin at the base of the continental slope. At 40-44°W a core of bottom water with few Si enrichment is found, which points to a relatively recent origin. At about 3,000 m depth a Si minimum is found, which originated from remote eastern sources outside of the Weddell gyre, and which is also detected with a CFC maximum. Unlike previous occupations of the section, the Si minimum seems to have spread all through the basin, which strongly confirms that the (ventilated) water formed at other places around Antarctica exerts strong influence on the water structure in the Weddell Sea. It also shows the existence of long-term circulation changes within the basin.

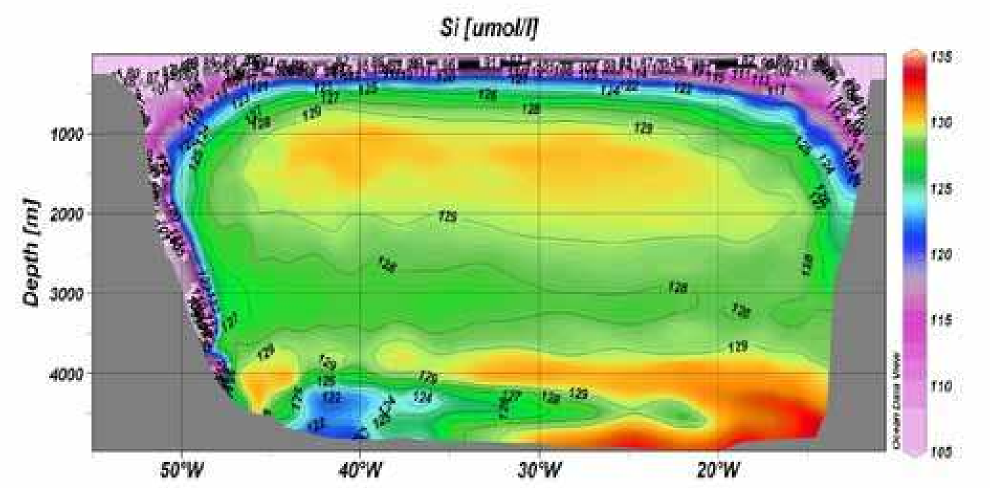

Fig. 3.4.1 Silicate in µmol/l across the Weddell Sea from Kapp Norvegia (right) to the tip of the Antarctic Peninsula (left)

References

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Hoppema, M., R. Middag, H.J.W. de Baar, E. Fahrbach, E.M. van Weerlee and H. Thomas (2007). Whole season net community production in the Weddell Sea. Polar Biology 31: 101–111.

Tanhua, T., A. Olsen, M. Hoppema, V. Gouretski (eds.) (2010). CARINA: a consistent carbon-relevant data base for the Arctic, Atlantic and Southern Oceans. Special issue in Earth System Science Data.

3.6 Sea-ice observations

Eberhard Fahrbach[1)], Maria Martin[2], Dirk Notz[3)] (not on board), Ricarda Winkelmann[2)]

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3.6.1 The ice conditions

Sea ice observations were obtained during the cruise from PolarView *(Spreen et al., 2008*) for operational and scientific use. Sea ice was encountered along the Greenwich meridian in a belt from 59° to 65°S. In the Weddell Sea proper two bands were encountered, one from 14° to 23°W and the second from 37° to 42°W (Figs. 3.6.1 to 3.6.4). The ice consisted overwhelmingly of floe fields which could be easily crossed and did not present any problem for the progress of the cruise. Due to the fast seasonal progress, the ice cover shrunk fast. The large scale pattern were to some extend unexpected: on the Greenwich meridian, a closer ice cover was encountered in the northern part of the Weddell gyre than in the southern part and in the Weddell Sea the ice cover was stronger in the east than in the west.

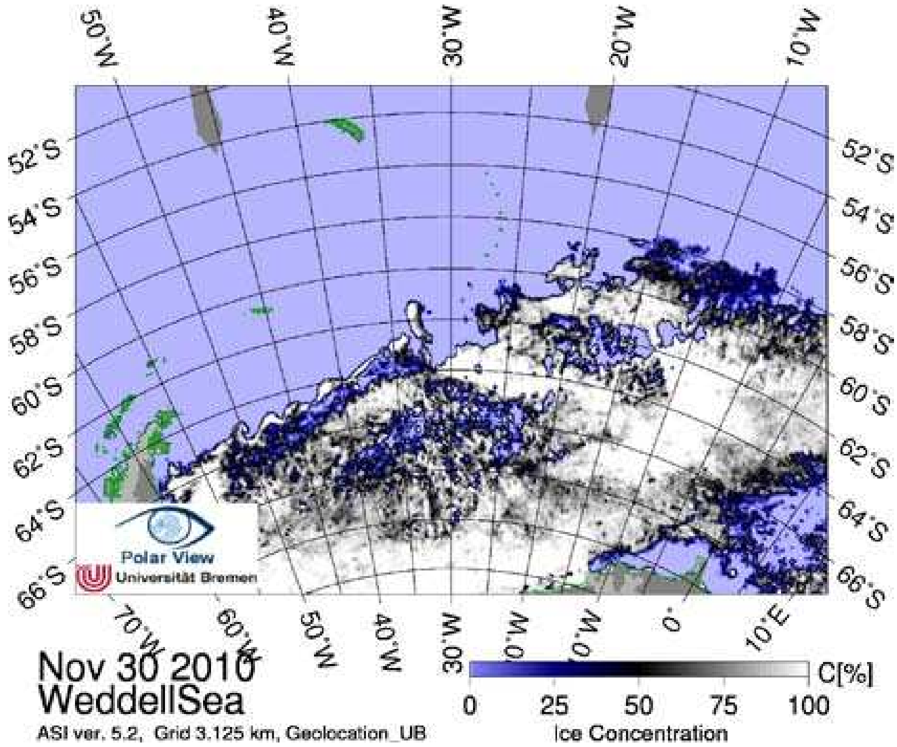

Fig. 3.6.1: Sea ice concentration the Weddell Sea at 30 November 2010 from Polar View (Spreen et al., 2008)

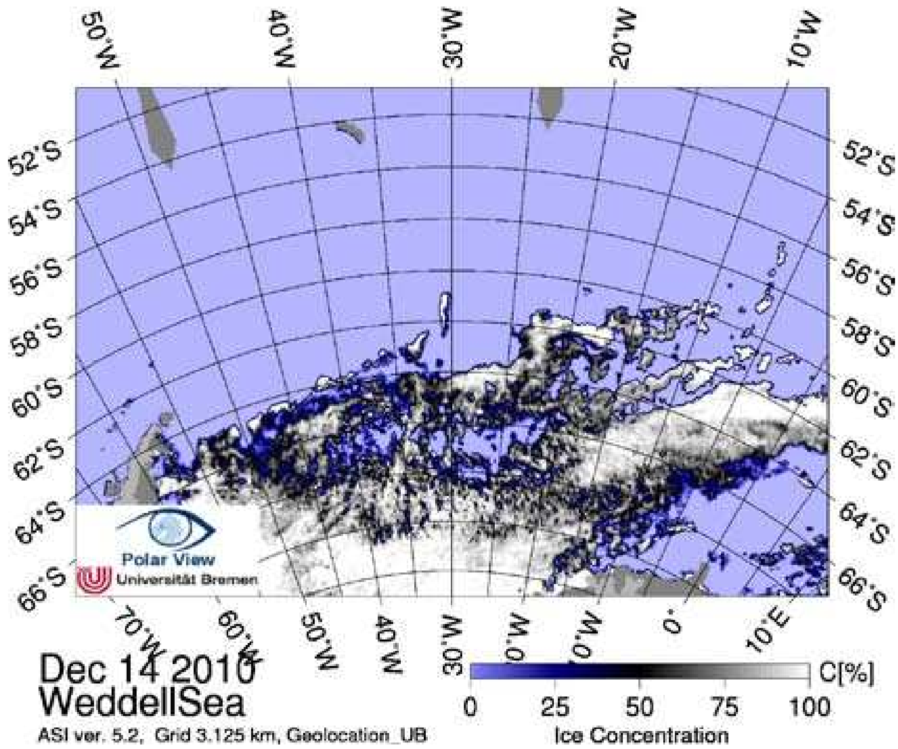

Fig. 3.6.2: Sea ice concentration the Weddell Sea at 14 December 2010 from Polar View (Spreen et al., 2008)

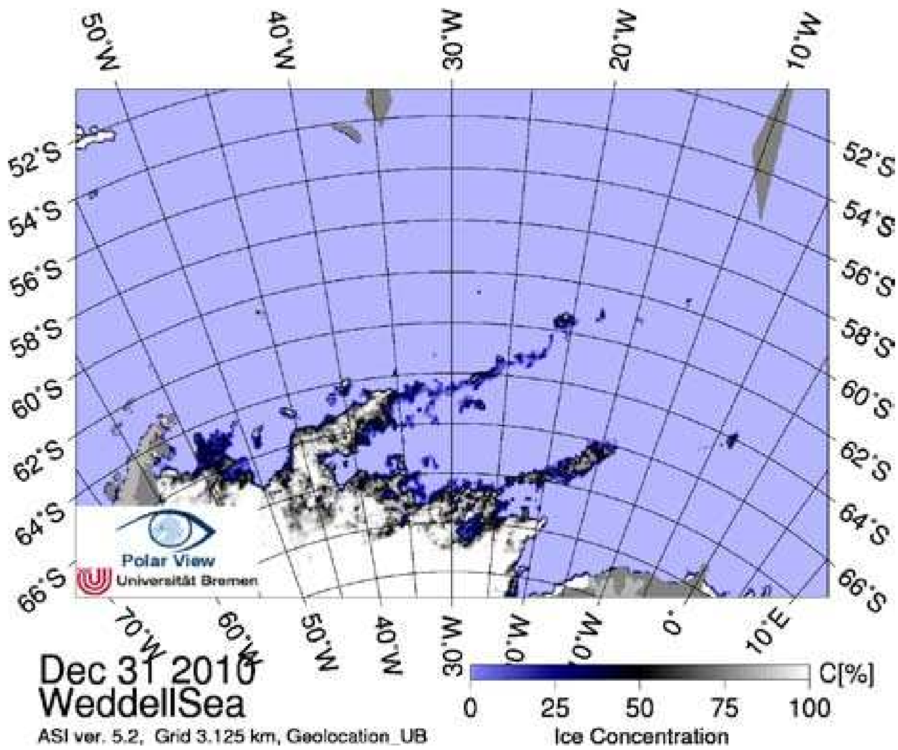

Fig. 3.6.3: Sea ice concentration the Weddell Sea at 31 December 2010 from Polar View (Spreen et al., 2008)

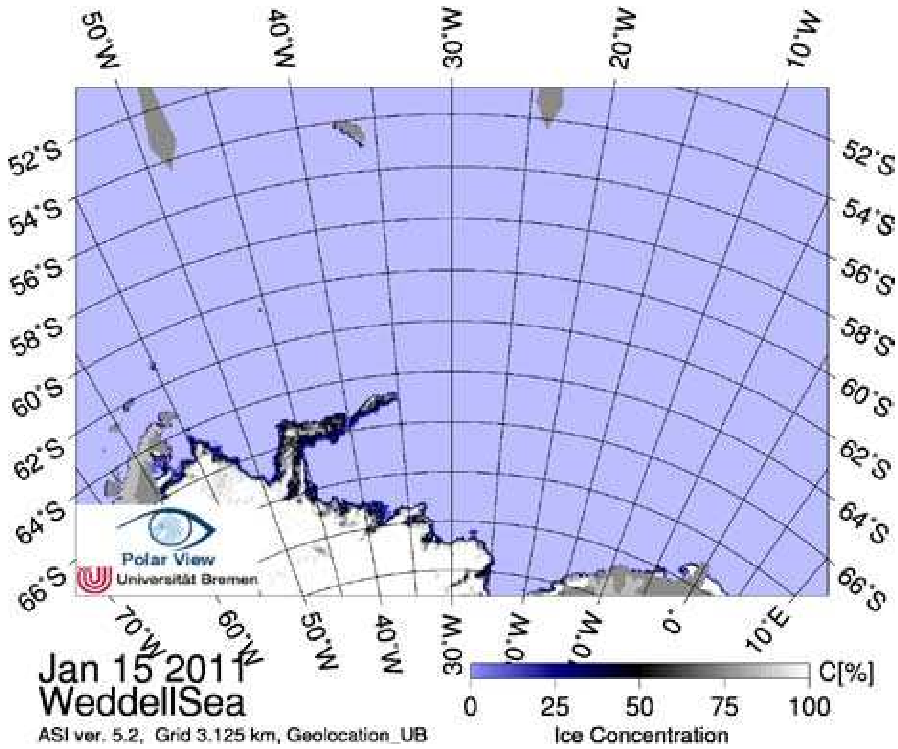

Fig. 3.6.4: Sea ice concentration the Weddell Sea at 15 January 2011 from Polar View (Spreen et al., 2008)

References

Spreen, G., L. Kaleschke, and G. Heygster (2008), Sea ice remote sensing using AMSR-E 89 GHz channels, J. Geophys. Res., doi:10.1029/2005JC003384

3.6.2 ASPeCt Program

Objectives

The sea-ice observations made on this cruise contribute to the Antarctic Sea Ice Processes and Climate Program (ASPeCt, www.aspect.aq). ASPeCt was established in 1996 and is an ongoing system of quantified shipboard observations that provide a statistical description of basic physical properties of the Antarctic sea ice that are important for the interaction of the ocean with the other components of the climate system. The ASPeCt dataset is the only dataset available for the Southern Ocean which includes data from all regions of the Antarctic pack ice throughout the different seasons. Currently, it comprises observations from 314 locations, 83 ice stations, 494 transects, 99 ice cores and 18 snow pits.

The ASPeCt Program aims to establish a better knowledge of the distribution and basic properties of the Antarctic sea ice including ice and snow cover thickness, floe sizes, lead distribution and the structural, chemical and thermal properties of snow and ice. This data is required in order to determine the controlling factors on key processes such as formation, modification, transport and decay of sea ice and the effect on the whole climate system including the biosphere. The data is used as forcing and evaluation fields for climate models.

Work at sea

The ASPeCt Program comprises a protocol for sea-ice observations made on board ships in the Antarctic pack ice which has become an international standard. According to this protocol, the sea ice observations were performed hourly, only under daylight conditions and while the ship was steaming such that there are observations in about 20 nm distance along the ships track. They were made with the bare eye from the ships bridge, with an observational radius of one kilometer.

Within this radius, a set of properties describing the ice conditions at the respective location was observed by the CTD watch and written into a standard observation form provided by the ASPeCt program. These properties include total ice concentration, the three major ice types and their thicknesses as well as snow cover and the snow and ice morphology. Meteorological conditions like wind speed and wind direction, air and water temperature as well as visibility and cloud cover were also recorded.

In total 576 observations were carried out from 10 December 2010 to 3 January 2011. The ice was structured in a series of bands reaching from southwest to northeast. The first one on the Greenwich Meridian was encountered from 10 December to 16 December. . At 3 January 2011 we left the ice at 42°W in the Weddell Sea.

Preliminary and expected results

The collected data will be included in the central data archive at the Antarctic Cooperative Research Centre located in Hobart, Tasmania (Australia). There it will be analyzed so that distributions of the observed sea-ice properties can be mapped in a way that is comparable to the output of numerical models allowing for the ASPeCt data to be used in comparison with model predictions.

3.6.4 Ice Core Drilling

Objectives

Sea ice is always a mixture of solid freshwater ice, liquid salty brine and some air bubbles. The relative ratio of these three phases determines the physical properties of the sea ice, and without their proper knowledge, realistic modeling of sea ice in large scale models is impossible. The ice cores that we collected are meant to improve our knowledge of the properties of Antarctic sea ice and to hence guide improved modeling. In these cores, we measured profiles of sea-ice temperature and salinity as well as density and air content. In particular the latter parameters are largely unknown for Antarctic sea ice and would be of great importance for improved modeling of sea-ice thermodynamics.

Work at sea

We have collected sea-ice samples in the Weddell Sea and performed some standard measurements (temperature and salinity profiles) on them as well as a feasibility study concerning the measurement of the air content within the ice under ''field work conditions'' on a ship.

Since ANT-XXVII/2 was a summer cruise the ice cover in the Weddell Sea was much reduced compared to winter conditions. To the west of the Antarctic Peninsula, sea ice was fully absent and there were not many opportunities to take suitable sea-ice samples. Nonetheless, we were able to collect 13 ice cores in total from 5 different sites during the cruise.

As table 3.6.1 shows, the samples were taken from floes mostly close to the ship that could be reached via a short flight with the helicopter. While the helicopter then waited within visual range on the ship, the sampling was done with the help of Fabian Gall and Matthias Monsees or Markus Heckmann. Given suitable ice-floe conditions up to three cores were drilled with a manual ice core drill that was equipped with a fuel-powered motor. At each drilling site, air temperature 50 cm above the snow surface, snow thickness and a snow temperature profile were recorded. The ice temperature of the cores was immediately measured every five centimeters to obtain a profile.

The cores were sawed into disks of five centimeters thickness and the salinity was measured for each disk back on the ship.

Table 3.6.1: Coring positions and floe properties

Date	Station No	Position		Cores	floe properties	ice concentration
13.12.10	49	61°58' S	1°00' E	no floe found that was sufficiently stable	--	~20 % of 1st year ice
14.12.10	51	62°60' S	0°00' W	2 cores (1.80 m and 2.00 m)	diam ~40 m, ridged	~30 % of 1st year ice
15.12.10	53	63°59' S	0°30' W	2 cores (1.30 m and 2.80 m)	diam ~20 m, ridged	~40 % of 1st year ice
26.12.10	77	69°33' S	15°59' W	3 cores (0.95 m, 0.98 m and 0.85 m)	diam ~15 m, level	~30 % of 1st year ice
27.12.10	78	68°59' S	17°34' W	no floe found that was sufficiently stable	--	~10 % of 1st year ice
01.01.11	91	65°37' S	36°23' W	3 cores (0.90 m, 1.15 m and 1.30 m)	diam ~25 m, level	~50 % of 1st year ice
02.01.11	93	~65°24' S	~38°00' W	3 cores (1.45 m, 1.40 m and 2.50 m)	diam ~20 m, level	~90 % of 1st year ice

Preliminary and expected results

One of the main tasks of our ice-core sampling program was to develop and test several methods to measure the volume of the air bubbles enclosed in the ice body. These methods are based on different principles: direct measurement of the air bubble volume, replacement and buoyancy.

For the methods based on the buoyancy measurements the ice is to be enclosed in a vacuum-sealed bag, which is then hung under water with an additional weight. After carefully removing the air from the bag with the melted ice in a second step, the difference in buoyancy will indicate the volume of the air. However, this method only works in calm sea and was clearly not usable with swell in the open sea.

The method based on replacement works as follows: A disc of ice in a vacuum-sealed bag is put in a container with a scale attached to the lid. After filling this container with water to the top of the scale the ice can melt inside the bag, which will lead to a drop of the water level due to density change during the phase transition from ice to water. Then the bag can be opened by means of a long needle introduced into the container through the scale, releasing the air and leading to a further drop in water level allowing to read the volume of the released air.

To apply this method properly, a container is needed which firstly has a wide opening for placing the ice inside and secondly can be closed tightly enough such that the atmospheric pressure does not push the water out the seal of the lid once it has been filled up to the level of the scale.

Two types of direct measurements have been performed on the cruise under different weather and sea conditions.

For the first method, a disc of ice is enclosed in a vacuum-sealed bag. While melting, the air is released from within the ice and forms a distinct air bubble which can be extracted from the bag by means of a syringe. In order to avoid air being lost through the small hole from the needle, it is put through rubber. After reading off the volume of the air content from the scale of the syringe, the conductivity and temperature can be measured for the remaining melted ice in order to determine the salinity.

For the second method, the disc of ice is placed in a water bath under a funnel with an attached scale. Once the whole scale is under water it is closed, such that the air released from the ice while melting can rise into the scale where its volume can then be determined. The salinity of the melted ice can be determined by means of conductivity measurements of the bath before and after melting the ice disc inside.

After a testing phase the latter two methods were selected to be applied on generally two out of the three cores from each drilling site, while the third core was preserved under vacuum in a -20°C environment for later analysis of the air bubble content with established but complex methods that are not suitable for on-ship work. The results were analyzed preliminarily for systematic errors of the respective methods. A thorough analysis including a comparison to the measurements on the third ice core are planned to be performed after the cruise.

4. CHEMISTRY

4.1 Repeat sections of total carbon dioxide and total alkalinity across the southern Antarctic Circumpolar Current and Weddell gyre

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Objectives

The level of atmospheric carbon dioxide (CO_2) has been continuously rising due to anthropogenic causes. The CO_2 content of the oceans is following this rise, although it is still not completely known to what extent and how the rise is regionally distributed. In the Southern Ocean, and particularly in the Weddell Sea, ventilation of the deep ocean takes place with concomitant uptake of anthropogenic CO_2. Deep water upwelling into the surface layer, which occurs before the water masses participate in ventilation processes, leads to additional exchanges of heat and CO_2 with the atmosphere. Estimates of net oceanic CO_2 uptake south of 50°S for are as low as 0.1 Pg C per year (Takahashi et al., 2009), but it should be realized that the uptake of anthropogenic CO_2 is much larger than this. This is because natural CO_2 loss from the Southern Ocean is counteracting the uptake of anthropogenic CO_2. While the rising atmospheric CO_2 level is well known, it is much harder to monitor the oceanic CO_2 increase due to the large background level of CO_2 in the oceans and the high natural variation. Our overall objective is to trace anthropogenic CO_2 in the deep and surface waters of the Antarctic Ocean and to investigate which factors exert influence on the CO_2 distribution. Substantial progress in these issues can only be made with data time series, in particular as regular repeat sections. Data from this cruise will extend the longest combined oceanic time-series of CO_2 and transient tracers, hydrography, nutrients and oxygen on the Greenwich meridian which started in 1985. Also the section across the Weddell Sea from Kapp Norvegia in the east to the tip of the Antarctic Peninsula has been occupied since the early 1990s. The region is also important from a biogeochemical point of view; our data will explore this further in combination with data from previous cruises on board *Polarstern* and data from the recent British project ANDREX (ANtarctic Deep water Rates of EXport).

Specific objectives include the following:

- Quantification of the carbon budget of the Weddell Gyre
- Repeat sections for total CO_2 (TCO_2) and total alkalinity (TA) and ancillary variables will be used for estimating temporal changes in the carbon cycle, including ocean acidification
- Comparison with earlier carbon data and determination of inter-annual variability

Work at sea

We have determined TCO_2 (DIC) and Total Alkalinity in discrete water samples taken from the rosette sampler from all depths. A total of 110 stations were sampled with 2,270 analyses. The whole section along the Greenwich meridian was sampled, and also the section across the Weddell Sea. The additional deviating stations near Joinville Island for investigating a possible different route of bottom water export, were only partly sampled. West of the Antarctic Peninsula, the TCO_2 and alkalinity of three out of ten inshore to offshore transects was determined.

Measurements of the water were carried out immediately after sampling. Generally, this means that the samples did not have to be stored for longer than 12 hours. In a very few cases, the time before measuring was somewhat longer, and then the samples were stored in the dark. TCO_2 is the sum of all dissolved inorganic carbon species and is determined by a precise coulometric method. The accuracy is set by internationally recognized and widely used certified reference material (CRMs). For every coulometric cell that was used in the coulometer, two CRMs were measured at the beginning and the end of the analyses. The alkalinity measurements were made by potentiometric titration with a strong acid (HCl) as a titrant. The acid consumption up to the second endpoint is equivalent to the titration alkalinity. The system uses a highly precise Metrohm Titrino for adding acid, a pH electrode and a reference electrode. Both TCO_2 and alkalinity are measured together with a VINDTA instrument (MARIANDA, Kiel), which combines the two measurements. This set-up of VINDTAs has also been used during the previous realization of the transects during ANT-XXIV/3 in 2008. In addition to the CRMs, some sample bottles were measured on both VINDTAs to check the internal consistency of the data. The measurement temperature for both TCO_2 and total alkalinity was 25°C.

The TCO_2 and alkalinity data will be largely processed after the cruise. The final data will be submitted to data centers, as has been done with all data of previous cruises with *Polarstern*. The usual data center for carbon research is the Carbon Dioxide Information and Analysis Center (CDIAC; Boulder, U.S.A.) together with CCHDO. In the past, data have also been transferred to Pangaea, which shall also be done with the carbon and nutrient data of cruise ANT-XXVII/2. They should be public within two years after the end of the cruise.

Preliminary (expected) results

All analyses were finished, but the processing of the data is still going on. At station 19 all bottles were fired at the same depth. The preliminary alkalinity data of this station show that we measure with a precision of about 1 μmol/kg, which is very satisfying indeed. All through the Weddell Sea, the vertical profiles of alkalinity and TCO_2 showed a high consistency. As alkalinity is thought to be conservative, the gradient within the deep water column was expected to be very low. This could be confirmed. Still some slight signals deviating from this trend could be distinguished, which appeared to correlate with small silicate signals. This again confirmed the high precision achieved. Also the newly formed Weddell Sea Bottom Water at the continental slope near the Antarctic Peninsula could be discerned from the alkalinity (but also TCO_2) determinations as a minimum towards the bottom. This can be expected since the alkalinity and TCO_2 are lower in the surface layer, the signal of which is transferred into the bottom water that has a surface water component. Within the surface, there was high variability across the region, both in TCO_2 and alkalinity. The lowest values were generally measured in the western Weddell Sea.

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

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Objectives

Persistent organic pollutants (POPs) are persistent, bioaccumulative and toxic chemicals which additionally can undergo long-range atmospheric transport (LRAT) caused by their hydrophobic and semi-volatile properties. The atmosphere is known to be the most important and rapid transport pathway for semi-volatile POPs from source regions to remote regions such as Antarctica. During atmospheric transport, POPs are subject to exchange mechanism with the sea surface water including air-water gas exchange (deposition and volatilization), particle-bound dry deposition as well as wet deposition (rain and snow). Once deposited into the ocean, they can be further transported via ocean currents, accumulated by organisms or transported to deep water masses which might act as final sinks. Besides the legacy POPs, (e.g., polychlorinated biphenyls (PCBs), polychlorinated dibenzodioxins/furans (PCDD/Fs) and organochlorine pesticides (OCPs)) which are officially listed as POPs in the Stockholm Convention, there are several emerging pollutants whose occurrence and behaviour in the marine environment is not (well) studied such as brominated and organophosphorus flame retardants (BFRs and OPFRs) and current-use pesticides (CUPs) which are the main POP classes of interest within this project.

BFRs, in particulate polybrominated diphenyl ethers (PBDEs), have been used for several decades in industrial and consumer products to reduce the inflammability of various industrial and consumer products. Since the technical Penta- and OctaBDEs were banned by the Stockholm Convention, there is increasing demand, production and, therefore, emission into the environment of non-regulated non-PBDE BFRs such as hexabromobenzene (HBB), 1,2-bis(2,4,6-tribromophenoxy)ethane (BTBPE) and the highly-chlorinated flame retardant Dechlorane Plus (DP).

Besides BFRs, halogenated and non-halogenated OPFRs such as tris-(2-chloroethyl) phosphate (TCEP) and triphenyl phosphate (TPhP), are the second important group of organic flame retardants which are also widely used as plasticizers and hydraulic fluids. In the 1990s, they have been qualitatively found in air of the Antarctica while concentration levels and distribution in the marine environment are lacking.

Among the legacy POPs of interest for this project are PCBs. Their production peaked in the 1960s. First restrictions and bans were established by individual countries in the 1970s and the following decades until PCBs were globally banned in 2001. It was used in closed systems e.g. as a cooling agent in transformers as well as in open systems like paints and glues. PCBs were produced as a mixture of different congeners with a varying grade of chlorination. Current sources for PCBs are dumps and old systems. Also part of the monitored POPs are OCPs like DDT and its degradation products DDE and DDD, as well as the chlordane, lindane and hexachlorobenzene (HCB).

This study is focused on the environmental occurrence, distribution, fate, and transport mechanism of several different POPs along the cruise leg of ANT-XXVII/2. By taking simultaneously air and water samples we will be able to identify the direction of the air-seawater gas exchange and to calculated deposition fluxes from the atmosphere, derived from source regions emitting POPs, into the remote oceans. Snow samples were taken in order to estimate the dry deposition flux of POPs to Antarctica. Furthermore, all samples taken will be used to screen for possible “new” POPs which have not been yet determined in remote areas but have a potential to do be widely transported.

Furthermore, the behaviour and transport of mercury and its compounds was studied. In contrast with other heavy metals mercury and many of its compounds behave exceptionally in the environment due to their volatility. LRAT of mercury, its transformation to more toxic methylmercury compounds, the ability to photochemical reactions and their bioaccumulation in the aquatic food chain have made it to a subject of global research activities even in polar regions. The following questions of sources and trends of mercury are of particular importance:

1.) Have the sources of mercury, its LRAT and deposition substantially increased in comparison with pre-industrial times ?

2.) How do atmospheric mercury concentrations reflect the control measures adopted to control and reduce anthropogenic mercury emissions ?

Work at sea

High-volume air sampling

Air samples of HZG were collected using two simultaneously running high-volume air samplers installed at sea upper deck operating at a constant flow rate of ~250 L min-1. The samplers were run for 3 - 4 days obtaining a typical air sample volume of 1,000-1,500 m^3. The high volume air sampler consists of a high volume pump (ISAP 2000, Schulze Automation & Engineering, Asendorf, Germany), a digital flow meter, a metal filter holder. The airborne particles were collected on a glass fiber filter (GF/F) and gaseous substances were trapped on a PUF/PAD-1 or PUF/PAD-2 column. Along the cruise leg of ANT-XXVII/2, 15 duplicate air samples were collected (see Fig. 4.2.1). Samples collected with PUF/PAD-1 columns are used to determine OPFRs, BFRs, and Dechlorane Plus, and samples collected with PUF/PAD-2 will be used to investigate the concentrations of currently used pesticides such as trifluralin, endosulfan isomers, and other emerging organic pollutants, respectively. Field blanks were prepared by exposing the filter and column to the sampler and run the sampler for ~10 s (~50 L). Air samples were stored at -20 °C in the cooling room.

Lancaster samples were taken by two high-volume samplers at the upper deck containing glass fibre filter and polyurethane foam (PUF) plugs. Samples were run for 3 days and field blanks were taken by exposing the filter and PUF to the routine sampling preparation in the lab for every second sample.

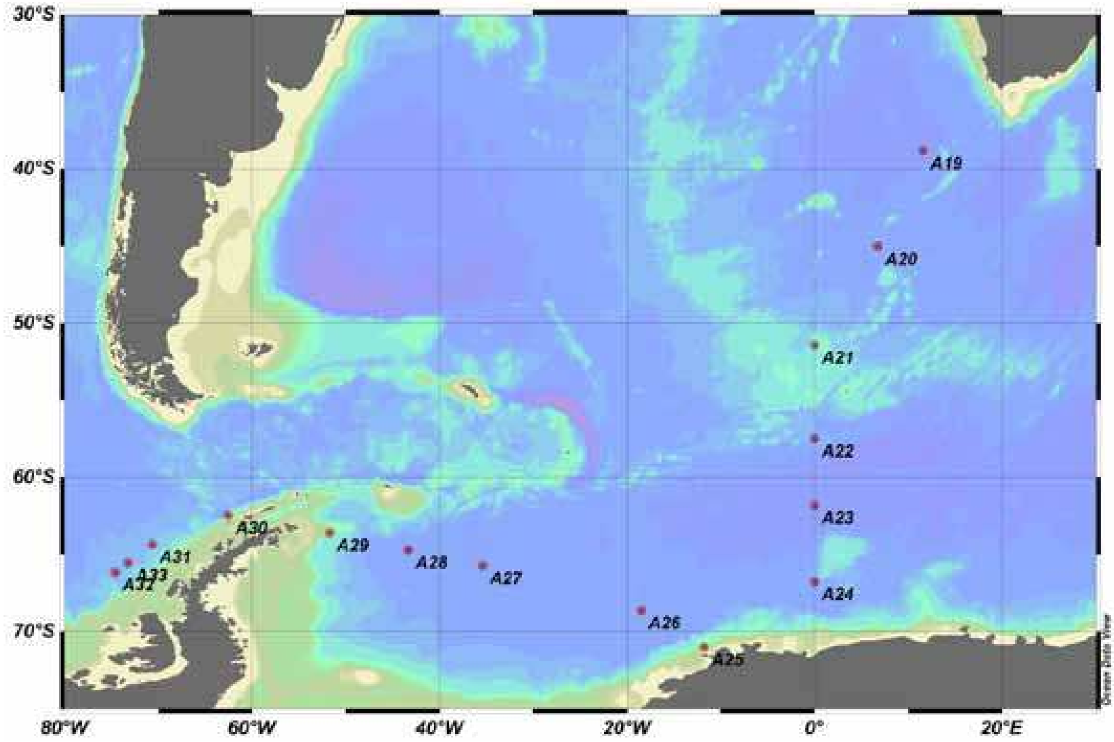

Fig. 4.2.1: High-volume air samples taken along ANT-XXVII/2

High-volume water sampling

High-volume water samples were taken from the ship's seawater intake system (stainless steel pipe/Klauss pump) at 11 m depth. The seawater was passed directly from the intake system through a glass fiber filter (GF/C) for the suspended matter following a glass cartridge packed with PAD-2/-3 resin for the dissolved phase. Each sample was taken for ~24 h obtaining a volume of ~1,000 L while 2 - 10 filters were used per sample depending on the amount of suspended matter and biomass in the seawater. In total, 39 samples were taken alternatively using PAD-2/-3 cartridges (see Fig. 4.2.2). Field blanks were taken by exposing the filter and column to the routine sampling and passing 1 L seawater. The breakthrough of target analytes was controlled using tandem columns. Samples were stored at 0°C.

Water sampling using solid-phase extraction (SPE)

2 L water samples were collected from the ship's seawater intake system continuously along the leg. In total, 27 duplicate samples were taken while half were extracted using OASIS WAX cartridges and half using Chromabond HR-X cartridges. They will be used to determine perfluoroalkyl compounds (PFAS) such as perfluorooctane sulfonate (PFOS) and dissolved organic matter in the surface seawater (see Fig. 4.2.3). In addition, each 5 samples from different depths were taken at the CTD stations PS77-21, PS77-49 and PS77-79 and extracted using OASIS WAX cartridges in order

to investigate the depth distribution of PFAS since the deep ocean might act as a final sink. All cartridges were stored at -20°C.

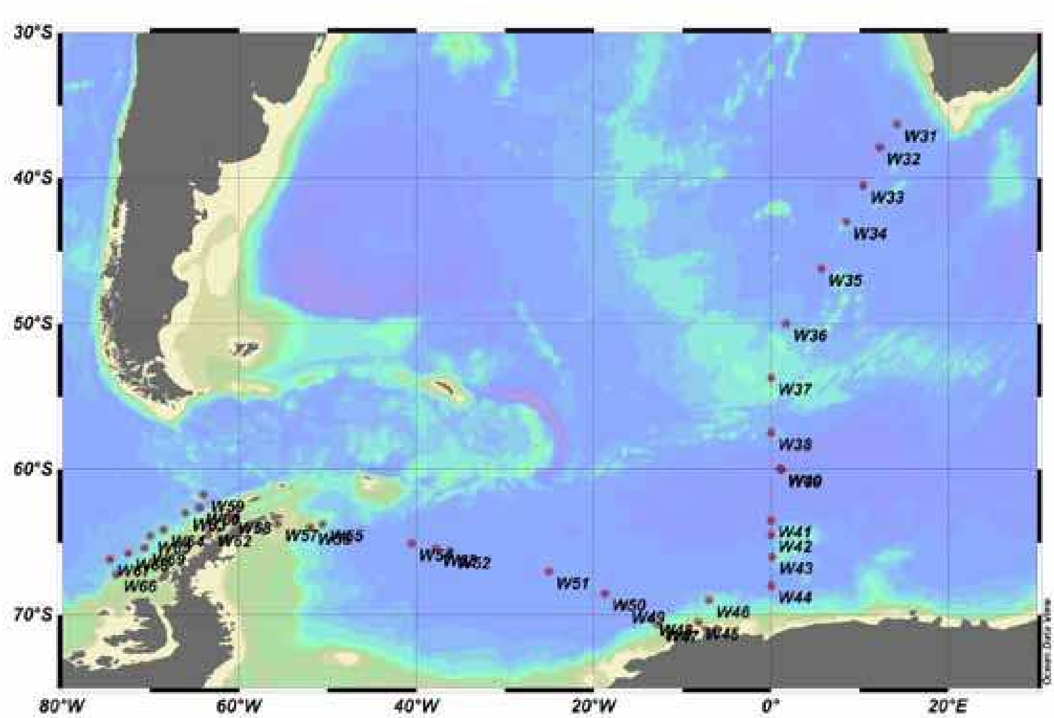

Fig. 4.2.2: High-volume water samples taken along ANT-XXVII/2

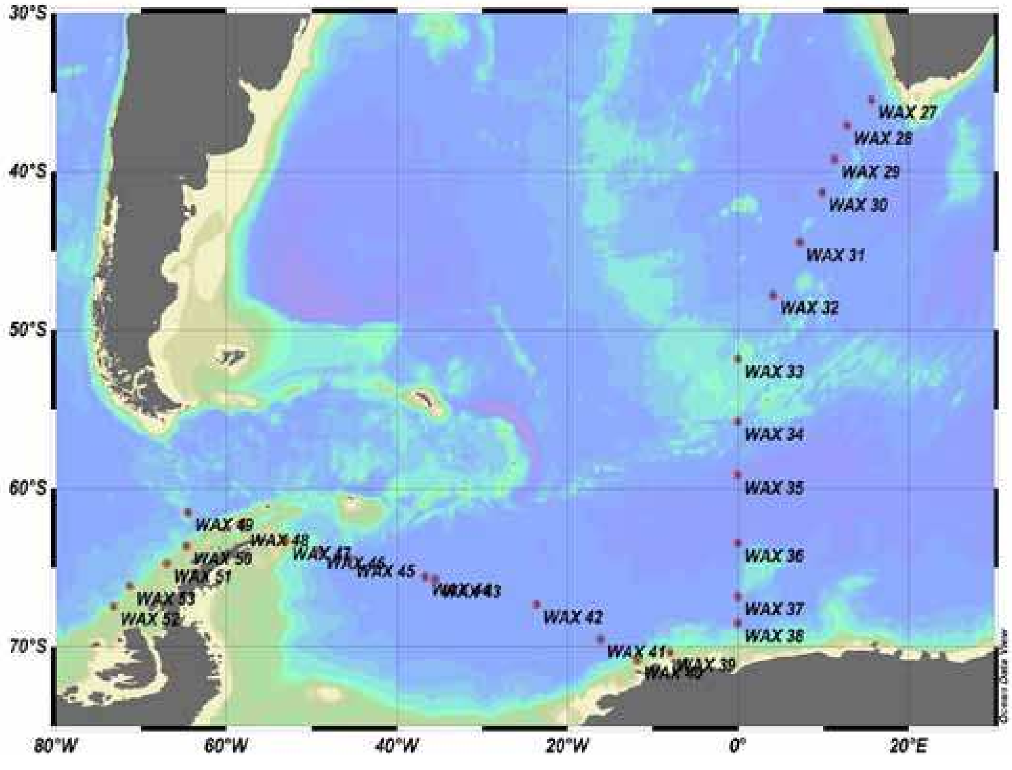

Fig. 4.2.3: SPE water samples taken along ANT-XXVII/2

Snow sampling

Snow samples were taken at 4 locations: from the Ekström shelf ice close to Atka Bay (5 samples), from Low Island (4 samples), Hugo Island (3 samples) and Adelaide Island (4 samples). Surface snow samples with a mean volume of ~50 L snow were stored in metal barrels or precleaned and aluminium foil covered aluminium boxes, respectively. The samples were melted at room temperature onboard leading to a water volume of 10 - 25 L depending on the snow density. The melt water was passed through PAD-2/-3 columns which were then stored at 0°C. In addition, 2 L snow samples were taken at each station, then melted at room temperature and extracted using OASIS WAX cartridges to determine PFAS in Antarctic snow. Cartridges were stored at -20°C.

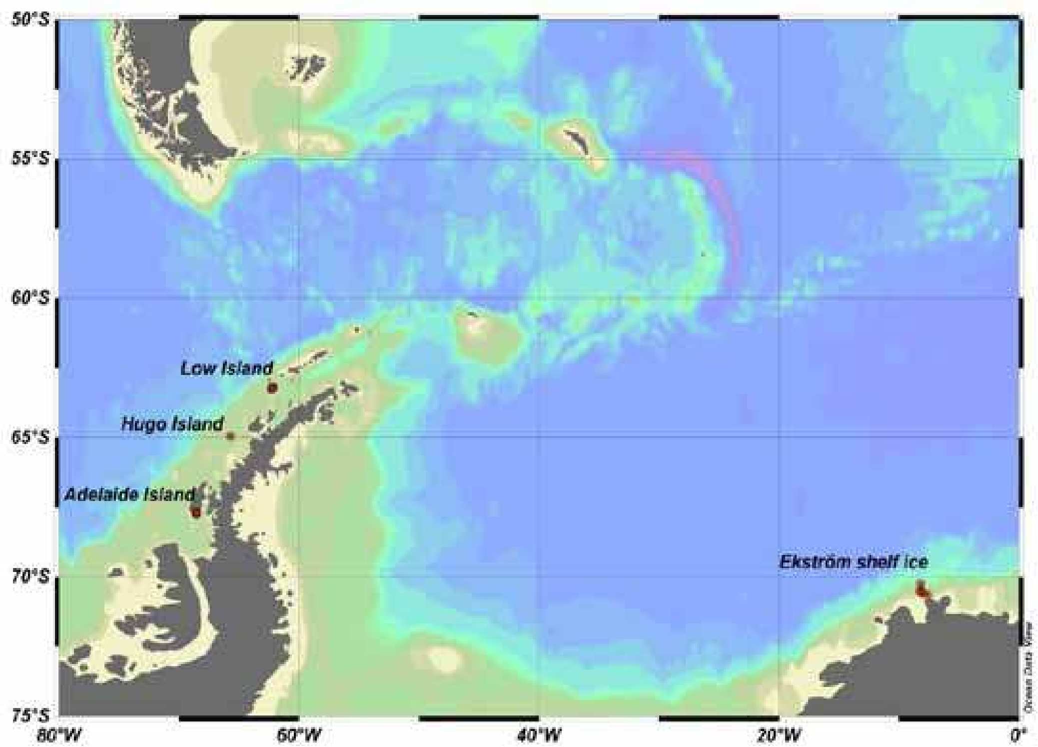

Fig. 4.2.4: Snow sampling locations during ANT-XXVII/2

Mercury analyses. The automated dual channel, single amalgamation, cold vapor atomic fluorescence analyzer in operation on board of *Polarstern* (Tekran-Analyzer Model 2537 A, Tekran Inc., Toronto, Canada) is capable of measuring TGM concentrations, even at background locations. The instrument features two gold cartridges. While one is adsorbing mercury during a sampling period (15 min) the other is being thermally desorbed and is subsequently analyzed for total gaseous mercury. The functions of each cartridge are then reversed, allowing continuous sampling of the incoming air stream. The amalgamated mercury is thermally desorbed into an Argon carrier gas stream and analyzed using cold vapor atomic fluorescence spectroscopy (CVAFS). A detection limit of the order of 0.3 ng Hg m^{-3} can be achieved under these conditions. The Tekran-Analyzer is equipped with an internal permeation source so that the instrument can be automatically calibrated.

Preliminary (expected) results

All HZG samples will be further extracted, cleaned and measured in the clean lab at HZG. PUF/PAD-1, PUF/PAD-2, PAD-2 and PAD-3 columns and filters will extracted with organic solvents (hexane, dichloromethane, acetone) or mixtures for ~24 h. Samples will be further cleaned using silica gel to improve the analytic performance. The SPE cartridges are eluted with methanol for PFC measurements, and with hexane/DCM mixture for dissolved organic matters, respectively.

BFRs, OPFRs and CUPs are analyzed by gas chromatography-mass spectrometry (Agilent 6890 GC/5975 MSD) in negative chemical ionization mode (electron impact mode for OPFRs). Neutral PFAS are analyzed by GC-MS in positive chemical ionization mode. Ionic PFAS are analyzed using liquid chromatography coupled to tandem mass spectrometer (LC-MS/MS) with an Electrospray interface in negative mode.

The data obtained from the cruise will set up a background of BFRs, CUPs and PFAS both in seawater and the atmosphere in the Southern Ocean and Antarctica. In addition, the samples will enable us to determine OPFRs for the first time in the atmosphere of the southern hemisphere and, more important, in the remote region of Antarctica. Furthermore, the air-seawater gas exchanges will be investigated to discover the importance of atmospheric transport for the occurrence of these emerging persistent organic pollutants in open Ocean and towards Antarctica. Since sea ice covered parts of the Southern Ocean and the Weddell Sea were passed, this enables us to investigate the influence of sea ice and sea ice melting on the transport mechanism on POPs. Together with the results of ANT-XXVII/1 using modeled air mass back trajectories, the origin and atmospheric transport pathways of POPs from possible source regions (e.g., Africa, Asia) to Antarctica will be investigated. Data from snow samples will enable us to estimate wet deposition fluxes of several emerging pollutants to Antarctica.

Legacy POPs will be monitored in air samples including PCBs, PAHs, DDT, HCHs, HCB and PBDEs. The samples cannot be analyzed on the ship, but have to be analyzed in clean laboratory conditions at Lancaster University.

Data

All obtained data will be open to science and public since they will be published in scientific journals in the field of environmental chemistry as well as presented on national and international scientific conferences.

5. BIOLOGY

5.1 Marine mammal survey

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Objectives

Knowledge on distribution, density and abundance of cetaceans in the Southern Ocean is rather limited. Especially in pack-ice regions, little research has been conducted, as only few vessels can penetrate into the ice. In previous studies (Scheidat et al., 2007a & b, Kock et al., 2009) we showed, and confirmed earlier investigations (Plötz et al., 1991; Franeker, 1992), that helicopters provide a useful platform to survey cetaceans in open water and pack-ice. By means of a dedicated aerial and shipboard cetacean sighting survey following standard line-transect distance sampling methodology, our project aims to contribute to solid base-line data on cetacean occurrence and abundance, needed by decision makers for their management and conservation. In addition behavioural observations shall investigate response behaviour of cetaceans towards vessels in Antarctic waters.

Work at sea

Aerial surveys

Aerial surveys following standard line-transect distance sampling methodology (Buckland et al., 2001) were conducted with the two helicopters (BO 105) of *Polarstern*. Flying time during each survey was generally around 2 ½ hours, with a range of 15 minutes to 3 ½ hours. During the transit from Cape Town to Neumayer-III-Station, the crossing of the Weddell Sea and the transit from the Antarctic Peninsula to Chile, surveys were planned in an "ad-hoc" way, depending on the position and the track of *Polarstern*. For the area on the western side of the Antarctic Peninsula, a survey was conducted sampling pre-designed representative transect lines. All surveys were dependent on the actual weather conditions.

Survey flights were conducted at 600 ft with a speed of 80-90 nm per hour. Two observers were positioned in the back of the helicopter and were observing the area to the right and to the left side of the helicopter, respectively. The third observer was sitting in the port front seat of the helicopter and observed the area to the front, focusing on the transect line. The observer sitting in the right back seat of the helicopter used the VOR software (Hiby & Lovell 1998), running on a laptop computer, to continuously store GPS data, environmental conditions and sightings information.

During the flight, environmental information on sea state, cloud cover, glare, ice coverage in percent and overall sighting conditions was stored. For each sighting of a marine mammal in the water the following data were collected: species, distance to transect (via declination angle), group size, group composition, behaviour, cue, swimming direction and potential reaction to the helicopter. Inclinometers were used to measure the declination angle to each sighting when abeam the helicopter. With the known survey height this angle will be used to calculate the distance of the sighting to the transect line. Using the software Distance (Thomas et al., 2010) the effective searched strip widths for the different cetacean species can be estimated post-survey. Furthermore, swimming penguins, vessels, floating debris and the encountered remains of fishing gear (e.g. net parts, buoys, ropes) were recorded.

If a sighting was made and species or group size could not be identified, the survey was interrupted in order to approach the sighting. After identification the helicopter returned to the transect line and the survey was continued (closing mode).

Digital photography was used for photo identification of humpback whales, killer whales and for general species identification.

Shipboard surveys

Observations following distance sampling methodology were conducted from the crow's nest platform with two observers scanning the area in front of the vessel. The two observers were situated in wooden observer boxes located on the left and right side of the platform. The scanning was done naked eye but binoculars were used to identify species and group sizes. An additional team member was situated inside the crow's nest operating as data recorder. During shipboard observations the same environmental and sightings information as for the aerial surveys was collected. Surveys were generally conducted if *Polarstern* had a speed of at least 7 kn. Some observations were done in lower speed while breaking through ice.

Tracking

In order to investigate potential responsive behaviours of whales towards the survey vessel, high powered binoculars (Big Eyes) were used to follow the track of detected animals as long as possible while the ship passed by the sighting. These behavioural studies were conducted from the crow's nest. "Tracking" is only possible under perfect weather conditions with winds of less than three Beaufort, good visibility (clear horizon), a low swell and no ice breaking activity of the ship.

Preliminary results

Aerial surveys were conducted from 2 December 2010 to 1 February 2011. During this time a total of 60 flights were conducted in 132 hours, covering 8,224 nm. During these surveys 154 cetacean sightings with a total of 378 animals were made. Overall, 11 different species were identified. Table 5.1.1 gives an overview of the number of sightings and animals for all cetacean species encountered.

During the shipboard surveys a total of 44 h were surveyed on effort covering about 440 nm. A total of 50 cetacean sightings, totalling 76 animals, were made (Table 5.1.2). These observations will be compared with infrared cetacean detection data collected by the MAPS project (AWI) during this cruise.

Figure 5.1.1 gives an overview of the positions of all cetacean sightings from the aerial survey and shipboard observations combined.

The distribution of different cetacean species was distinct. Only two species were seen in waters covered by ice; these were Antarctic minke whales (*Balaenoptera bonaerensis*) and Antarctic type B killer whales (*Orcinus orca*). During surveys in open water, particularly along the western side of the Antarctic Peninsula, the number of species and animals sighted increased considerably. The most commonly seen species were humpback whales (*Megaptera novaeangliae*) (153 individuals in total) north of the pack-ice, and minke whales in the pack-ice (78 individuals in total). All other species were encountered occasionally only (Tables 5.1.1 & 5.1.2).

On the southbound leg from Cape Town to Neumayer-III-Station bad weather with high sea state and low clouds repeatedly hampered our survey work. Thus, it was only possible to conduct four helicopter flights and 4.5 hours of observations from the crow's nest between 40°S and 55°S. Only two fin whale (*Balaenoptera physalus*) sightings, three beaked whale sightings and one group of unidentified dolphins were recorded in this area. Between 55°S and 60°S, just north of the ice edge, sighting rates of baleen whales increased significantly with humpback whales being the dominant species. Also several beaked whale sightings were recorded in this area.

Minke whales became the dominant species when the vessel entered the pack-ice at 58°S. A total of 31 minke whale groups consisting of 41 individuals were seen in pack ice regions with ice coverage of at least 10 %. The maximum group size was six animals. It was striking that all sightings of larger groups occurred very close to the ice edge or in open water, while deep in the pack-ice sightings of mostly solitary animals, with a maximum of three animals were made. One pod of 35 Antarctic type B killer whales was sighted in the pack-ice and another group of 18 animals was encountered in the Antarctic Sound in very loose pack-ice.

At the western side of the Antarctic Peninsula a systematic aerial line transect distance sampling survey was conducted. Sampling occurred along pre-designed parallel transect lines, representatively covering this subarea. During 3,224 nm of effort 98 cetacean sightings were recorded. Again, humpback whales were the dominant species encountered, but also minke whales were frequently recorded. Fin whales, sei whales (*Balaenoptera borealis*), different beaked whale species, one blue whale (*Balaenoptera musculus*), hourglass dolphins (*Lagenorhynchus cruciger*) and long-finned pilot whales (*Globicephala melas*) were also encountered. Humpback whales were sighted both, close to the coast, in the shallower waters of the shelf, as well as in deeper waters further offshore. Fin whales are thought to prefer to feed on certain age classes of krill (mature krill) occurring further offshore (Santora et al., 2010). However, our expectation to sight increased numbers of fin whales in deeper waters and along the slope, similar to a previous study off Elephant Island and the South Shetlands in 2006/07 (Scheidat et al., 2007a) were not met.

For the pre-designed survey in this area distribution patterns and density of some cetacean species can be estimated.

During our aerial surveys an increased number of debris and remains of fishing gear, like buoys, were recorded either floating at the surface or stranded on rocks along the coast. This was especially apparent along the western side of the Antarctic Peninsula.

Photo-identification

A total of 17 humpback whale fluke ID photographs were taken from the ship and helicopter. A total of four killer whale sightings were made. During three sightings photos in sufficient quality for photo-identification were obtained.

Behavioural data

During one survey flight a pod of Antarctic type A killer whales was observed hunting a small minke whale calf. This behaviour was documented by means of digital photographs. Although Antarctic type A killer whales are known to feed on minke whales (Pitman and Ensor, 2003) to date few attacks have been documented. In addition, few sightings exist of Antarctic minke whale calves.

Tracking from the crow's nest has been possible on three days of the cruise during which five groups of whales could be tracked, recording 56 re-sightings in total. The tracking data will also be compared with infrared cetacean detection data collected by the MAPS project during this cruise.

Beaked whales

During the aerial surveys, a total of 15 beaked whale sightings, with 38 animals were made. Using digital photography from the helicopter and later analyses of pictures, it was possible, to identify 12 beaked whale sightings to species level.

On our way southward, travelling on the 0 meridian, five groups of southern bottlenose whales (*Hyperoodon planifrons*), consisting of 10 individuals, one group of three strap-toothed whales (*Mesoplodon layardii*) and one group of not yet identified beaked whales were sighted, just north of the ice edge (Figure 5.1.1).

Additionally, a total of 8 sightings of beaked whales were made at the western side of the Antarctic Peninsula. Two of these were unidentified, the others being southern bottlenose and strap-toothed whales.

From the ship one group of two southern bottlenose whales was recorded.

Data

Publication in scientific journals in the fields of marine biology and zoology and presentation on scientific conferences will make the data obtained available for science and public.

Acknowledgements

We would like to thank Captain Wunderlich and the whole crew of *Polarstern* for their friendly assistance throughout the whole trip.

These surveys would not have been successful without the helicopter crew, Klaus Hammrich, Roland Lindner, Markus Heckmann and Fabian Gall. Thank you for your safe and careful flying.

We would like to thank the meteorological office, Manfred Gebauer and Klaus Buldt. Their excellent weather predictions made it possible to do these surveys in an extremely variable environment.

We would like to thank the chief scientist on board *Polarstern*, Eberhard Fahrbach, for his support of the project during the cruise.

This project was financed by the Federal Agency of Environment (UBA) under the project: FKZ 3708 91 101-2 Erhebung und Auswertung von Daten zum Vorkommen, zu Verteilung und zu relativen Abundanzen von Meeressäugern in der Antarktis nach international anerkannten Standards.

Table 5.1.1: Cetacean sightings by species from the aerial surveys during ANT-XXVII/2

Species	**Number of groups**	**Number of individuals**	
Antarctic minke whale (*Balaenoptera bonaerensis*)	42	67	
Dwarf minke whale (*Balaenoptera acutorostrata*)	1	2	
Humpback whale (*Megaptera novaeangliae*)	58	112	
Fin whale (*Balaenoptera physalus*)	6	17	
Sei whale (*Balaenoptera borealis*)	4	31	
Blue whale (*Balaenoptera musculus*)	1	1	
Antarctic killer whale type A (*Orcinus orca*)	2	10	
Antarctic killer whale type B (*Orcinus orca*)	2	53	
Southern bottlenose whale (*Hyperoodon planifrons*)	9	16	
Strap-toothed whale (*Mesoplodon layardii*)	3	16	
Hourglass dolphin (*Lagenorhynchus cruciger*)	1	3	

Species	Number of groups	Number of individuals	
Long-finned pilot whale (*Globicephala melas*)	1	13	
Unidentified baleen whale	21	31	
Unidentified beaked whale	3	6	
Total	154	378	

Table 5.1.2: Cetacean sightings by species from the shipboard surveys during ANT-XXVII/2

Species	Number of groups	Number of individuals
Antarctic minke whale (*Balaenoptera bonaerensis*)	8	11
Humpback whale (*Megaptera novaeangliae*)	26	41
Fin whale (*Balaenoptera physalus*)	1	2
Southern bottlenose whale (*Hyperoodon planifrons*)	1	2
Hourglass dolphin (*Lagenorhynchus cruciger*)	1	7
Unidentified baleen whale	13	13
Total	50	76

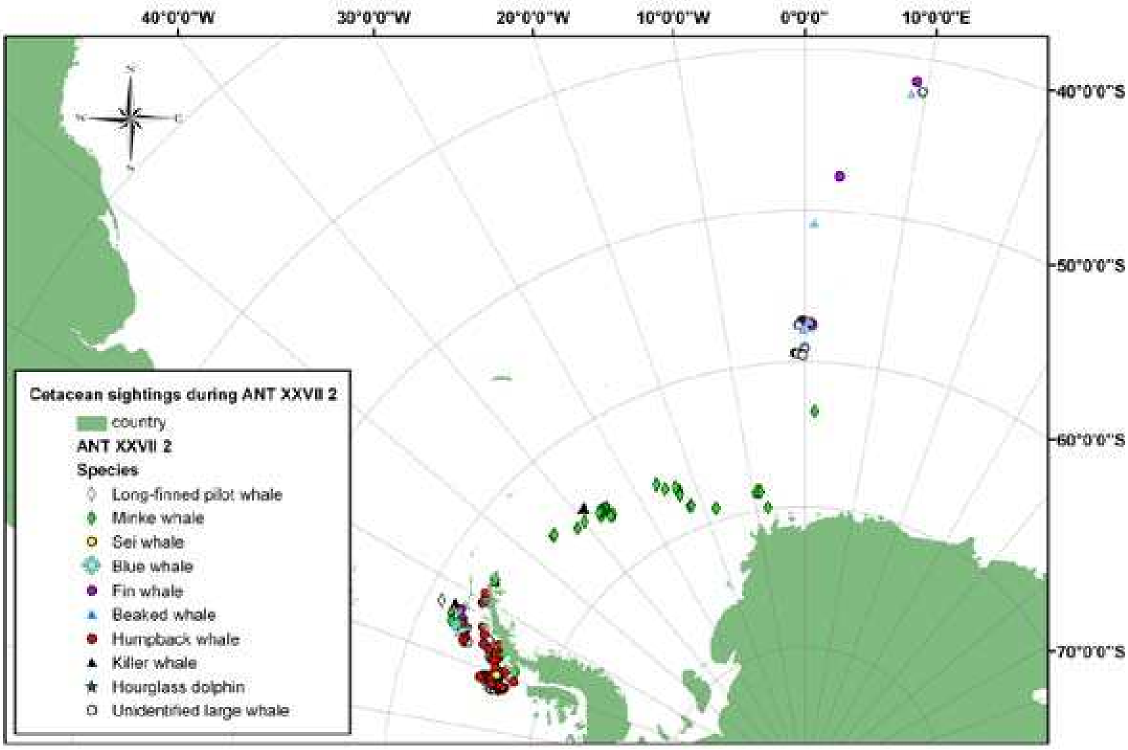

Fig. 5.1.1: Distribution of cetacean sightings along the cruise track of Polarstern during ANT-XXVII/2

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5.2 MAPS: Marine Mammal Perimeter Surveillance

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Objectives

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

Data collected with this system during two recent *Polarstern* cruises resulted in numerous detections during retrospective human visual screening, even in relatively warm waters of 6°C. These encouraging results however only represent a first step, as now a robust computer based image recognition algorithm needs to be developed and tested, which automatically processes the video stream for the occurrence of whale blows, ultimately resulting in real-time alerts to the marine mammal observers and ship's crew.

To test the efficiency of detection algorithms for various species and under varying environmental conditions, false and positive auto-detections shall be compared with sightings from an independent observer team (FTZ-Büsum).

The primary purpose of our participation in this cruise was to test the entire system under operational conditions, including a first version of the automated detection algorithm. In addition, visual sighting data (from distance sampling and tracking surveys by the FTZ-Büsum (See chapter 5.1), as well as from precise records of times of whale spouts) shall be obtained concurrently to allow the abovementioned comparisons.

Last but not least, the communication software between a visual camera system installed during ANT-XXVII/1 and the IR based autodetection system shall be implemented to allow automatic acquisition of high resolution visual images for retrospective species identification.

Work at sea

Thermographic Imaging

The FIRST system was operated continuously throughout the expedition for a total of 59 days (1,410 h in total), however using two sensor heads, UN 002 and UN 003 with a brief interruption of 4 days.

The system (using sensor head UN 002) was powered up in Cape Town on 28 November 2011 (Table 5.2.1). This sensor head stopped acquiring images on 29 December 2010 due to a hardware failure in the sensor's cooling system, after 740 h of operation. (It should be noted though, that the UN 002 had been used continuously in a previous project for a total operation time of about 7 weeks). This interruption was used to develop necessary communication software for the continuous retrieval of status information from the sensor unit in real-time. Using UN 002 which - except for the proper image acquisition - was still operational (rotation of sensor head, communication between sensor and control computer) avoided the risk of crashing a fully operation sensor head during this rather sensitive programming effort. The resulting sensor status software module was incorporated into the *Tashtego* automated whale detection software package, which is under continuous developed at the AWI to control, handle and analyze the IR data stream from the FIRST Navy thermal imager.

On 3 January 2011 a spare sensor head was mounted (UN 003), which has been running continuously for the rest of the cruise with a maximum uninterrupted operation period of 27 days (669h).

Table 5.2.1: Timetable showing the operation periods of the FIRST Navy.

Start	End	Hours operational [hhh:mm]	Unit Number (UN)
2010.11.28 12:21	2010.12.02 12:42	96:21	002
2010.12.02 13:17	2010.12.04 08:43	43:26	002
2010.12.04 08:45	2010.12.05 15:20	30:35	002
2010.12.05 15:52	2010.12.07 11:10	43:18	002
2010.12.07 11:11	2010.12.23 20:14	393:03	002
23.12.2010 20:15	2010.12.28 14:05	113:50	002
2010.12.28 15:14	2010.12.29 11:22	20:08	002
2011.01.03 15:00	2011.01.31 12:23	669:22	003
		∑ 1410:03	

Additionally, since 11 December 2010 every 10 seconds a single thermal image was saved to document the system performance under all occurring conditions. This sums up to 3.2 TB of image data.

Software development

Throughout the cruise several necessary improvements were made to the *Tashtego* software.

1. Detection and tracking of the horizon:

   The FIRST Navy scanner is mounted on a stabilized platform (gimbal) to maintain a “horizontal” horizon (Fig. 5.2.1). In spite of that, we observed vertical movements of the horizon in order of 5 % of the image size with a frequency of 0.1 – 0.2 Hz. A possible hypothesis for this behavior would be that motion induced centripetal forces cause the gimbal to falsely correct pan/tilt. Since the gimbal only measures pan/tilt using a gravity sensor, it can’t take centripetal forces into account. Resulting offsets in pan/tilt lead to a sinusoidal shaped horizon across a single image with wandering phase between images. We implemented a robust automated horizon detection algorithm that fits a sinus shaped artificial horizon line into each image. The other Tashtego modules were adopted to handle localized horizons. This automated horizon detection is a necessary prerequisite for reliable distance measurements.

2. Automatic detection of whale spouts:

   A first whale-spout autodetection algorithm, as implemented prior to this cruise, was based on a restoration-after-destruction approach, which required substantial image filtering in a preprocessing step. However, these filters turned out to be very sensitive on the sea state and brightness conditions. During this cruise we implemented a new, much simpler algorithm (based on STA/LTA algorithms adopted from seismology) which now serves as a preselecting algorithm. This algorithm focuses on the changes of the local contrast in small tiles of the image (21x21 pixels). The local contrast is then tracked over time and a spatio-temporal adaptive threshold defines whether an anomaly shall be reported. A second classification step will be implemented by a learning algorithm designed as a support-vector-machine. The implementation of this module commenced during the cruise.

3. Thermal imager status information

   A module for Tashtego was developed which continuously polls the FIRST Navy scanner for status information. This information is logged with 1 Hz frequency and might help to realize upcoming sensor malfunctions (e.g. increased power consumption due to increased friction). The information is graphically presented in real-time to the operator.

4. Image acquisition:

   An image acquisition and storage software was provided by the manufacturer (First DVDR) with the system. However, the First DVDR software proved unstable and caused the workstation (operating system Windows XP) to freeze approximately every 3-5 days. Due to the large hard drive array (up to 8 TB), a reboot can take up to 2 h if the operating system demands a file system check. To overcome these limitations, we adopted the self-developed image storage module of the

Picture-in-Picture (PiP) camera (presented in the ANT-XXVII/1 cruise report) to work with the FIRST Navy scanner, so the image storage can now be operated without the FIRST DVDR software.

5. Integration of data from Walog visual sighting software:

   Visual sightings entered into the Walog software (see cruise report ARK-XXIV/1) now directly trigger Tashtego to store this event and permanently save the acquired infrared images. The period for which infrared data will be saved is computed dynamically depending on the ship's speed to make sure that all possible signs of a whale while in sighting range will be captured. It has a maximum limit of 1h (which corresponds to 120 GB). If longer time spans shall be saved, start and end times may be entered manually.

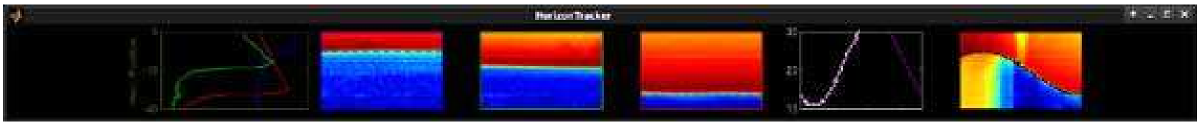

Fig. 5.2.1: Screenshot of the horizon detection module, which shows the elevation of the horizon in three different view directions (port, ahead, star) together with the modeled sinusoidal function.

Visual imaging

In addition to the thermal imager, hardware for a visual camera system was installed during ANT-XXVII/1. This PiP system consists of a high resolution pan-tilt digital camera system (Prosilica GE4000C, 11 megapixel) with a 400 mm tele-lens. It automatically acquires close-ups of objects detected by the IR scanner with a frame rate of 5 fps, equal to the FIRST Navy image rate. Technical details can be obtained from the ANT-XXVII/1 cruise report. For trained marine mammal observers these photographic images may allow offline species identification of the whales whose spouts have been automatically detected by the infrared imager. During this cruise we developed the corresponding communication software and graphical user interface to operate the camera from the Tashtego software. This system was operational throughout the cruise. Examples are given in Fig.5.2.2.

Visual whale blow logging

In order to test the performance of the infrared imager and the automatic detection algorithm, a dedicated observer was visually logging whale blows as accurately as possible (to the second) and making time stamped photos if possible. Such accurate information is necessary to be able to identify false positive (missed) events in the IR images. In addition, such accurately timed sightings significantly facilitate searching for a whale's blow in the thermal images during retrospective analysis as only short (2-3 s) periods needs to be searched.

Fig. 5.2.2: Three examples of automatically triggered whale detections, which were captured by the PiP system. They could retrospectively be identified as humpback whales (top at 5,568 m distance and middle, 1,864 m) and a minke whale (bottom, 1,525 m).

For this task the observer was provided with a small GPS logging device mounted on a pair of binoculars. This setup allowed registering the GPS-timestamp of a whale's blow with a single click while simultaneously following the whale through the binoculars to identify its species. If multiple whale groups surrounded the ship, an additional observer manually took as many photographs of whale blows as possible, as it was not feasible to log them all with the GPS device. Those pictures, which were also time stamped, also allow a comparison between the visual and thermal signature of a blow. To calibrate the timestamp of the digital camera, a picture of the ships GPS clock was taken at irregular intervals. Observations were conducted under varying environmental conditions (sea state 1-5, and also during various levels of fog).

In addition, independent visual observations were conducted at selected times from the crow's nest in cooperation with the marine mammal observing team from the FTZ who conducted distance sampling and tracking surveys. Once an observer from the FTZ team made a sighting, the dedicated additional whale-blow logger tracked that animal as long as it was in sight and recorded the exact time stamps of blows sighted.

Walog

In addition to these MAPS-IR activities, the nautical officers used the Walog software to log any opportunistic whale sightings for MAPS-vis. The Walog software worked well throughout the cruise. We simplified it further, so that the local ship time is now automatically updated while several bug fixes were implemented during the cruise. In addition, a second digital camera (Canon EOS7D, Sigma 150-500 mm lens) was supplied and integrated into the Walog WLAN, which now allows continuous image acquisition with 7 fps.

Preliminary results

Visual whale blow logging

In total we acquired 1,283 logs of visually detected whale blows and 575 photographs. These counts however are preliminary, as they represent minimum numbers of observed blows. On three occasions the ship was surrounded by so many whales that it became impossible to log/photograph all cues. Further, when groups of animals were encountered, blows eventually occurred so frequently that only a subset could be logged. Nevertheless near simultaneous blows can frequently be separated on the photographs. The whale logger was on effort for a total of 61 hours and additional blows were collected during the shifts of the marine mammal observing team from the FTZ in the crow's nest.

Walog

The cruise was very successful in terms of opportunistic visual sightings registered via the *Walog* software. A total of 175 overall detections were logged (Fig. 5.2.7), of which 147 could be identified with certainty to species level. Humpback whales were by far the species most frequently encountered during this cruise (87 sightings). Of special noteworthiness are two beaked whale sightings (most likely southern bottlenose whales) and the first blue whale sighting since the inception of the MAPS-vis project. All sightings will be validated in Bremerhaven and will support the development of a species distribution model.

Automatic detection of whale spouts

The newly developed autodetection algorithm has been operational since 11 January 2011, delivering 145 auto-detections of blowing cetaceans (Figs. 5.2.3-5.2.6). False alarms were mainly induced by a fast-motion of the horizon induced due to false gimbal motion compensation and swarms of birds. On a number of times, the system triggered alarms before any observer or nautical officer spotted a cue. These events were reported to the bridge and dedicated observers to verify the detection and identify the species. If visual species identification was not possible, the *PiP* images were visually analyzed for footage of the whale.

The collected visual whale blow logs and photographs are expected to prove sufficient training data for the classification by a supervised learning algorithm.

The newly introduced *PiP* system worked most satisfactory and was capable of capturing several hundred images of whales after automatic detections (with a total of 138,974 image files recorded). The 400 mm tele-lens however had a magnification which was too small for species identification if the animal is at a distance greater than approximately 2 km. The available examples show that humpbacks at that distance of 3 km can be identified, yet only due to their unique body shape. It is planned to add a 1.7x magnifier and replace the zoom lens (100-400 mm) by a fixed focus 400 mm lens. Finally, the metal housing of the camera proved to be too heavy, slowing the PTU down, which will be remedied by replacement with a plastic housing.

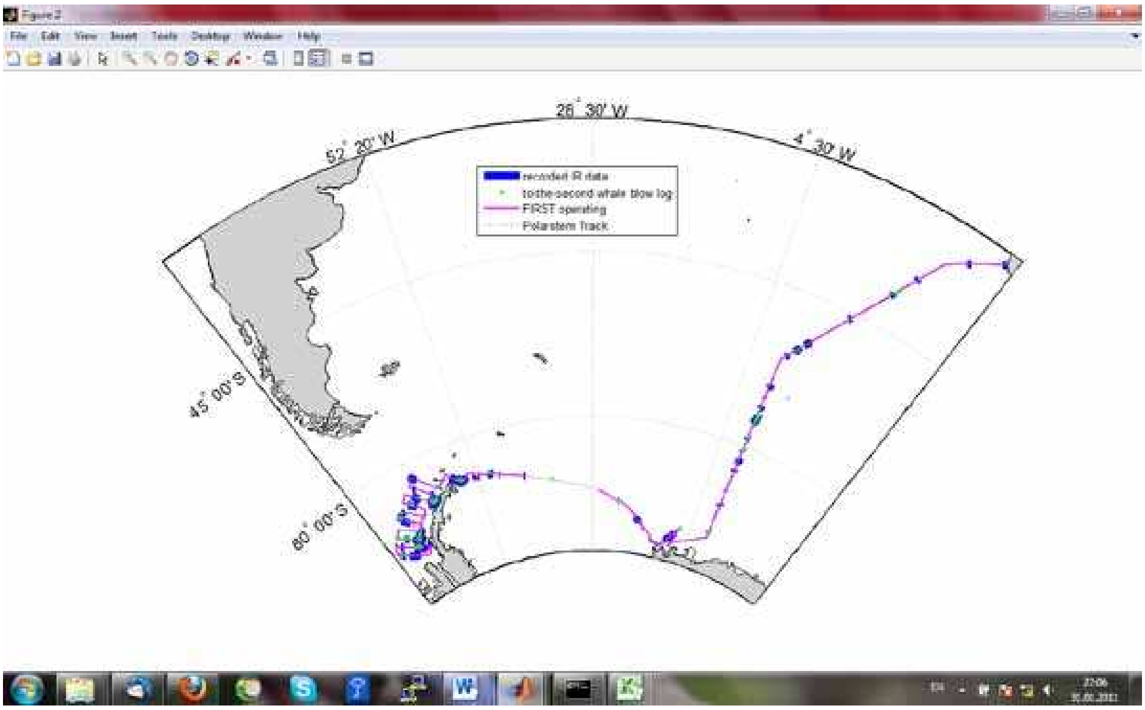

Fig. 5.2.3: Polarstern's cruise track, marking location at which the FIRST Navy scanner was operational in magenta and locations of permanently recorded images for retrospective analysis marked in blue. Whale sightings with a precise timestamp are shown as green dots.

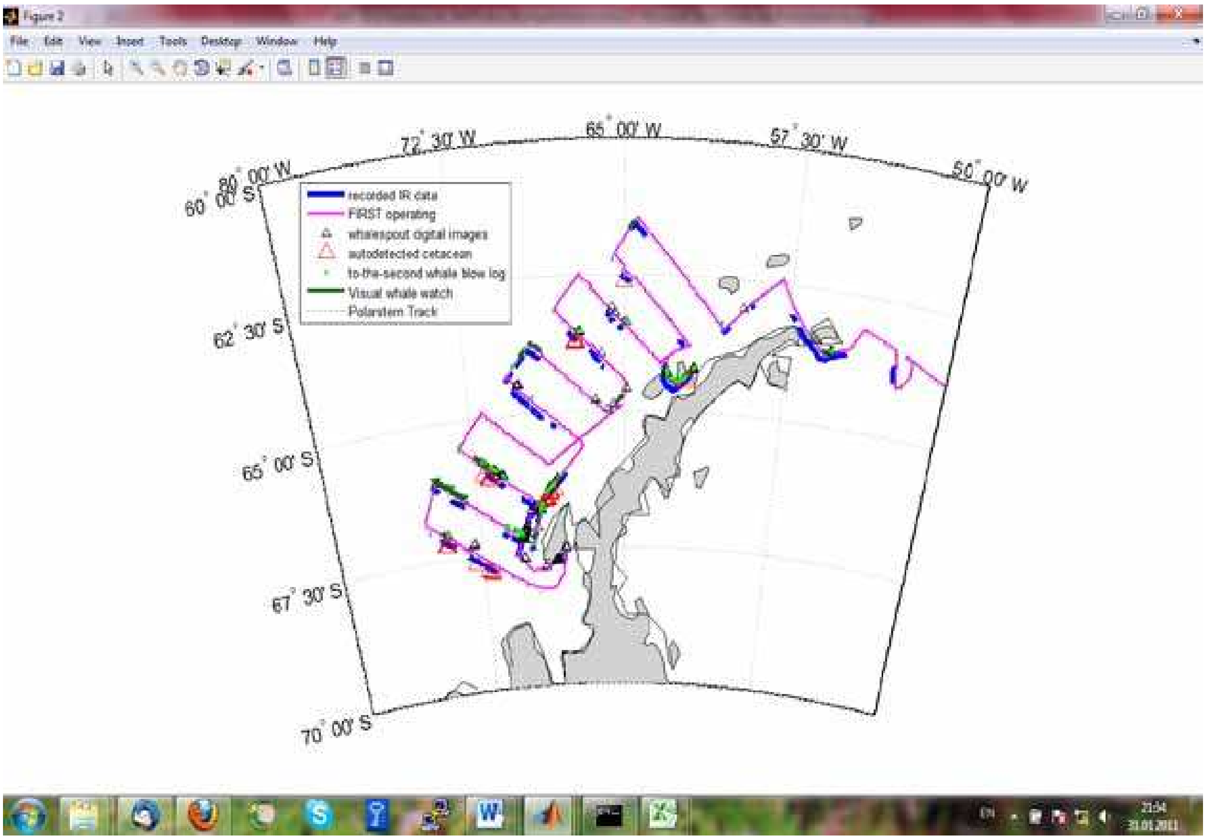

Fig. 5.2.4: Magnification of Fig. 5.2.3 for the region of the Antarctic Peninsula

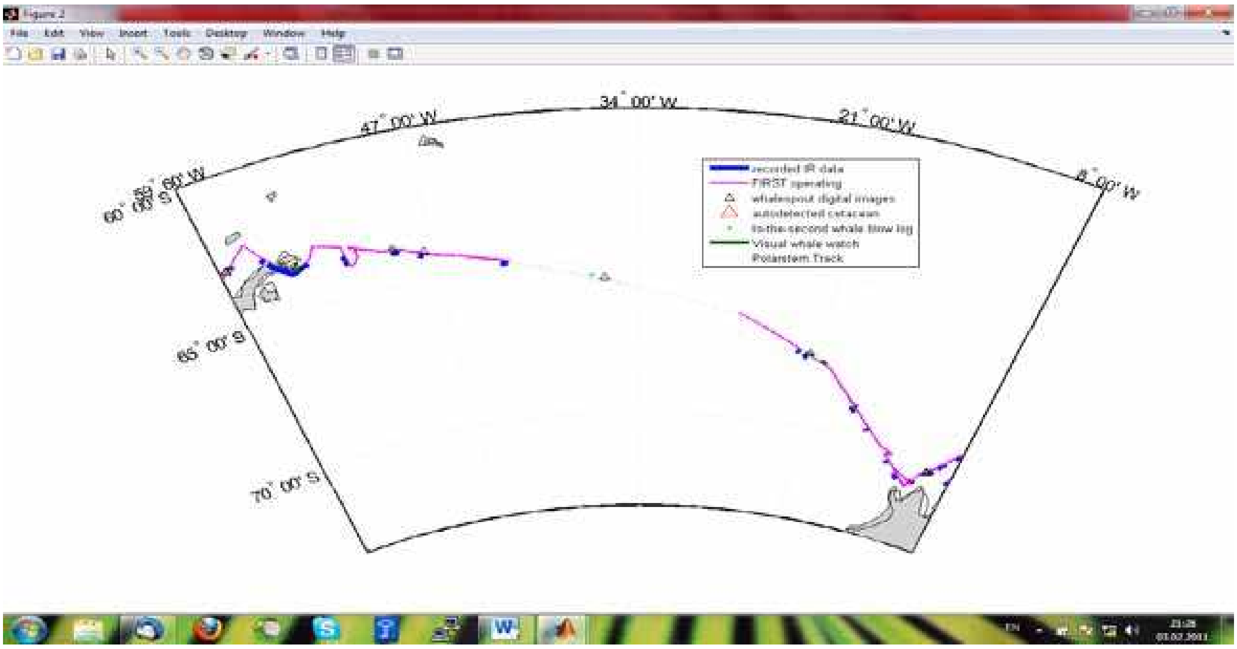

Fig. 5.2.5: Magnified sections of the cruise plot for the Weddell Sea transect, showing the concurrently recorded data

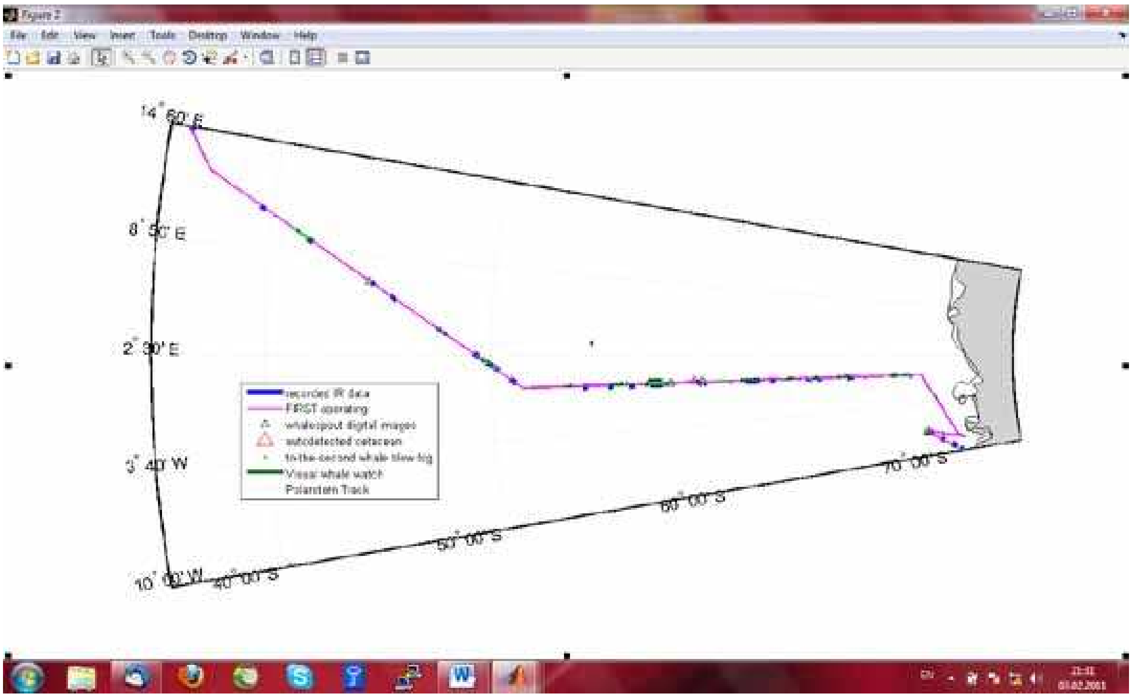

Fig. 5.2.6: Magnified sections of the cruise plot for the Greenwich meridian transect from Cape Town to Atka Bay, showing the concurrently recorded data

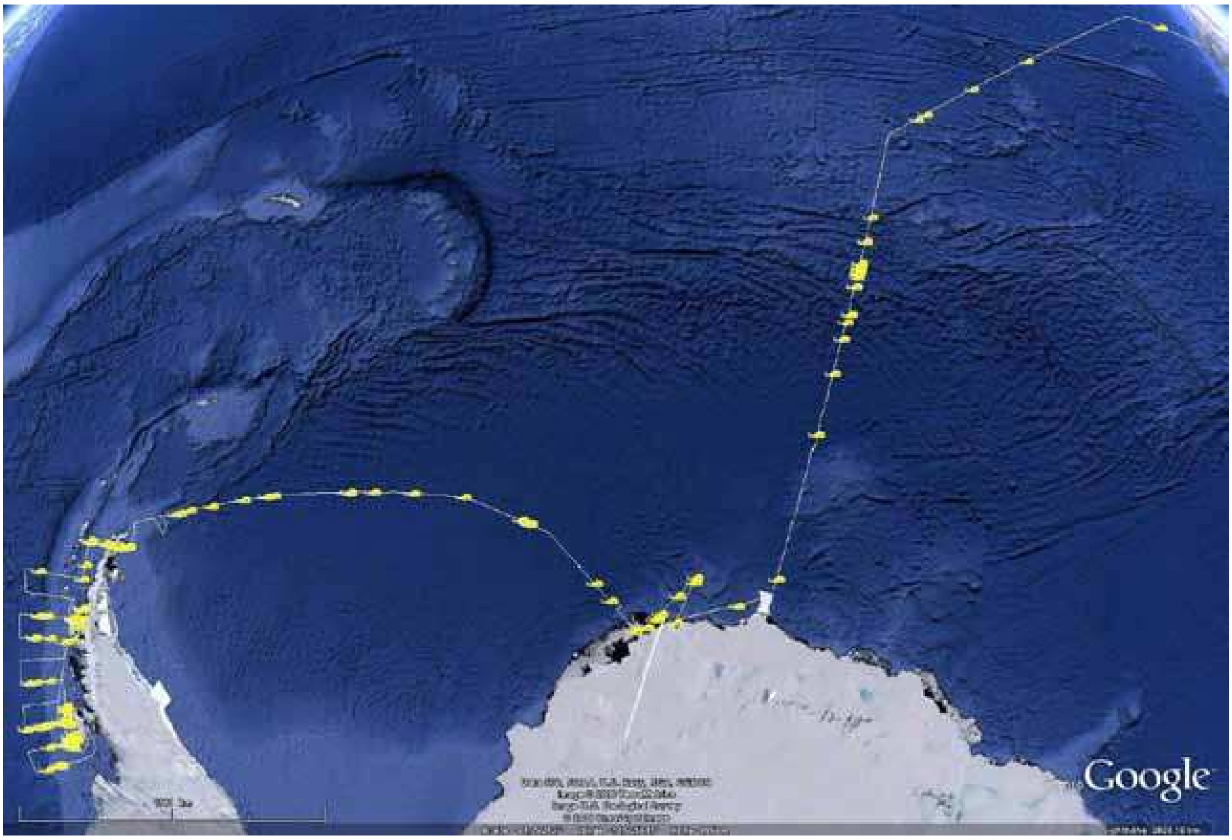

Fig. 5.2.7: Overview of all sightings entered into the Walog software during the expedition ANT- XXVII/2

Data description and metadata will be accessible through the Pangaea database, however as the image data occupy more than 26 Terabytes, it will not be available online.

5.3 Ocean acoustics: moored recorders, PALAOA observatory and field recordings

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Objectives

Detecting marine mammals using their vocalisations is an alternative to the traditional visual sighting methods or automated methods based on machine vision utilizing video or infrared cameras. The main advantages of passive acoustic monitoring are a long detection range (several low frequency vocalisations of cetaceans can be heard over hundreds of kilometres), independence of weather and light conditions and the possibility to conduct long term monitoring using moored recorders. While sighting based detection requires sea- or airborne surveys and is thus restricted to expedition tracks, passive acoustic monitoring (PAM) provides a unique option to determine the spatial-temporal distributions of vocalizing marine mammals, especially for the ice covered areas of the Southern Ocean, where accessibility is extremely difficult during austral winter. The PALAOA (PerenniAL Acoustic Observatory in the Antarctic Ocean) observatory at the Ekström Ice Shelf continuously recorded the soundscape in the vicinity of Atka Bay since 2006 and provided a wealth of knowledge on the presence and behaviour of whales and seals in this area. By adding recently developed acoustic recorders to the oceanographic HAFOS mooring array (see 3.1) we utilize this well established infrastructure to extend the coverage of acoustic monitoring to significant parts of the Weddell Sea to determine the distribution and migration of marine mammals. A necessary prerequisite to analyze PAM data on species level is the knowledge of the acoustic repertoire of the species of interest. This can only be acquired by simultaneously acquiring acoustic field recordings and visual identification of a single animal. While for many marine mammals their respective sounds are already well known for some species their underwater vocal repertoire remains unknown as yet (e.g. Antarctic minke whale, elephant seal), if at all existent.

Another goal of using bioacoustic methods is to understand the influence of human activities to marine animals. Many seaborne activities generate noise or intentionally use underwater sound for data acquisition. Echo sounders for navigation or reckoning, air guns for geophysical research or exploration and various other anthropogenic sound sources may have notable effects on marine life. Passive acoustics is a convenient way to acquire both the anthropogenic sound signal and a possible (acoustic) reaction of animals to it, necessary requisites to understand the relationship and to develop methods to mitigate possibly negative effects.

Work at sea

During the cruise we recovered three moored acoustic recorders; one was inaccessible due to ice conditions. In addition, a total of 13 acoustic recorders were deployed in 10 moorings. During the supply of Neumayer-III-Station we performed maintenance and calibration work at the PALAOA acoustical observatory on the Ekström Ice Shelf and collected the data recorded during 2010. During the Rothera base supply we made hydrophone field recordings with support from BAS from the shore of Rothera bay.

Recovery of moored recorders

During ANT-XXIV/3 in March 2008, two autonomous recorders of type AURAL-M2 (manufactured by Multi-Electronique, Canada) had been deployed and were recovered successfully during this cruise (Table 5.3.1, Fig. 5.3.1). Both devices were still operational and recorded since 1,025 days. They were equipped with alkaline batteries. Both recorders did record 5 minutes at four-hourly intervals, starting at midnight each day. The sampling rate was 32,000 Hz and data was digitized with 16 Bit resolution to WAV files and saved on a 140 GB harddisk. The internal amplifier was set to 22 dB gain. Every 8th day at noon, only a few seconds were recorded instead of the five minute period, probably due to a firmware bug. This problem made data extraction difficult because of unequally sized data blocks in the internal WAV files. A MATLAB program was developed to remedy this problem and to extract the correct 5 minute sequences to single, time stamped files named “nnnn yyyymmdd-HHMMSS AURALn.WAV”. A short preliminary analysis containing waveform, spectrogram and power spectrum plots was saved as correspondingly named jpeg files to allow for fast visual inspection of each file. Each AURAL recorder stored 6 files of 5 minutes, i.e. about 30 minutes of audio per day, resulting in 332 hours per year. In total, for the 1,025 days of deployment 6,090 files worth 500 hours or 21 days of audio were collected.

In December 2008 during ANT-XXV/2, two additional MARUs (Marine Autonomous Recording Units) had been deployed at about 5,000 m depth in collaboration with the Bioacoustics Research Program (BRP) at the Laboratory of Ornithology, Cornell University, NY (Table 5.3.1). One of them could be recovered during this cruise while the other one was inaccessible due to dense pack ice covering its position. When MARU #1 was opened, a small amount of water (a few cm^3) was found inside the Benthos sphere. Batteries were empty and the hard disk was not accessible in any normal way. However, a low level dump of the physical sector layout produced a disk image file in which sections containing acoustic data could be identified. A MATLAB program was then developed to retrieve the data structures from that. It revealed that the device had recorded successfully for about one year, however with, the last data sets being incomplete, probably due to the low battery state. Probably the last attempt to write to disk had destroyed the partition table. Nevertheless, we were able to extract all 8,556 hourly records of six-minute audio files from the disk covering 2008-12-12 9:53 till 2009-12-03 21:25 and summing up to 855 hours of audio data. All files were saved to time-stamped WAV files (2,000 Hz sampling rate, 16 Bit resolution, gain setting 23.5dB, LSB=85.5dB, saturation=151.3 dB) named “nnnn yyyymmdd-HHMMSS MARU1.WAV”. A short preliminary analysis containing waveform, spectrogram and power spectrum plots was saved as “nnnn yyyymmdd-HHMMSS MARU1.jpg” to allow for fast visual inspection of the files. The recordings contain a strong 40 Hz signal with harmonics which had been identified previously by BRP as a problem with the MARU’s double-bubble configuration. Additionally a hard drive spin up noise is present in every file at exactly the third minute.

Table 5.3.1: Recovery of moored audio recorders

Mooring	Position	Water Depth	Deployment Date	Recovery Date	Device	S/N	Recorder Depth
MARU#1	59°10.28‘S 000°00.39‘ E	4838 m	12.12.2008 18:00	12.12.2010 03:00	MARU	5	4798 m
MARU#2	64°05.07‘S000°05.24‘ W	5194 m	14.12.2008 10:00	not recovered	MARU	1	5144 m
AWI 230-6	66°01.13‘S 000°04.77‘E	3577 m	08.03.2008 14:00	16.12.2010 15:47	AURAL	086	200 m
AWI 232-9	68°59.74‘S 000°00.17‘ E	3419 m	11.03.2008 14:00	19.12.2010 06:28	AURAL	085	216 m

Deployment of moored recorders

Both recovered AURAL recorders were fitted with new battery packs (SAFT Lithium LS33600), new zinc anodes; the pressure ports were refilled with grease. The harddisk was formatted externally to FAT32 using Linux because we observed recording problems when using the formatting program supplied by Multi-Electronique. AURAL SN 86 was started 29.12.2010 13:00 and set to interval=180 min, duration=4:30 min, filesize=32MB, gain=22dB. It is expected to record until 31.1.2014. AURAL SN 85 was started at 4.1.2010 12:00, a restart was issued at 5.1.2010 18:00. Settings are: interval=180 min, duration=4:30 min, filesize=960MB, gain=22dB. It is expected to record until 4.2.2014.

Additionally, 8 new SonoVault (manufacturer Develogic, Germany) recorders were deployed. These newly developed underwater recorders use a RESON hydrophone and can record at 24 Bit resolution (19 Bit effective) with up to 20 kHz sampling rate and 16 Bit Data (15 Bit effective resolution) with up to 200 kHz sampling. They are equipped with 1 Terabyte of memory (5 memory modules housing 7 32-GB SD-cards each). Optionally a DSP board can perform various signal processing tasks. They were set to continuous recording to 24 Bit WAV format at a sample rate of 5,333 Hz. This allows for three years of continuous sound acquisition. We used various gain settings (see Table 5.3.2) to determine the optimal setting for later deployments. During the cruise some modifications were suggested by the manufacturer, especially the addition of a 150 kΩ resistor to the AD board to compensate for DC drift at depth. Prior to deployment, the firmware Version 1.4 was uploaded to all boards/recorders, but S/N 1. We tried two types of o-rings of different thickness to fix the hydrophone to the pressure housing to determine the best low-frequency decoupling from the mooring. Two short test deployments on a hydrographic wire were performed on 12 December 2010 00:38 on station PS77/0043-1 (1,500 m) and on 15 December 2010 04:16 on station PS77/0053-3 (1,000 m) to evaluate the recording behaviour at its nominal depth.

An additional SonoVault was deployed during the first leg of this expedition, ANT-XXVI/I in mooring AWI 2471 and is also included in the following tables and maps. This mooring's position off the coast of Namibia was chosen to gather complementary information about whale presence in the presumed winter and breeding locations of blue and fin whales which are thought migrating forth and back to the Southern Ocean. The sample rate of this unit was set to 5,120 Hz, slightly different than for the later ones.

Three C-PODs (POrpoise click Detectors, manufactured by Nick Tregenza) were deployed additionally together with three recorders. These PODs are frequently used in the North and Baltic Seas to detect the echolocation clicks of harbour porpoises. Here we set the click detector to a broader frequency range. All C-PODs (IDs 844, 845 and 846) were set to record click events continuously without limits to the number of clicks events that is logged per minute. The build-in high-pass filter was set to 20 kHz. For deployment, the C-PODs were set to start recording events immediately (no delay between activation and onset) with a switch angle of 110-0 degrees (i.e. the C-POD stops logging when hydrophone cap floats higher than lid of C-POD). The combination of these high frequency click detectors with the acoustic waveform recorders will allow evaluating the performance for beaked whale detection in Antarctic waters.

Table 5.3.2: Deployments of moored audio recorders

Mooring	Position	Water depth	Deployed	Device	S/N	Device depth	Gain	Clock calib	Remark
AWI 247-1	20° 58.90‘ S 05° 59.59‘ E	4288 m	20.11.2010 11:40	SonoVault	0001	789 m	60	32768	3
AWI 227-11	59° 03.02‘ S 00° 06.63‘ E	4597 m	11.12.2010 16:45	SonoVault	0002	1007 m	10	43472	
AWI 229-9	63° 59.56‘ S 00° 02.65‘ W	5170 m	15.12.2010 15:17	SonoVault	1000	969 m	253	44114	1
AWI 230-7	66° 01.90‘ S 00° 03.25‘ E	3540 m	16.12.2010 18:45	SonoVault	1001	934 m	315	43500	1
AWI 231-9	66° 30.71‘ S 00° 01.51‘ W	4524 m	17.12.2010 10:27	SonoVault	1002	1083 m	253	42778	1,2
AWI 232-10	69° 00.11‘ S 00° 00.11‘ W	3344 m	19.12.2010 08:57	SonoVault	1003	1288 m	315	44030	1,2
			9:11	C-POD	846	2046 m	-	-	
AWI 244-2	69° 00.30‘ S 06° 58.89‘ W	2900 m	23.12.2010 09:34	SonoVault	1005	903 m	315	44010	1,2
AWI 245-2	69° 03.52‘ S 17° 23.05‘ W	4740 m	27.12.2010 10:40	SonoVault	1004	1051 m	315	43694	1,2
AWI 209-6	66° 36.70‘ S 27° 07.31‘ W	4830 m	29.12.2010 12:25	AURAL	086LF	200 m	22 dB	-	
AWI 207-8	63° 43.20‘ S 50° 49.54‘ W	2500 m	06.01.2011 11:02	AURAL	085LF	219 m	22 dB	-	
			11:47	C-POD	845	2101 m	-	-	
AWI 206-7	63° 28.93‘ S 52° 05.87‘ W	950 m	06.01.2011 20:32	SonoVault	1006	909 m	253	43500	1,2
			20:25	C-POD	844	709 m	-	-	

Remarks: 1: 150 kOhm Resistor soldered to board, 2: Thick O-Rings used for hydrophone suspension, 3: Firmware Version 1.1

PALAOA maintenance

The PALAOA observatory is designed for autonomous operation year round. In contrast to the other Neumayer observatories no overwinterer is permanently assigned to the maintenance of PALAOA. The electronics engineer is responsible for necessary repairs. Thus, regularly maintenance has to be performed during summer season. This year we had two days during the supply of Neumayer by *Polarstern* for this work. In particularly we conducted the following tasks on 21 and 22 December 2010:

- Inspection and cleaning up of the observatory. When we arrived the container was found partly filled with snow. We removed all the snow and all the parts left from repairs during wintertime. (Because of the extreme cold during these operations, actions are usually restricted to the absolutely necessities to restore operation). Cleaning up is left to the summer visits.
- Installation of a real time clock, a timer relay and new firmware for the PLC controller unit. This will ease the process of recovery after power loss, enabling a time scheduled operation mode during low energy supply and the possibility to modify the firmware remotely. In case of power failure or intentional shutdown, the station will try to reboot every day at 12:00 UTC. Additionally the Iridium phone will power on at noon for 10 minutes to allow contact in case of failed contact.
- Repair and reinstallation of the low-energy PC. The hard drive had crashed and was replaced by a new solid state disk drive and the PC was reinstalled in the container, restoring two features: stand alone operation with recording to a local disk when the WLAN link to Neumayer Station is down and the use of the additional high quality audio system to make timed recordings at 192 kHz/24 Bit/ uncompressed WAV mode in addition to the default 48 kHz/16 Bit/192 kBit MP3 recordings.
- We replaced a fuse compartment with oxidized contacts which had led to problems with one battery section and also the computer keyboard which was damaged by the snow inside the container.
- The data server at Neumayer was provided with software updates and new 2 TB hard disks. A hot spare was prepared for installation in the Neumayer computer room.
- Two replacement fuel cells were stored at Neumayer as backup energy sources for dark and calm periods in austral winter. These SFC EFOY-Pro Cube 1600 fuel cells can deliver up to 60 watts for about two month from a 60 litre tank of methanol. For deployment in the extremely cold environment of Antarctica (up to -50°C) we have developed and installed an automated exhaust hose heating system to avoid clogging from condensing water steam using a minimal amount of energy itself. A replacement wind generator (WindSide Type A10,3) was stored at Neumayer for the case of failure of the original one. A replacement for the door was provided for later instalment by the technical staff. The spare part stock at Neumayer was inspected and outdated components were prepared for shipping back to Germany.
- The PALAOA observatory also hosts a CTD (SBE 37-SMP MicroCAT) which

is recording continuously since December 2005 at half-hourly interval. Its intentional purpose was to determine the local speed of sound for precise acoustic measurements. However, the five year time series of under ice shelf oceanographic data has turned out to be interesting itself. While the PALAOA setup does not feature a current meter, the free hanging CTD is displaced by the under-ice current, resulting in changing depth readings. These depths should be a monotonic function of the magnitude of the local current, and thus should allow determining the speed of the current from the depth data. When *Polarstern* berthed at the “Nordanleger” (70°30.733’ S, 8°11.308’ W) from 20 December 2010 12:00 until 22 December 2010 18:00, the ADCP recorded the current profile beneath the ship at a horizontal distance of 1,000 m to PALAOA. The ships DWS (Deep Water Sounder) also continuously recorded the water depth at this position, thus providing a tidal gauge to compare the real local tide with data obtained from a model. After *Polarstern* left the ice port, a CTD (station number was PS77/0067-1 at 22 December 2010 23:00 on 70°31.32’ S, 8°5.81’ W, depth 214 m) was taken inside Atka Bay, as close to the pack ice as possible in order to get a reference measurement for the PALAOA CTD data.

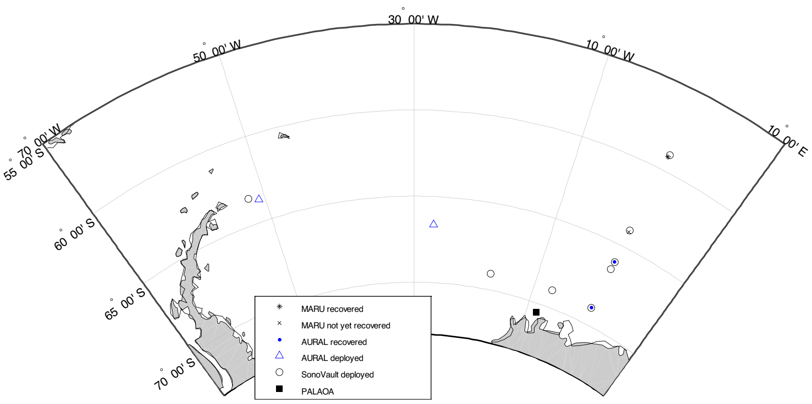

Fig. 5.3.1: Map of locations of moored acoustic recorders and the PALAOA observatory

Field Recordings at Rothera

When *Polarstern* arrived at Rothera base, we were informed by British Antarctic Survey personnel that elephant seals inhabit the beaches of the station since few weeks. As no underwater vocalisation of southern elephant seals is known so far, this seemed a unique occasion to possibly obtain recordings from these animals. We joined a biologist (Simon Reeves) from BAS to make hydrophone recordings at three locations of the peninsula, opposite to the wharf with *Polarstern*, to escape the ship’s noise. We deployed the hydrophone at about 50 m distance from the beach at a water depth of about 1.20 m. The hydrophone was located in a depth of about 60 cm. A Zoom H4N field recorder in a watertight bag was used to digitize the hydrophone signal at 96 kHz to 24 Bit WAV files. At location 1 the recorder was placed on a buoyant platform held in place by a little anchor stone. We did record for about 30 minutes. Amplification setting of the Zoom was 66 %. At locations 2 & 3 waves were too strong for this method so the recorder and the hydrophone cable had to be held by hand all the time. Recording times were 2x10 minutes at 66 % respective 100 % amplification setting at location 2 and 5 minutes (at 100 % gain) at location 3.

Preliminary results

The total amount of collected acoustic data – 1,850 hours or 119 days from the 3 recovered recorders and more than 8,000 hours or 332 days retrieved from PALAOA - made it impossible to attempt a comprehensive analysis during this expedition. However, we were able to get first results from inspecting only a small amount of the files. We could clearly identify crabeater and leopard seals, blue, humpback and fin whales and the unidentified "bioduck" signal in these files. Extensive analysis of the combined data from all recorders and PALAOA is expected to provide year round distribution and migration data of many marine mammal species.

Since the beginning of the PALAOA observations in 2006, a signal at 26.8 Hz is present in most of the PALAOA recordings. We were not sure about the origin of the signal and even could not rule out an (electronic) artefact because of the quasi continuous nature of this signal. However, we found the exact same frequency to be present on all three moored recorders during much of the time, too. This almost excludes any technical interference as three technically completely different systems on four locations separated each by hundreds of kilometres are unlikely to suffer from the same noise. So it is most likely a sound permeating the entire Weddell Sea. In several recordings by the moored recorders we could clearly identify "Z" shaped calls with their main energy exactly at 26.8 Hz (Fig. 5.3.2). "Z" shaped calls are attributed to blue whales. So we can conclude that blue whales are acoustically present almost continuously in the Weddell Sea. Assuming source levels from literature and modelling the transmission properties at this frequency it should be possible to derive abundance estimates for rather large areas from these recordings. Notably, right after the recovery of the MARU a blue whale was sighted and photographed by the nautical officer on duty very close to the MARU position, suggesting that blue whales are in fact present exactly at this area and at that time of year when the acoustic detection was made one year before.

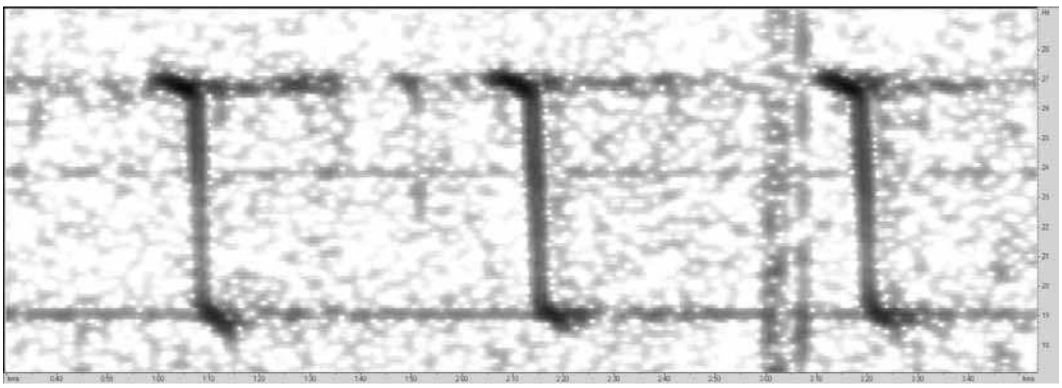

Fig. 5.3.2: Spectrogram of blue whale „Z"-calls, recorded by MARU#1 on 28 December 2008 17:55.

The calibration of the current signal from the PALAOA CTD with the ADCP readings from *Polarstern,* kindly provided by A. Macrander, showed a high correlation. This allows calculating approximate current strengths from the 5-year CTD data series now. The comparison of the echo sounder readings from *Polarstern* with a tide model also showed good correspondence for this location (Fig. 5.3.3 and 5.3.4). However, GPS data from PALAOA suggests that the ice shelf is following the ocean tide with smaller amplitude, which might help modelling the strain-stress response of the floating ice shelf. CTD taken at Atka bay showed like temperatures to the PALAOA CTD readings from that day, yet with a scatter of about +/- 0.1°C (Fig. 5.3.5). Interestingly, the ship based CTD showed significantly higher salinities (0.04) at corresponding depths. This might indicate a drift of the conductivity sensor after 5 years of deployment.

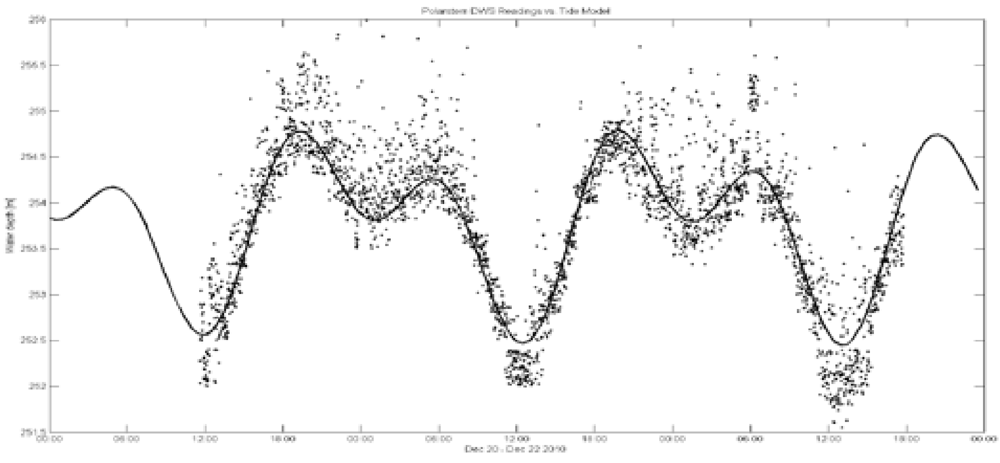

Fig. 5.3.3: Echo sounder depth readings from Polarstern near PALAOA compared with the forecast from a tide model.

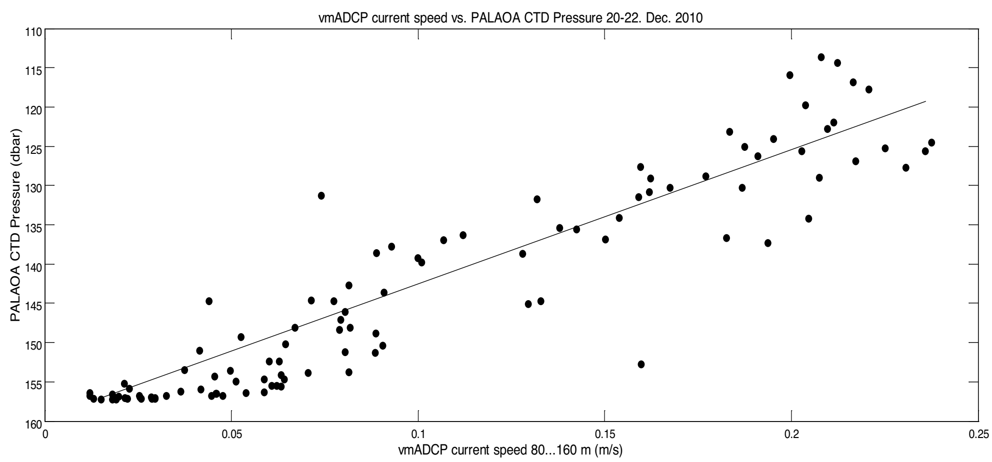

Fig. 5.3.4: Current magnitude as measured by Polarstern's ADCP vs. vertical CTD displacement at PALAOA. Correlation coefficient is 0.93.

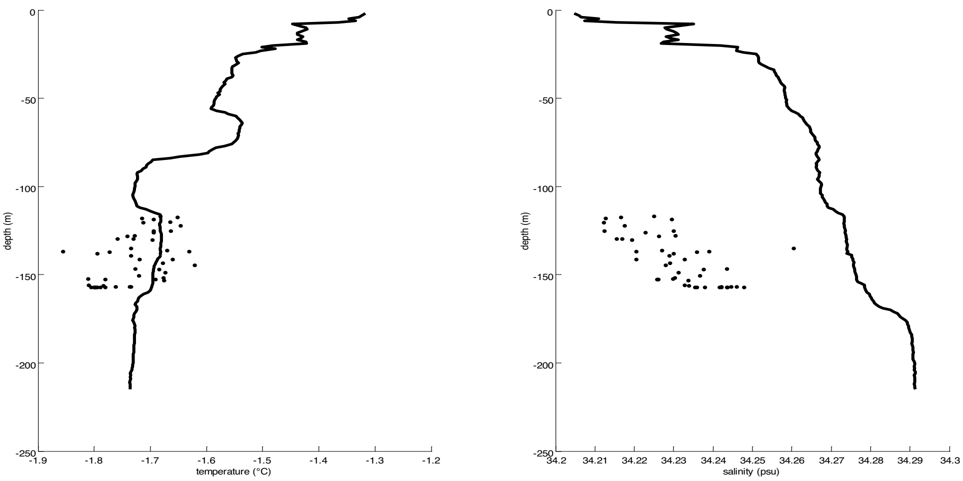

Fig. 5.3.5: Comparison of the PALAOA CTD (dots) and the Polarstern CTD (line). As the PALAOA CTD is not intentionally profiling but driven by current the readings from 12 hours before and after PS-CTD are pooled.

The field recording at Rothera did not catch any animal vocalizations in spite of a group of three crabeater seals which closed in to about 2 meters distance to the hydrophone at location 1. However, for the crabeater seals this is not surprising, as PALAOA data shows that their underwater vocalisations are restricted to times between October and December, probably their mating season. Disappointingly, no elephant seals were spotted in the water at that time and no vocalisations could be picked up. However melting pieces of glacier ice produced lots of clicking sounds due to exploding little bubbles of enclosed pressurized air. This effect produced a significant level of background noise which should be taken into account when computing ocean noise budgets of areas affected by glacier ice melting.

Data from the recovered moored recorders, in total 1,355 hours of audio, will be made accessible through the Pangaea database.

5.4 Antarctic krill demography and population dynamics west of the Antarctic Peninsula in 2010/11

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Objectives

Since 1978 krill data have been collected by German surveys or by international cooperations which contribute to the long-term monitoring of the stocks in the Antarctic Peninsula region. Data were collected on an annual basis but they also cover the seasonal cycle. This allows the study of seasonal as well as interannual aspects in krill demography and population dynamics. During *Polarstern* cruise ANT-XXVII/2 a continuation of this activity was carried out and studies focused on Antarctic krill as the primary target species. However, other heterospecific krill species as well as salps were also recorded quantitatively.

The South Atlantic sector of the Antarctic – especially the Antarctic Peninsula region - is not only known as the area where krill is most abundant, it is also thought to represent the most productive spawning area of the circum-Antarctic krill populations. These ideas have been developed since the early 'Discovery' expeditions, which show the Scotia Sea as a seasonally important area for the occurrence of krill larvae. This idea was in principle confirmed during the international FIBEX expedition in 1982 and the CCAMLR Survey 2000. These surveys showed a large amount of krill larvae in the western part of the Atlantic sector.

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

1. How do timing and intensity of spawning events relate to successful reproduction of krill?
2. Which key factors trigger krill larval survival and subsequently recruitment?
3. Can we detect significant inter-annual variation in reproductive and recruitment success?
4. Is krill recruitment success or failure related to stock size or density?
5. Are there geographical variations in krill distribution patterns, density or growth and mortality rates?
6. How does breeding and recruitment success relate to krill stock size?
7. Are there long-term trends in krill distribution patterns as well as abundance/ biomass and if so, are they related to long-term trends in the environment?

These questions are of complex nature and require a large amount of data collected in a standardised way to allow direct comparisons between data sets. The German krill data have been collected over the years with standard gear (RMT1+8 net) and standard methods for net sampling procedures as well as for sample handling and measuring and staging krill. These allow interannual comparison of quantitative aspects of krill demography and population dynamics. Results from interdisciplinary work with the physical oceanography will also be required during the further analysis.

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

Work at sea

The planned investigations were carried out in the area west of the Antarctic Peninsula during austral summer 2010/11, the main spawning season for the Antarctic krill. 81 established standard stations were covered along regularly spaced transects (Fig. 5.4.1) during a survey period of 22 days from 9 to 30 January 2011. The area extended between Bransfield Strait in the north and Adelaide Island/Marguerite Bay in the south. The 10 transects were located perpendicular to the main current flow along the Peninsula.

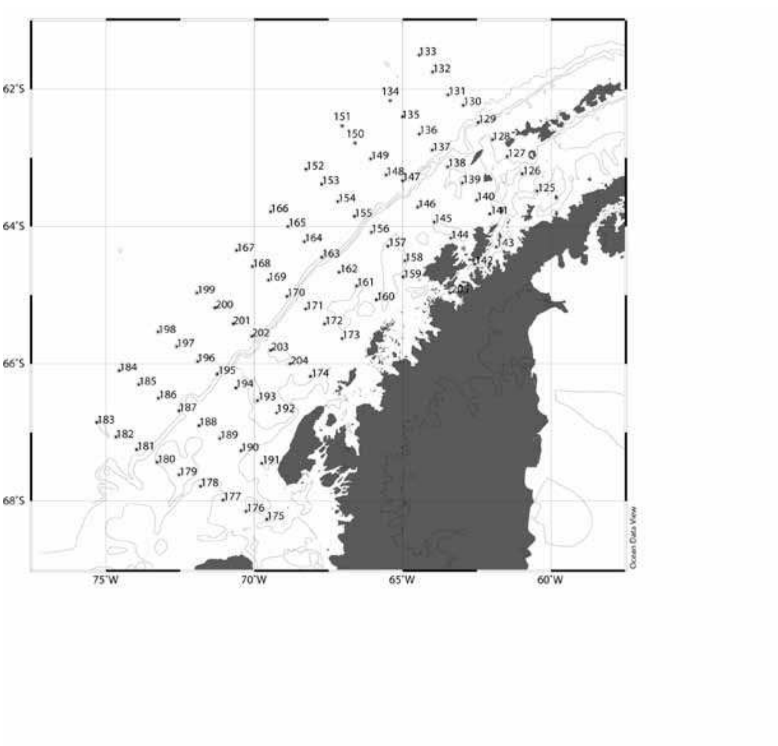

Fig. 5.4.1: Station chart of the RMT1+8 net sampling and CTD casts west of the Antarctic Peninsula in January 2011. Solid and dotted lines indicate the location of the frontal zones.

The plankton net RMT1+8 equipped with a real-time time-depth-recorder (TDR) was used as standard gear to collect krill samples from the upper 200 m surface layer. A double oblique net tow was carried out routinely at all stations. The total time of the net haul from surface to bottom to surface was approximately 40 minutes. Calibrated flowmeters were used to give a measure of net speed during the haul as well as the total distance travelled. The flowmeter was mounted outside the net opening to avoid clogging which may reduce the efficiency. The dependence of mouth angle to the vertical of net speed had been investigated for the RMT system (Pommeranz et al 1982). The average filtered water volume of a standard net tow was approximately 25,000 m^3

Immediately after the tow samples were sorted for Antarctic krill and other euphausiid species as well as salp species. These data were collected quantitatively from the RMT 8. However, if the sample size was larger than one litre then a representative subsample was taken with a Folsom plankton splitter and analysed subsequently. Krill and other euphausiids were stored in 4 % formalin-seawater solution for later length measurements and maturity stage analyses. These samples were usually analyzed after two days on board. Biological parameters were routinely collected from total krill samples such as length; sex and maturity stages were determined from each krill. We used the 'Discovery' method for *E. superba*, i.e. total length from the anterior margin of the eye to the tip of the telson (Mauchline, 1980). The standard unit is given in mm below, with an accuracy of 1 mm size classes. All measurements were done by one person to remove observer variation. Additional information was collected for sex and maturity stages of euphausiids according to the classification established by Makarov and Denys (1981). A representative fraction of the total zooplankton sample was preserved for later analysis on land.

These data will be analysed as part of the CCAMLR (Convention for the Conservation of Antarctic Marine Living Resources) related research activities of the Institut für Seefischerei in Hamburg and results will be submitted to the CCAMLR Working Group meeting 2011 to support the monitoring of the krill stocks in the Atlantic sector and the management of the krill fishery. Studies on the spawning success, survival rates and recruitment success are essential to develop prediction models for the development of the krill stocks.

The estimation of the actual standing stock biomass will be based on the data collected continuously during the survey with the multi-frequency SIMRAD EK 60 hydro acoustic equipment, which was agreed upon by CCAMLR as the standard multi-frequency ecosounder. The biomass estimate resulting from this operation will help the CCAMLR working group to estimate the potential yield of the krill stock and set catch limits for the commercial fishing operations. A close international cooperation is envisaged with the US AMLR programme.

Preliminary results

Krill was caught at 70 out of 81 stations and these yielded a total number of 60,858 krill. Length measurements were taken from representative sub-samples with a minimum of 150 specimens. Length measurements and detailed maturity stages were identified from 6,160 krill specimens (see Tab. 5.4.1) under the microscope

Table 5.4.1: Total number of specimens caught with the RMT8 net and number of individuals measured for length frequency data and classification for sex and maturity stages according to Makarov and Denys (1981).

Species	Total catch	Sample measured
Euphausia superba	60,858	6,160
Euphausia triacantha	2342	297
Euphausia frigida	173	53
Euphausia crystallorophias	1112	380
Thysanoessa macrura	57,442	4,822
Salpa thompsoni	117,400	later in lab

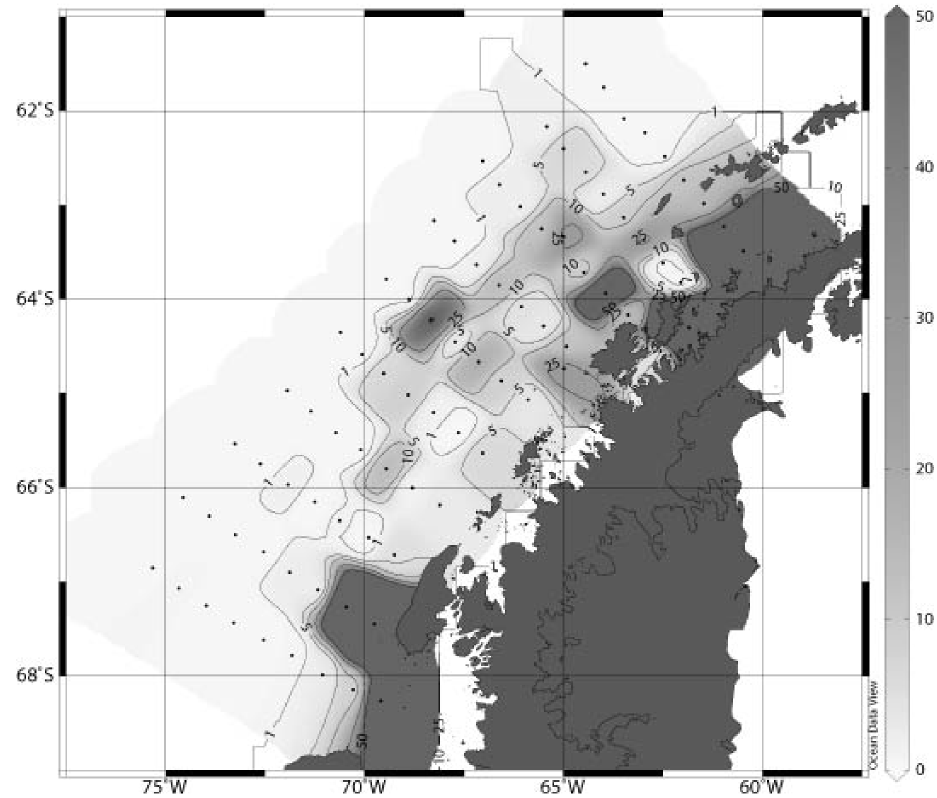

Fig. 5.4.2: Distribution of Antarctic krill E. superba (numerical density given as N 1,000 m^{-3}) in the Antarctic Peninsula region during January 2011

Largest catches of Antarctic krill were taken in the southern Bransfield Strait (12,700 Krill), in Gerlache Strait (21,200 krill) and off Adelaide Island (10,600 krill). All three stations were dominated by one-year-old juveniles (Fig. 5.4.2). Stations which did not yield any krill were located at the outer offshore ends of the transects, indicating that the survey area covered almost the entire distribution range of the species between the continent and the oceanic region.

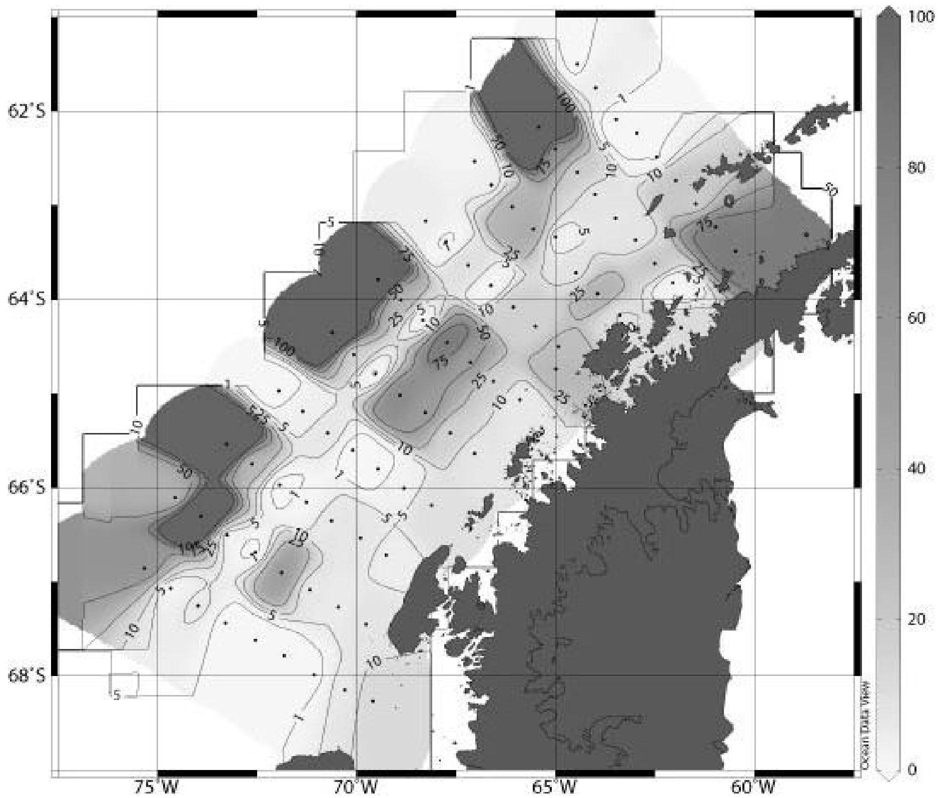

Fig. 5.4.3: Distribution of Thysanoessa macrura (numerical density given as N 1,000 m^{-3}) in the Antarctic Peninsula region during January 2011

The overall mean density of Antarctic krill for the entire survey area was 7.2 m^{-2} and 35 krill 1,000 m^{-3}, respectively. The longterm mean density from net sampling surveys since 1978 is approximately 45 krill m^{-2} and 230 per 1,000 m^{-3}, respectively. These results indicate that Antarctic krill abundance was relatively low west of the Antarctic Peninsula in summer 2010/11.

The other common species in the samples was *Thysanoessa macrura*, which were almost as abundant as Antarctic krill (Table 5.4.1), however, due to its smaller size, the overall biomass is much less than the one of *E. superba.* This species concentrated more in offshore areas, although it was present at each station of the entire RMT grid (Fig. 5.4.3).

The ice-krill *Euphausia crystallorophias* is known as a neritic species and was therefore only found in relatively low numbers in the southern Bransfield Strait, Gerlache Strait and Marguerite Bay/Adelaide Island (Tab. 5.4.1). Representative samples have been collected and data will be analyzed at a later stage.

The epipelagic species *Euphausia triacantha* is known to have its distribution centre just south of the polar front. It does perform diel vertical migrations and consequently may appear in the upper 200 m water column during the night. It was therefore not surprising that this species occurred only in some of our night samples in the oceanic region (Fig. 5.4.4). One sample with high densities of more than 1,000 individuals indicated that this species might also form swarms during their vertical migration.

Subsamples were collected for later analysis.

The second epipelagic Euphausiacea species was *Euphausia frigida*, however, catches were relatively sparse and distribution patterns cannot be interpreted due to the low number of specimens.

Salps (*Salpa thompsoni*) were studied as an important component of the Antarctic zooplankton. More than 117.000 salps were caught (Tab. 5.4.1). More than 1,000 samples were collected for genetic analyses and representative quantitative samples from the RMT8 were preserved in 4 % seawater solution for later detailed analysis of size and developmental stages. Figure 5.4.5 displays the distribution patterns of salps according to RMT8 data. Highest salp densities were observed in offshore areas with lower numbers of salps over the shelf. Aggregate forms clearly dominated the population, while solitary forms were relatively sparse. Compared with densities observed during other years, salp abundance was above the longterm average, but was not as extreme as e.g. in the 1990 summer season.

Size distribution of the Antarctic krill *Euphausia superba* was not uniform across the survey area. Small juvenile krill was concentrated in near-shore areas, while adult specimens dominated the outer shelf and oceanic regions. The overall composite length frequency distribution showed a bimodal pattern. The juvenile krill were of a modal size of 27 to 28 mm (Fig. 5.4.6), which is within the expected range of one-year-old krill in the Antarctic Peninsula region in mid-summer. Medium sized krill between 35 and 45 mm seemed to be underrepresented in the samples from the 2011 summer, while animals larger 45 mm and up to 62 mm size were proportionately well represented. From the figure it is obvious that the krill population in summer 2011 was dominated by a large fraction of one-year-old juvenile krill. More than 64 % of the population consisted of this size and age group, indicating a relatively strong 2010 year-class in the Antarctic Peninsula region. However, a more detailed analysis of the quantitative data and a comparison with other surveys from different years is required before this hypothesis can be confirmed.

These larger size groups were clearly dominated by mature males and gravid to spent female stages, indicating that the spawning season was well advanced. Figure 5.4.6 summarizes the composite maturity stage composition across the entire survey area.

Finally, Fig. 5.4.7 shows one interesting aspect according to the current spawning season of krill in the Peninsula region. We found females bearing spermatophores and these adults were dominated by females in advanced spawning conditions and a high number of spent animals. Adult males also showed the occurrence of well-developed spermatophores or even empty ducti pointing to a post-spawning condition. These observations were confirmed by the finding of increasing numbers of Calyptopis larvae of Antarctic krill.

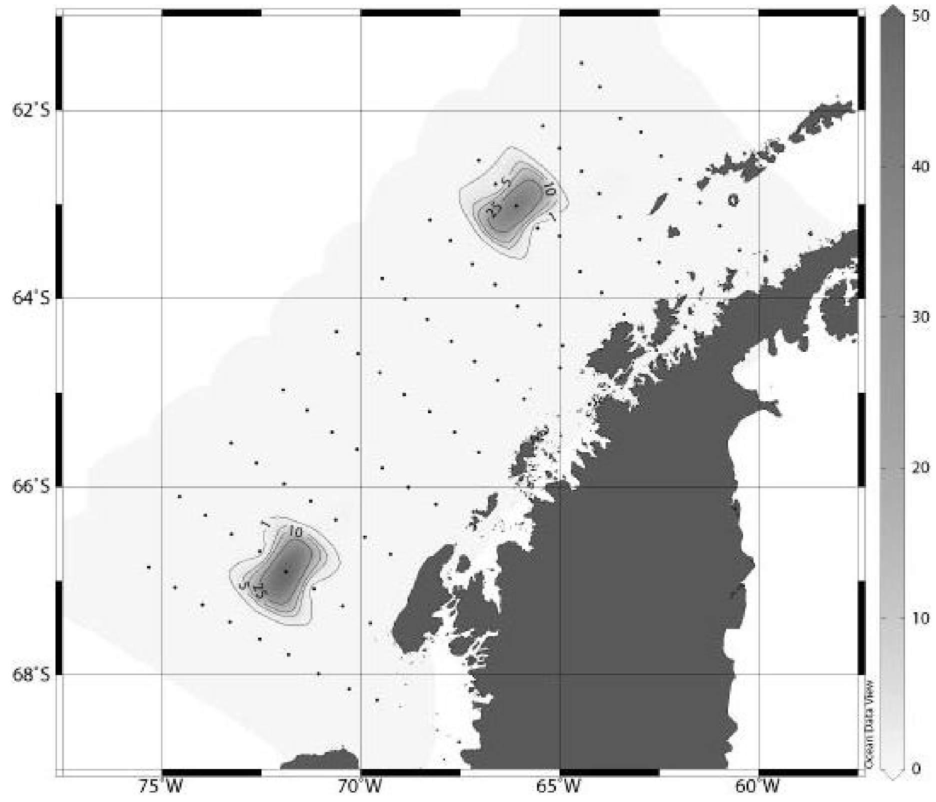

Fig. 5.4.4: Distribution of Euphausia triacantha (numerical density given as N 1,000 m⁻³) in the Antarctic Peninsula region during January 2011

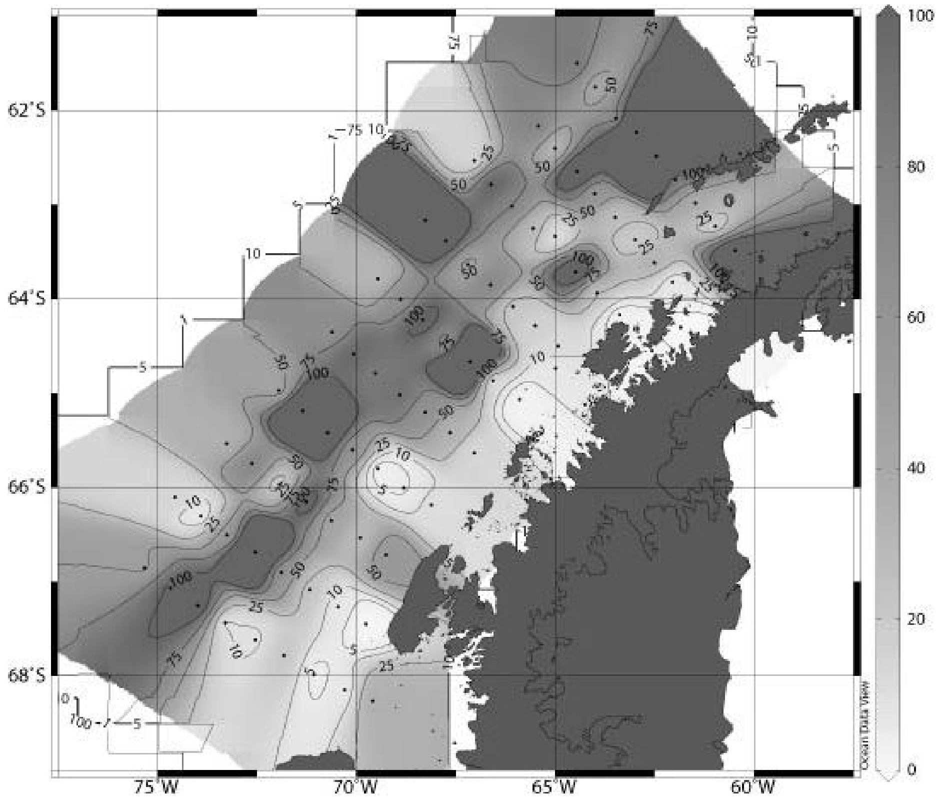

Fig. 5.4.5: Distribution of Salpa thompsoni (numerical density given as N 1,000 m⁻³) in the Antarctic Peninsula region during January 2011

First preliminary conclusions can be drawn from the data analyzed so far. In the season 2010/11 krill was less abundant than the longterm annual mean since 1978. The overall krill density was in the lower third of all observed values. Salp concentrations (Salps are probably food competitors for krill) ranged above the longterm average density. However, abundance of krill larvae in the RMT1 samples and the early progress of the spawning season indicate a successful spawning and a potential good recruitment for next year.

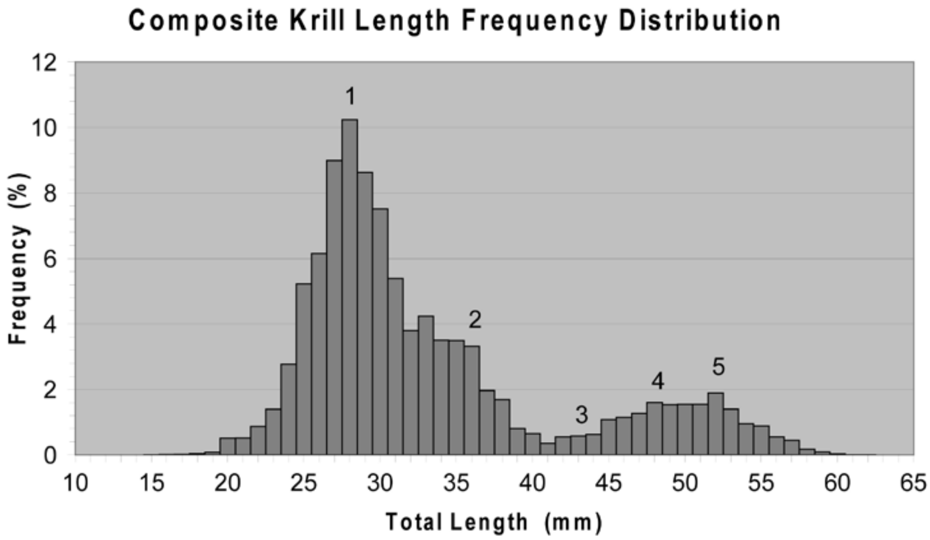

Fig. 5.4.6: Composite length frequency distribution of Antarctic krill Euphausia superba for the entire survey area. Numbers indicate the age groups 1 to 5 at the expected mean length classes.

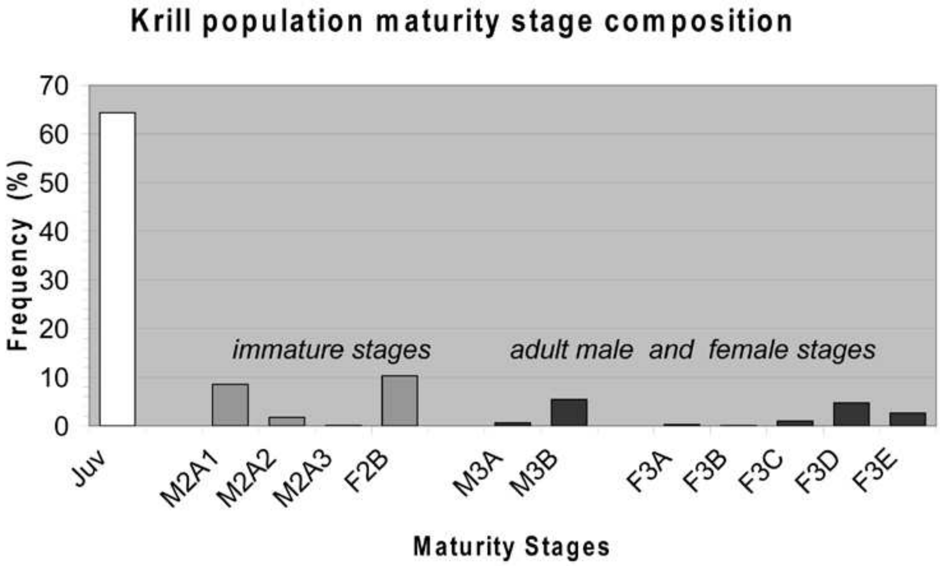

Fig. 5.4.7: Maturity stage composition of Antarctic krill for the entire survey area; stage are juvenile, male (M) and female (F), stage 2 = immature; stages 3A = pre-spawning, 3B =already with spermatophores, 3CD = gravid, 3E = spent.

Samples and data

Representative subsamples from the RMT 8 catches have been preserved in 4 % formalin seawater solution and will be stored at the Institut für Seefischerei in Hamburg (vTI/SF). Catches of the RMT 1 were split in halves; the first part will also be stored at the Institute für Seefischerei in Hamburg, the second half will be deposited at VNIRO Institute in Moscow. Access to samples can be obtained from either institution. Data from the net samples will be stored in the data base of the Institut für Seefischerei in Hamburg and will be available on request from there after processing and corrections have been finalized, but not later than January 2012. Acoustic raw data from the SIMRAD EK 60 echosounder will be stored in the data base of the Institute für Seefischerei in Hamburg and the PANGAEA data base of the AWI in Bremerhaven. Access to all samples and data will be possible on request, which should include a brief description of the objectives of the work planned.

5.4.1 Abundance and distribution of larval Euphausiids at the western Antarctic Peninsula

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[2] Johann Heinrich von Thünen-Institut
[3] Russian Federal Research Institute of Fisheries and Oceanography
[4] Moscow State University/N.K. Koltsov Institute of Developmental Biology

Objectives

Knowledge about krill and Euphausiid larval ecology is an essential part to understand the variations found in adult Euphausiid populations. Still little is known about the general Euhapusiid larval ecology and almost nothing about what triggers the spawning of adults, the mortality at different larval stages and how their abundance and distribution is affected by the physical environment (Siegel 2000). For these kinds of questions long-term data is important as it gives the opportunity to investigate variations between years. Meanwhile, estimates of larval abundances give a direct measure of the spawning success at that specific year, which is also important information for stock assessment work. The main objective of this study is to get an overview of Euphausiid larval abundance and distribution at the western Peninsula in relation to their adult population, with detailed information of the larval development during this time of the year. Furthermore, genetic data on the population structure of Euphausiids in relation to their larval development is missing. A second part of this investigation aims to establish the knowledge of distribution of Antarctic krill larvae associated with particular water masses. For general understanding of the role of Euphausiids in evolution history of the Antarctic biota, a subset of samples will be used for molecular bar-coding analysis. Finally, samples of amphipod *Themisto gaudichaudii* has been collected for bar-coding studies and subsequent reconstruction of evolutionary history of the Antarctic Hyperoidea with particular emphasis on relationships between the Southern and the Northern Hemisphere species. With these objectives, the krill monitoring program was an excellent opportunity for Euhapusiid larval studies, as the program offers a standardized sampling, coverage of large geographical area during subsequent years.

Work at sea

Net sampling

The Euphausiid larval study was part of the krill monitoring program performed during this expedition (see section on RMT 8 sampling), and all sampling of krill larvae were done simultaneously to the adult krill sampling using the RMT 1 net (Rectangular Midwater Trawl). The RMT 1 is a smaller zooplankton net mounted on top of the RMT 8 (for description see section on RMT 8 sampling) with a mouth opening of 1 m^2 and 330 µm mesh size designed to catch Euphausiid larvae and other meso-zooplankton. The station grid, timing and procedure of sampling are described by Siegel et al. (see section 5.4).

Treatment of samples

Immediately after net retrieval the RMT 1 net sample was split into two parts using a Folsom plankton splitter (van Guelpen et al. 1982) and preserved in a 4 % formalin-in-seawater solution. One half was preserved for analysis onboard, and one half stored away for further detailed analysis at the Russian Federal Research Institute of Fisheries and Oceanography in Moscow. At selected stations, one of the two halves was split further into two quarters. One of the subsequent quarters was either frozen down to -80°C for further chemical analysis, or fresh larvae and amphipods were picked out and preserved in ethanol for further molecular analysis.

After 1 - 2 days of preservation the subsequent analyses were performed. Due to the size of the RMT 1 samples they generally required further sub-sampling which was done using the Folsom plankton splitter. Larval Ephausiids were picked out from the subsample using a stereomicroscope and classified into developmental stages (nauplius, metanauplius, calyptopis 1 to 3, furcilia 1 to 6) according to Kirkwook (1982) and Baker et al. (1990). Damaged larvae which could not be identified into their exact stage were categorized into as detailed groups as possible, belonging either to unidentified calyptopis, unidentified furcilia, early furcilia (furcilia 1-3) or late furcilia (furcilia 4-6). Damaged larvae were most common for the older *Thysanoessa macrura* specimens, as this is smaller and more fragile species. Finally, all larval count data were standardized into density (m^{-2}) using filtered water volumes from the flow meter readings.

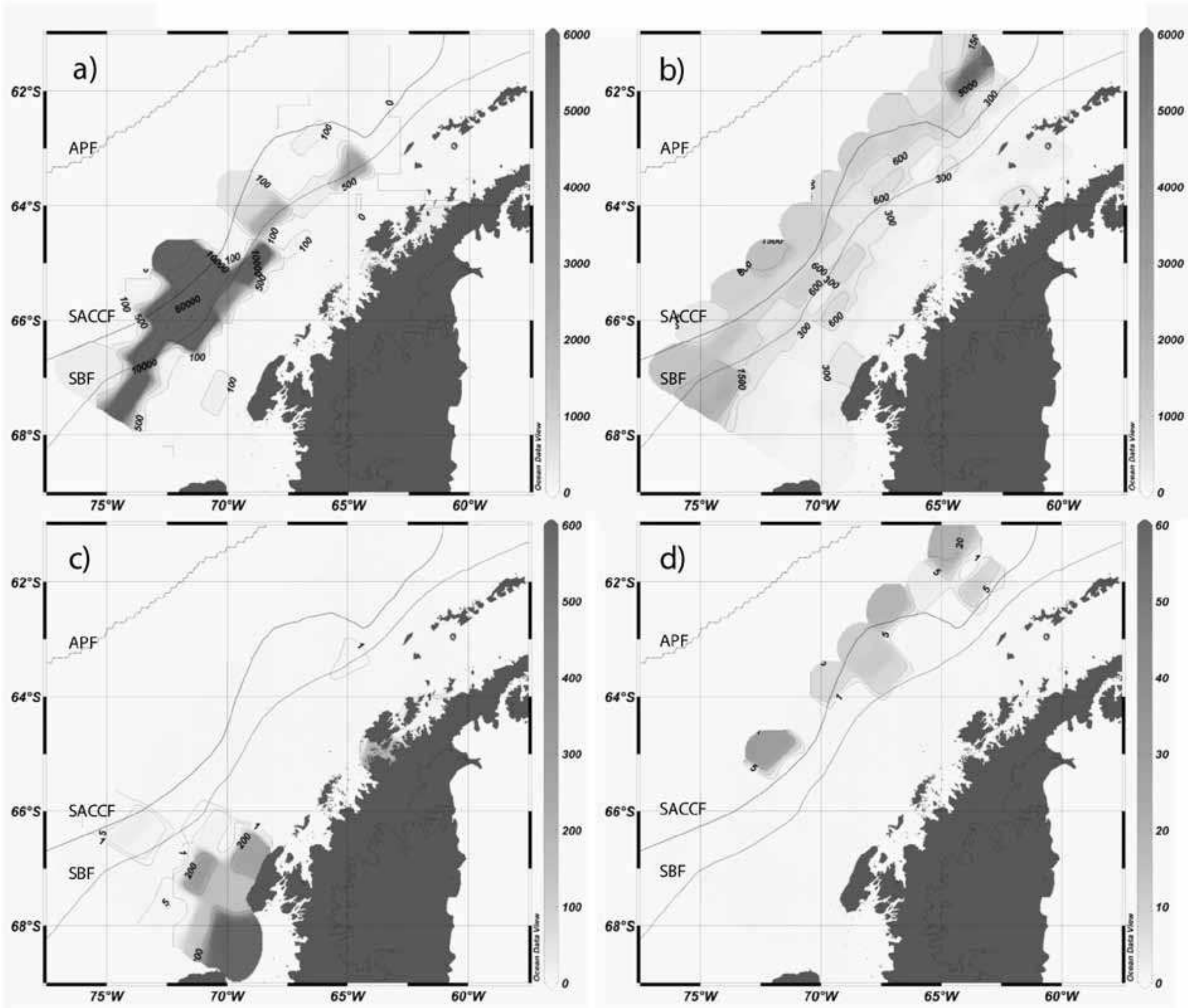

Fig. 5.4.8: Distribution of larval Euphausiids (given in m^{-2}) in the Antarctic Peninsula during January 2011. a) Euphausia superba, b) Thysanoessa macrura, c) E. crystallorophias and d) E. frigida. APF = Antarctic Polar Front, SACCF = South Antarctic Circum Polar Front and SBF = South Boundary Front. Note the different scale in the figure.

Preliminary results

Larval samples were successfully analyzed from all 81 stations of the krill grid, and larvae from four of the possible five Euphausiid species were found; *Euphausia superba*, *E. crystallorophias*, *E. frigida* and *Thysanoessa macrura*, while larval *E. triacanta* was totally missing.

Larval *E. superba* were found at 57 of the stations, and had the highest densities out of the four species with an arithmetic mean of 2449.5 m^{-2}. Their geographical distribution were concentrated to the southernmost and offshore stations of the grid (Fig. 5.4.8a). A high density patch was found around 66° S and 72° W with a maximum of 66,971 m^{-2}. The frequency distribution of developmental stages were highly dominated by calyptopis 1 (Fig. 5.4.9a). The mean developmental stage with time (Fig. 5.4.10a) shows that calyptopis 1 were dominating during the whole sampling period, while significant amount of calyptopis 2 and 3 were only found during the second part of the cruise. This indicates that *E. superba* most likely started spawning in mid December (based on developmental time from Ikeda 1984 and Witek et al. 1980) and that they had been continuously spawning at least during the first part of the sampling period due to the steady stream of calyptopis 1.

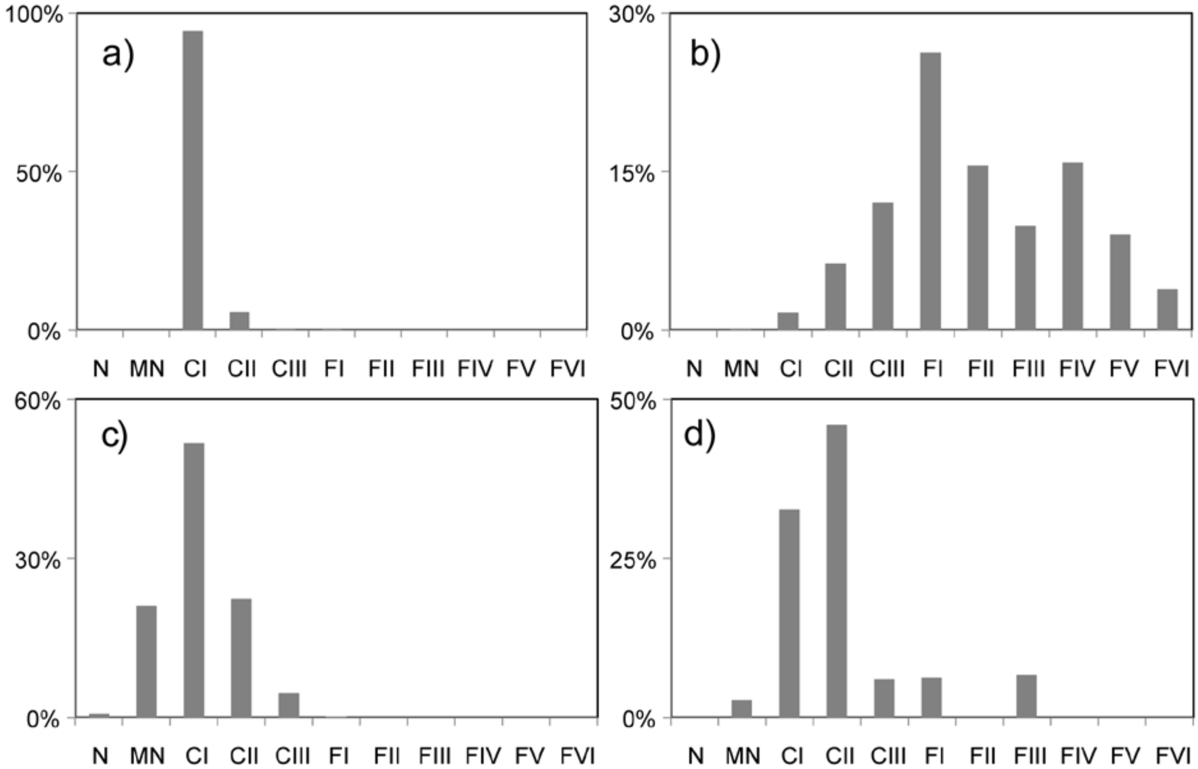

Fig. 5.4.9: Frequency distribution of larval developmental stage for a) Euphausia superba, b) Thysanoessa macrura, c) E. crystallorophias and d) E. frigida. N = Nauplius, MN = Metanuaplius, C = Calyptopis, F = Furcilia.

T. macrura larvae were the most widespread species found at every station of the grid. Their geographical distribution was even over the whole sampling area with slightly lower densities close to shore (Fig. 5.4.8b). Their overall mean density was 482.4 m^{-2}. All developmental stages from metanauplie to furcilia 6 were found for *T. macrura* (Fig. 5.4.9b). Furcilia were clearly dominating over calyptopis, with furcilia 1, 2 and 4 as the most common stages. The mean developmental stage with time shows a large variation in dominating stage, but with a clear decreasing trend in the representation of younger calyptopis stages as the cruise progressed (Fig. 5.4.10b). The presence of all stages indicates an extended spawning period for *T. macrura*, and based on the presence of furcilia 6 in the samples they started their spawning in September (based on developmental times from Menshenina and Spiridonov 1991).

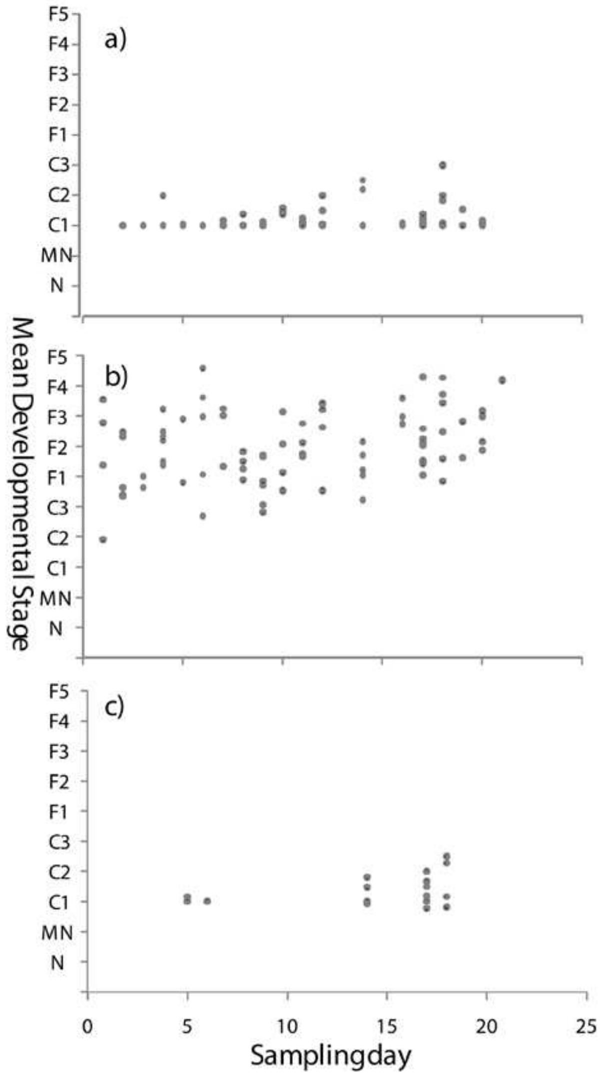

Fig. 5.4.10: Average developmental stage at a certain station against the day of sampling (day 1 at the 9 January 2011) for a) Euphausia superba, b) Thysanoessa macrura and c) E. crystallorophias. The figure for E. frigida is not included due to the low numbers of larvae. N = Nauplius, MN = Metanuaplius, C = Calyptopis, F = Furcilia.

Larvae of the coastal species *E. crystallorophias* were mostly found at stations closest to shore at Gerlaiche Strait and at the southernmost transects of the grid (Fig. 5.4.8c). They were found at 18 stations, and were comparably low in density with a mean density of 28.3 m^{-2}. Naupli to fucilia 1 stage were present in the samples, dominated by calyptopis 1 (Fig. 5.4.9c). Calyptopis 1 were continuously dominating throughout the sampling period, but with later calyptopis stages getting more represented with time (Fig. 5.4.10c). Given that furcilia 1 were found in the samples, *E. crystallorophias* may slowly have started their spawning already at the end of October (based on developmental time from Ikeda 1986).

E. frigida were only found at 10 stations, all offshore (Fig. 5.4.8d), and they had the lowest densities of all the species with a mean density of 1.5 m^{-2}. Larval developmental stages from metanaulius to furcilia 2 were found, dominated by calyptopis 2 (Fig. 5.4.10d).

Further work

For the genetic samples preserved in ethanol, two research activities will be carried out at the Moscow State University/N.K. Koltsov Institute of Developmental Biology in Moscow. First, a general phylogenetic relationship of Euhapusiid crustaceans will be done based on comparative analysis of sequences of mitochondrial gene COI - the first subunit of cytochrome oxidase *c,* which is commonly used in barcoding. DNA barcoding is a technique that uses a short gene sequence from a standardised region of the genome as a diagnostic "biomarker" for species and subspecies. Secondly, population structure of krill is going to be revealed using microsatellites which are appropriate for the description of heterogeneity within groups of individuals. It may provide us information on isolation of krill larvae originated from different water masses.

Samples and data

See section on RMT 8 sampling.

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5.4.2 Environmental transcriptomics of the Southern Ocean salp, *Salpa thompsoni*

Paola Batta-Lona, Ann Bucklin (not on board), Rachel O'Neill (not on board)
University of Connecticut,

Objectives

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

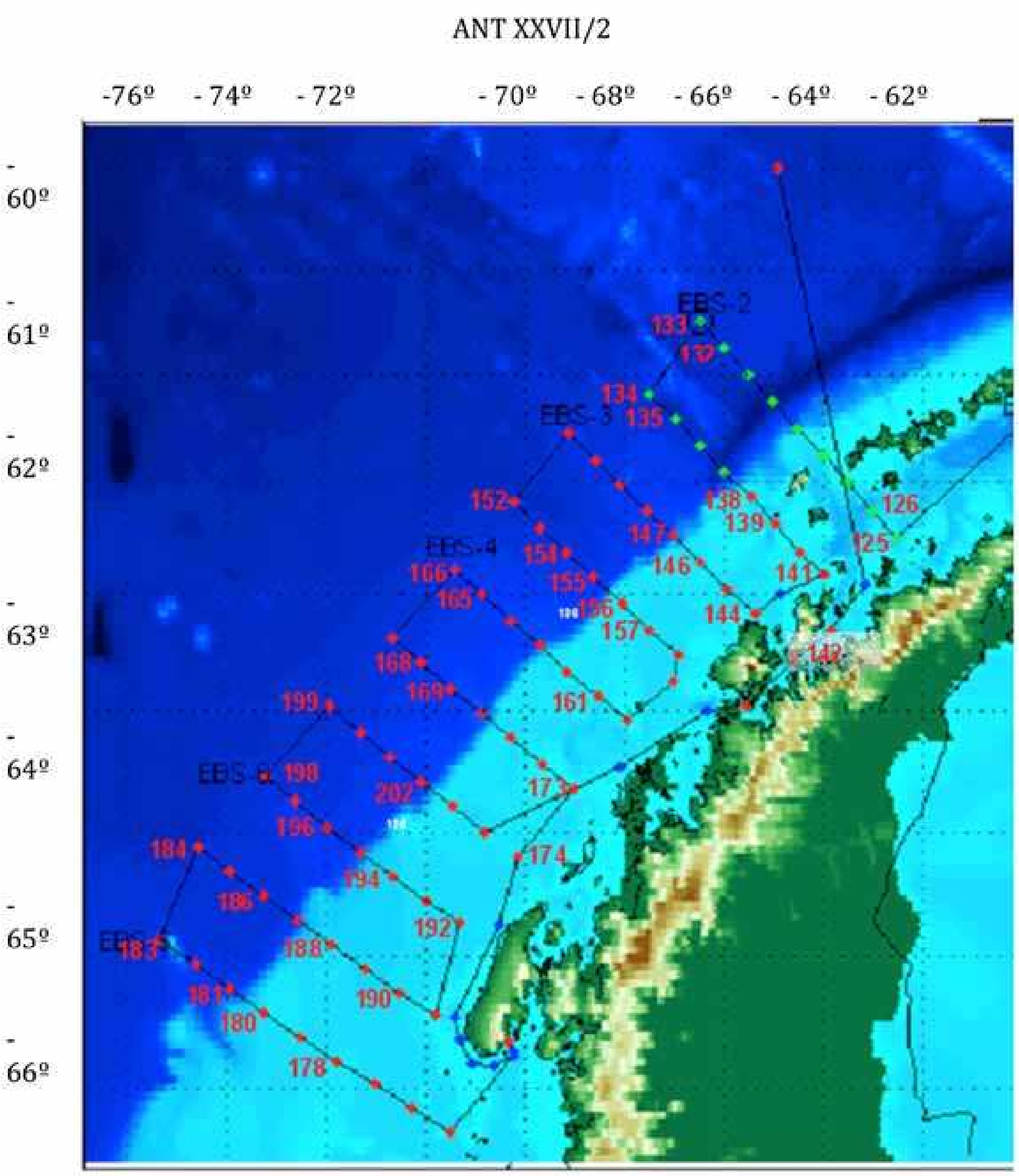

Fig. 5.4.11: Stations where Salpa thompsoni was collected and preserved for molecular transcripomic analysis during ANT-XXVII/2.

The goal of this effort is to analyze the *S. thompsoni* transcriptome by whole-genome RNA sequencing and to characterize gene expression profiles in relation to life history processes and environmental conditions. Specimens of *S. thompsoni* were identified from samples collected from different Southern Ocean locations and flash-frozen for molecular analysis. Environmental data was collected at the stations sampled and will be used to examine correlation among gene expression patterns and biological and physical environmental conditions at the time of collection.

Work at sea

During cruise ANT-XVII/2, 1,488 samples collected by Rectangular Midwater Trawl (RMT) from 40 different stations (Fig. 5.4.11) were examined for *Salpa thompsoni*. Samples were taken from the net RMT-8 towed at depths of 200m. A total of 1,052 identified specimens were removed. In order to ensure proper preservation of specimens and tissue for analysis of DNA and RNA, RMT-8 samples were examined immediately after collection and all salps were removed for identification of species while still living. Quantification of species of salps was done by counting colonies and zooids. Specimens of *Salpa thomsponi* were identified under a dissecting microscope and the stomachs were removed by dissection to avoid contamination of DNA from prey. The remaining tissue was flash frozen in liquid nitrogen and stored at -80° C. The frozen specimens will be returned to the University of Connecticut for molecular analysis at the University's Center for Applied Genetic Technologies.

The samples collected during this expedition are well-suited for the planned genomic and transcriptomic analysis, and will also be useful for population genetic studies of *Salpa thompsoni.* The samples were collected across much of the cruise sampling domain, including both shelf and offshore waters, and the preserved specimens reflect a variety of life stages and different life forms (Fig. 5.4.12).

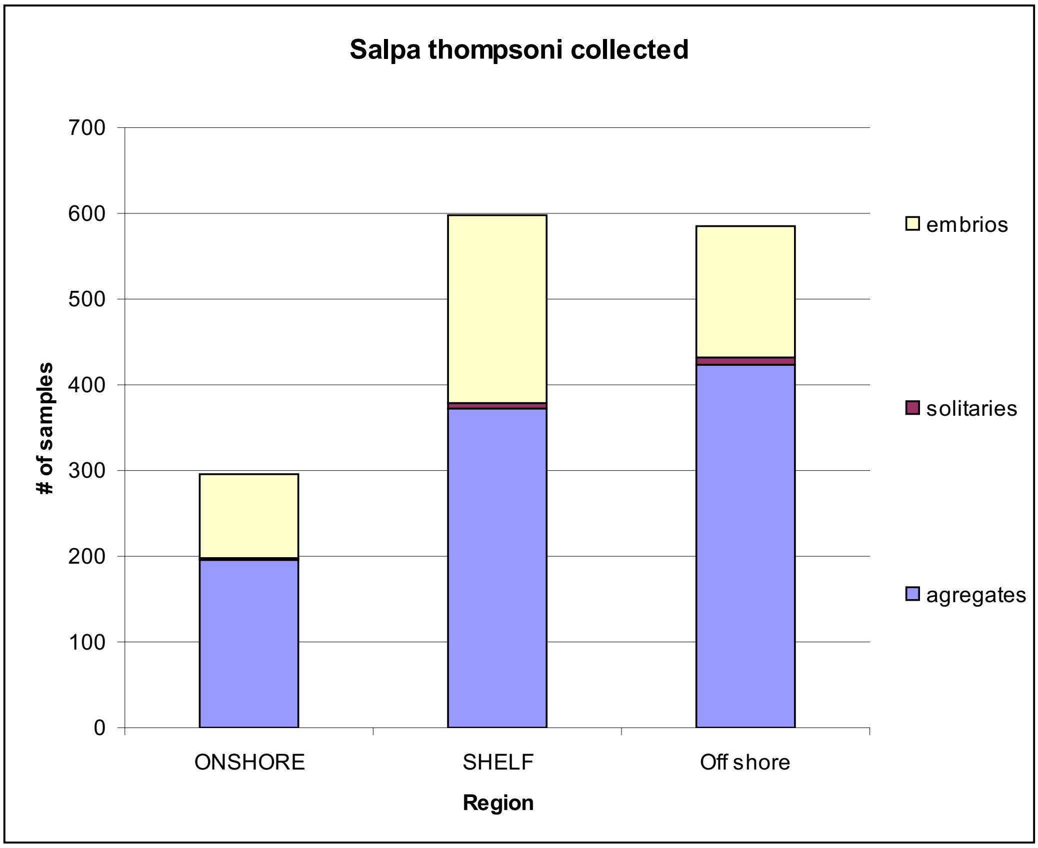

Fig. 5.4.12: Numbers of samples in onshore, shelf, and offshore zones with different life forms of Salpa thompsoni collected during ANT-XXVII/2

The scientific experiments and analyses to be carried out using the specimens collected during this cruise will be a critical component of my dissertation research, aiding in my qualification for a Ph.D. degree at the University of Connecticut.

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

Ute Mühlenhardt-Siegel
Forschungsinstitut Senckenberg

Objectives

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

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

The shelf and deep sea of the Antarctic regions in the vicinity of the Antarctic Peninsula, Weddell Sea and some parts of the Ross Sea are quite well investigated, as well samples from the Amundsen Sea are available, however, samples from the deep sea (deeper than 2000 m depth) from the Bellingshausen Sea are still missing. From the literature (Corbera et al. 2009) cumacean data for this region are known from the shelf and continental slope (1870 m maximum depth).

Method

The most successful sampling gear for small macrobenthic animals was the epibenthic sledge; the box- and multi corers, and Agassiz trawl were much less useful because of the limited sampling area or large mesh size, respectively. The epibenthic sledge, equipped with epi- and supranet of 500 μm mesh size, will be towed on the bottom at 0.5 m sec^{-1} for approximately 10 minutes (Brenke, 2005).

Aims

The information about the cumaceans from the deep sea of the Bellingshausen Sea will complete the results from the ANDEEP expeditions about the biodiversity, faunal overlap and biogeography of this peracaridean group from the Peninsula region, western and eastern Weddell Sea, South Sandwich Trench and Cape Basin. As the endemism is about 20 - 25 % in Antarctic deep-sea basins, a number of new species were expected.

Work at sea

The epibenthic sledge was deployed at 6 stations in the deep sea along the western Antarctic Peninsula from 61°30’ to 66°08’ S (northern Bellingshausen Sea) in depth ranges between 1,912 and 3,954 m. The towed distances vary between 808 and 2,540 m. In total the sampled area is 7,890 m².

As the most time consuming part of the sampling are the lowering and heaving phases, these were accelerated from 0.5 m/s as suggested by Brenke (2005) to 0.7 m/s and worked perfectly well. For 5,000 m rope length a time saving of 94 min is gained. Once the sledge is from the ground the heaving velocity can be accelerated to 1 m/s gaining a time saving of 20 min (bottom depth 3,000 m).

The material was washed on board and fixed in 4 % formalin–sea water solution, washed with fresh water after 48 hours and stored in 70 % ethanol. The sorting, determination and description of new species will be done at home.

Data and samples

The determined species will be deposited at the Zoological Museum, University of Hamburg; the undetermined rest of the samples will be stored at the DZMB, Wilhelmshaven. The Cumacea data will be submitted to SCAR-MarBIN. The SCAR-MarBIN (Marine Biodiversity Information Network) project aims at establishing and supporting a distributed system of interoperable databases, which will shape a coordinated network, forming the OBIS (Ocean Biogeographic Information System) Antarctic Node, placed under the aegis of SCAR (Scientific Committee on Antarctic Research).

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5.6 Effect of CO_2 and iron on phytoplankton

Clara Hoppe[1], Christopher Payne[2], Constance Couture[2], Ulrike Richter[1], Philippe D. Tortell[2] (not on board), Björn Rost[1] (not on board), Scarlett Trimborn[1]

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[2]University of British Columbia

Objectives

The Southern Ocean (SO) accounts for ~20 % of the global annual phytoplankton production and is considered to exert a large influence on the marine carbon cycle and to have the greatest potential to affect atmospheric CO_2 concentrations. While in other parts of the world’s oceans, nitrate and phosphate are usually the nutrients that limit phytoplankton growth, the SO as a large upwelling region has generally high concentrations of both nitrate and phosphate that even exceed the demand required for biological processes. *In-situ* fertilization experiments have revealed that iron availability is the key factor controlling phytoplankton growth in the SO. Neritic environments are known to be enriched in iron and to exhibit extensive phytoplankton blooms compared to oceanic regions where only low dissolved iron concentrations are found thus imposing different strengths on the phytoplankton community. Aside from this crucial factor, other environmental factors like changing atmospheric CO_2 concentrations due to the ongoing ocean acidification as well as to seasonal changes in CO_2 were found to also exert control on both phytoplankton structure and growth. Unfortunately, its effects on the physiological ecology of the phytoplankton community have thus far received very little attention, even though large seasonal changes in CO_2 can be observed over the course of the growing season. This lack in research is mainly due to the fact that dissolved inorganic carbon is always in excess relative to other nutrients. In seawater, inorganic carbon is mainly found in the form of HCO_3^- (~2 mmol L^{-1}), but also in low and varying concentrations of dissolved CO_2 (~5-25 µmol L^{-1}). Until now, research so far has focussed on the investigation of one of these two factors, while attention has not yet been paid to the assessment of iron availability in conjunction with CO_2, even though the combination of both factors may be crucial in controlling the phytoplankton species composition in the Southern Ocean.

Work at sea

In-situ sampling by CTD

Phytoplankton populations were characterized along the cruise track using Niskin bottles attached to a sampling rosette with conductivity, temperature and depth sensors (CTD rosette, 3 to 5 bottles à 12 L). To address the influence of iron availability on phytoplankton community structure stations were sampled in both coastal and oceanic areas that are well known to differ in iron concentrations. From 26 CTD stations in total (Fig. 5.6.1 and 5.6.2), seawater samples were collected either from the deep chlorophyll maximum when present or in case of a uniform surface mixed layer from the depth at which biomass appeared highest. From these water samples, taxonomic species composition, cell density and chemical parameters were taken that will be more described in the following.

To determine taxonomic composition aliquots of 200 ml unfiltered seawater were preserved with both hexamine buffered formalin solution at a final concentration of 2 % and lugol at a final concentration of 1 %. Preserved samples were stored at 4° C in the dark until further analysis by light and epifluorescence microscopy back in the home laboratory. For bacterial composition, seawater was transferred into cryo vials to which gluteraldehyde of a final concentration of 0.1 % was added. These samples were then stored at –80° C until they will be analysed at home.

Samples for the determination of chlorophyll a (Chl *a*) concentration were taken and stored at -20° C. Along the cruise transect, Chl *a* was extracted in 10 mL of acetone (overnight in darkness, at 2° C) and measured with a fluorometer (Turner Designs) on board. In addition to the Chl *a* samples, pigment samples were collected, filtered and stored at - 80° C until high performance liquid chromatography (HPLC) analysis will be performed in the home laboratory. Samples for the determination of biogenic silicate were taken, filtered and stored at -20° C until further analysis. To estimate the amount of humic-like compounds in the water, samples were taken and stored at -20° C. These samples will be sent to our Autralian collaborator Dr. Christel Hassler (University of Technology Sydney) who will analyze them using voltammetry.

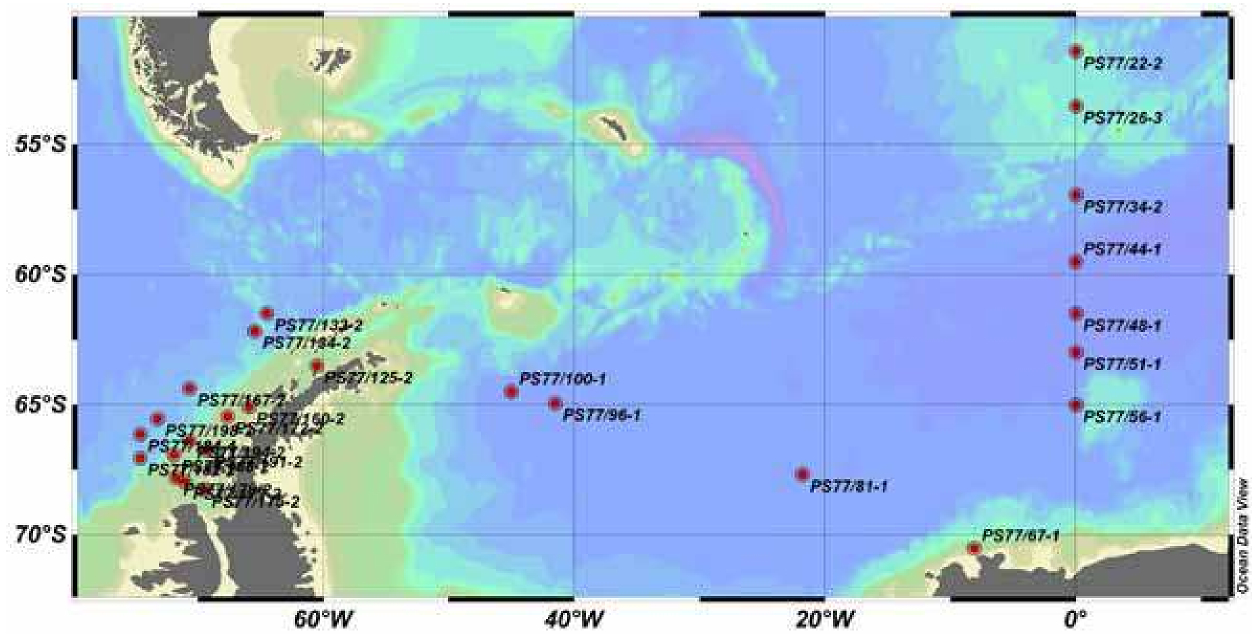

Fig. 5.6.1: Map of all sampled 26 CTD stations along the cruise track

For the determination of the seawater carbonate chemistry from each station samples for alkalinity, dissolved inorganic carbon and pH were collected. Alkalinity samples were taken from the filtrate (Whatman GFF filter, 0.6 mm), stored in 100-mL borosilicate flasks at 4 °C until further analysis by potentiometric titration at home. Dissolved inorganic carbon samples were sterile-filtered (0.2 mm) and stored in 13-mL borosilicate flasks free of air bubbles at 4° C until they will be measured with a Quaatro Autoanalyzer (Seal Analytical). pH was measured on board using a pH/ion meter (model 713, Methrom) that was calibrated (three-point calibration) at latest every third day. From these three parameters the carbonate system will be calculated using the program CO2Sys (Lewis and Wallace 1998).

Samples for particulate organic (POC) were filtered onto precombusted (500°C; 12 h) GFF filters and stored in precombusted petri dishes (500°C; 12 h) at -20°C. Primary production was determined by transfer of the unfiltered seawater into 24 h of light exposure (30 μmol m^{-2} s^{-1}) after addition of a 10 μCi spike of ^{14}C. At the end of the incubation time the sample was filtered onto GFF-filters and subsequently acidified and left in the fume hood to degas overnight. Then filters were collected and 10 ml of scintillation cocktail were added to each sample and measured with a scintillation counter (TRICARB) on board.

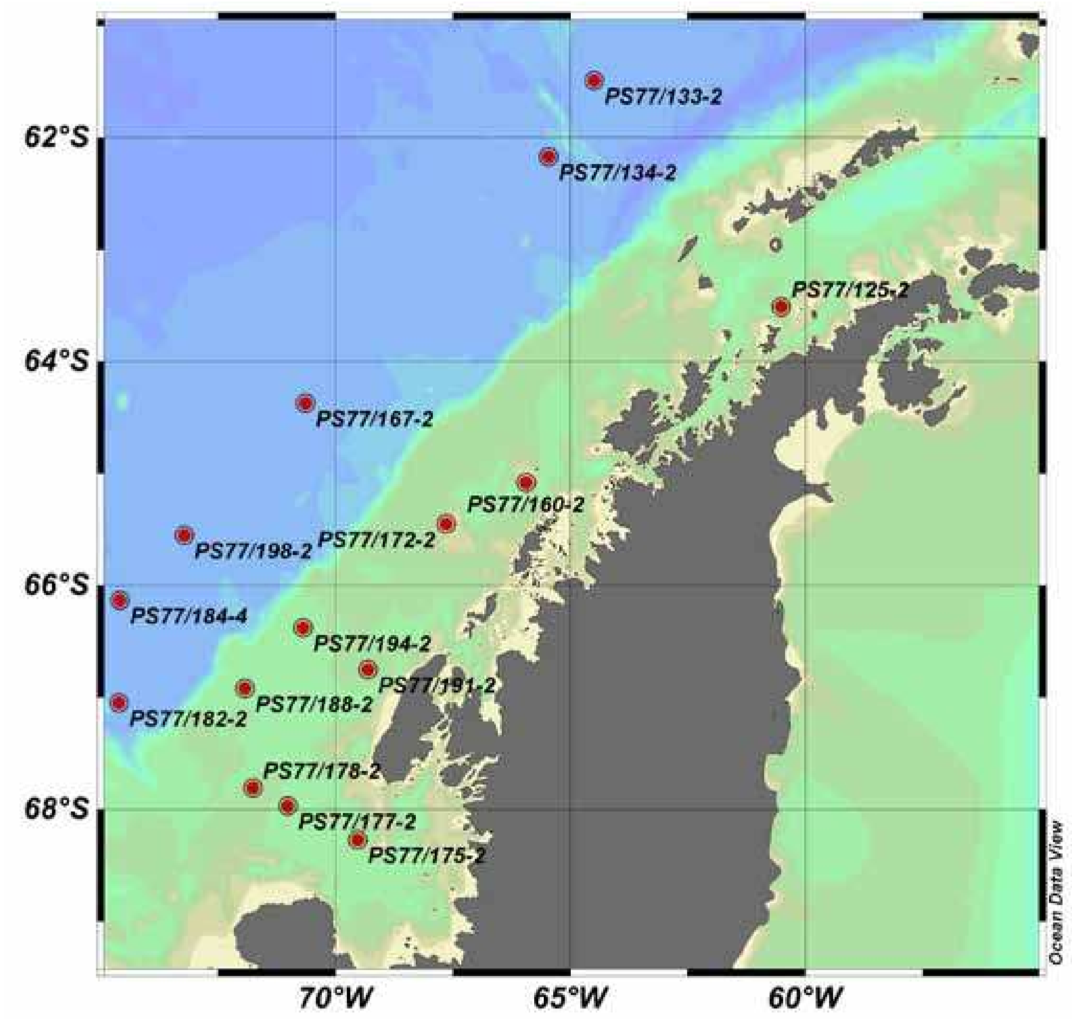

Fig. 5.6.2: Detailed map of sampled CTD stations at the Antarctic Peninsula section

Physiological characteristics of the living phytoplankton was derived by means of fast induction relaxation fluorometry (FIRe), ^{14}C and ^{55}Fe based assays. As these assays can only be carried out with higher biomass phytoplankton was concentrated by gravity filtration onto 2.0 μm poly carbonate filters by the use of special filtration units ensuring that cells were constantly and gently kept in suspension. From the cells concentrate, the ^{14}C disequilibrium technique, the ^{14}C kinetic assay as well as photosynthesis-irradiance curves were carried out. The ^{14}C disequilibrium technique is commonly used to estimate the fraction of HCO_3^- and CO_2 uptake for photosynthesis by phytoplankton. As this technique does not provide information on how efficient phytoplankton takes up inorganic carbon, the ^{14}C kinetic assay was performed. In this assay the ^{14}C incorporation is determined in cells that were transferred to an initially CO_2-free assay buffer, to which increasing amounts of ^{14}C spiked inorganic carbon were subsequently added. Using a fluorescence induction relaxation system (FIRe, Satlantic, Halifax, Canada), information on the efficiency of photochemistry in PSII during varying light exposure was gained

CO_2-/iron perturbation experiments

On-deck CO_2-/iron pertubation experiments with a natural phytoplankton community were performed to address the important question of how CO_2-related changes in carbonate chemistry e.g. ocean acidification in combination with different iron availability will directly affect primary productivity and phytoplankton species composition. 80 L seawater containing the starting phytoplankton community (only filtered through a 200 μm mesh to avoid zooplankton inside the experimental bottles) were sampled from 66°45' S - 66°55' S by towfish. To ensure prolonged exponential phytoplankton growth, in addition 200 L of iron-limited seawater were sampled using acid-cleaned 0.2 μm filter cartridges. This water was used to dilute the incubations when nitrate concentrations went below 10 μmol L^{-1}. For all experiments, triplicate incubations bottles were bubbled with CO_2 levels representing values of the last glacial maximum (~180 μatm), present-day (~380 μatm), and those projected for the year 2100 (~980 μatm) using a portable gas mixing system. To promote phytoplankton growth 1 nM iron were added while for the iron-limited treatments 10 nM of the chelator desferrioxime B (DFB) were given binding all the bioavailable iron.

No additional macronutrients were added to the incubation bottles.

The experiments were run in a temperature controlled growth chamber (2 °C) with a constant daylight irradiance of 30 μmol m^{-2} s^{-1}. Incubation experiments lasted between 20 and 28 days depending on experimental treatment. Nitrate, silicate and phosphate concentrations were measured on a daily basis over the course of the experiments. Chl a concentrations were regularly measured to determine phytoplankton growth rates. At the beginning and the end of each dilution taxonomic species composition, cell density and chemical parameters were determined as described above. As for the CTD stations physiological assays were carried out for all treatments. In addition to these measurements, filtered seawater samples were taken to estimate iron speciation and dissolved iron concentration. Iron uptake rates were estimated by transfer of the unfiltered seawater into 24 h of light exposure (30 μmol m^{-2} s^{-1}) after addition of a 1 nM spike of ^{55}Fe. At the end of the incubation time, the sample was filtered onto GFF-filters and 10 ml of scintillation cocktail was added to each sample and measured with a scintillation counter (TRICARB) on board.

Preliminary (expected) results

At this stage it is very difficult to discuss preliminary results as most of the taken samples still need either to be analysed or to be processed. However, the extensive characterisation of 26 CTD stations along the cruise track will help us to provide a better ecophysiological explanation for the spatial distribution of Southern Ocean phytoplankton. Especially, the successful performance of shipboard iron-/CO_2 manipulation experiments will bring us a step forward and will enable us to gain a process-based understanding of how the two environmental factors iron and CO_2 will shape the Southern Ocean phytoplankton community structure, alter productivity and phytoplankton growth in the future.

5.7 Biogenic gas distributions along frontal zones in the Southern Ocean

Constance Couture, Christopher Payne, Philippe Tortell (not on board)
University of British Columbia

Obbjectives

The broad-scale patterns of biological productivity and biogenic gas distributions in the Southern Ocean are reasonably well understood. However, satellite imagery reveals significant mesoscale and sub mesoscale variability in biological and physical fields that is likely associated with frontal zones, continental shelf interactions and sea ice dynamics. This small-scale heterogeneity (<10-100 km) is very difficult to capture using conventional hydrographic surveys with discrete sampling stations separated by large distances. The goal of this project was to map, with high spatial resolution, the fine-scale distribution of surface water pCO_2, biological oxygen saturation (O_2/Ar) and dimethylsulfide (DMS) using ship-board mass spectrometry.

Work at sea

Underway gas measurements were conducted using membrane inlet mass spectrometry (MIMS). Seawater from the ship's Teflon underway supply was continuously pumped to a flow-through sampling cuvette attached to a quadrupole mass spectrometer. Gases were extracted across a membrane interface and analyzed selectively on the basis of charge to mass ratios every ~20 seconds. Gas concentrations were calibrated using temperature controlled seawater samples continuously bubbled with standard gas mixtures. Measurements were made along the entire ship track.

Preliminary results

During our southbound transit from South Africa along the Greenwich meridian we observed very little change in gases, with O_2/Ar and CO_2 near atmospheric equilibrium. Once in the ice and in the Weddell Sea we observed large changes in all gases on small time and spatial scales. The lowest pCO_2 concentrations corresponded to areas of high phytoplankton biomass (as measured by chlorophyll *a*) in the Weddell Sea and west of the Antarctic Peninsula. O_2/Ar and CO_2 were strongly anti-correlated throughout the study area, indicating that biological activity rather than physical effects exerted a dominant control on CO_2 and O_2 distributions in this region. DMS concentrations were very low in the Southern Ocean transit and much higher and variable in the sea ice area, as well as in the Weddell Sea and area west of the Antarctic Peninsula. DMS concentrations of >250 nM were measured in the western side of the Weddell Sea, comparable to maximum concentrations previously measured on cruises in the Ross Sea and Amundsen Sea. Large shifts in DMS concentrations were often, but not always, correlated with shifts in both CO_2 and O_2.

This research has provided valuable new information on the distribution of climate-active biogenic gases in the Southern Ocean, with unprecedented spatial resolution. pCO_2 and DMS measurements will be used, in conjunction with sea ice and wind-speed data to compute sea-air fluxes. O_2/Ar data will be used to derive estimates of net community production (i.e. Water column photosynthesis minus community respiration).These parameters will be examined across a range of physical and biological conditions, enabling us to understand the influence of frontal zones, continental shelf inputs and sea ice dynamics in driving Southern Ocean biogeochemical processes.

6. PAINTING AND PHOTOGRAPHY

Frank Rödel

The work on board and later on land comprises four aspects:

1. Documentation by digital photographs life on board, scientific work and landscape.
2. At the end of the cruise 900 processed slides will be made available to the cruise participants and AWI.
3. Analog photographs will be available after the cruise and after processing at home.
4. On board, 40 paintings displaying observed landscapes were produced in pastel, Indian ink and water colour on copper plate printing paper. The major part of the painting work will occur after the return in the artist's workshop.
5. The main objective of the artist's activity will be a series of medium and large scale pictures on canvas in reference to the 100th anniversary of the race to the pole by Amundsen und Scott. It will be a mix of techniques including free painting and printing on Japanese tissue paper laminated on canvas. The printed parts will be derived from original historic photographs and those taken during the cruise. This work will occur in the artist's workshop.

The results will be presented in a series of exhibitions during the next few years.

7. ACKNOWLEDGEMENTS

We collected impressive data sets and obtained a wealth of samples. We achieved our logistic tasks at Neumayer-III-Station and Rothera what provided a fascinating experience to the scientists. Mostly calm weather and easy ice conditions facilitated our progress and work. However, beyond the excellent technical equipment of *Polarstern*, it was the crew who made our lives and our work on board easy and enjoyable with their outstanding professionalism and willingness to help. We like to express our sincere gratitude to Master Wunderlich and his entire crew for their hospitality and support. Beyond that, we are aware that numerous people of whom we are not able to call them all by name, contributed to the success of the cruise by planning, preparation and while we have been at sea.

APPENDIX

A.1 PARTICIPATING INSTITUTIONS

A.2 CRUISE PARTICIPANTS

A.3 SHIP'S CREW

A.4 STATION LIST

A.5 Technical report Posidonia

A.6 Technical report PIES

A.1 TEILNEHMENDE INSTITUTE / PARTICIPATING INSTITUTIONS

	Address
AWI	Stiftung Alfred-Wegener-Institut für Polar- und Meeresforschung in der Helmholtz-Gemeinschaft Am Handelshafen 12 27570 Bremerhaven Germany
DWD	Deutscher Wetterdienst Geschäftsbereich Wettervorhersage Seeschifffahrtsberatung Bernhard-Nocht-Strasse 76 20359 Hamburg Germany
DZMB	Forschungsinstitut Senckenberg Deutsches Zentrum für Marine Biodiversitätsforschung Südstrand 44 26382 Wilhelmshaven Germany
FTZ-Westküste	FTZ Westküste Hafentrön 1 25761 Büsum Germany
HeliService	HeliService International GmbH Am Luneort 15 27572 Bremerhaven Germany
HZG	Helmholtz-Zentrum Geesthacht - Zentrum für Material- und Küstenforschung GmbH Max Planck- Str. 1, 21502 Geesthacht Germany
IFM-GEOMAR	Leibniz-Institut für Meereswissenschaften an der Universität Kiel Düsternbrooker Weg 20 24105 Kiel Germany

	Address
IUP	Institut für Umweltphysik Universität Bemen Otto-Hahn-Allee, NW1 D-28334 Bremen, Germany
Laeisz	Reederei F. Laeisz (Bremerhaven) GmbH Brückenstrasse 25 27568 Bremerhaven Germany
LEGI	LEGI-MEOM B.P. 53 38041 Grenoble / Cedex 9 France
MPI	Max-Planck-Institut für Meteorologie Bundesstraße 53, 20146 Hamburg Germany
MSU	Moscow State University and N.K. Koltsov Institute of Developmental Biology, Russian Academy of Sciences) Moscow, Russia
NIOZ	Koninklijk Nederlands Instituut vor Onderzoek der Zee Department for Marine Chemistry and Geology P.O. Box 59 1790 AB Den Burg The Netherlands
OPTIMARE	OPTIMARE Sensorsysteme AG Am Luneort 15A 27572 Bremerhaven Germany
PIK	Potsdam-Institut für Klimafolgenforschung Telegrafenberg 31 14473 Potsdam Germany
VNIRO	Russian Federal Research Institute of Fisheries and Oceanography 17, V.Krasnoselskaya Moscow 107140 Russia

	Address
UBC	University of British Columbia Department of Earth and Ocean Science 6339 Stores Road Vancouver, B.C. Canada V6T 1Z4
UC	University of Connecticut - Avery Point 1080 Shennecossett Road Groton CT 06340 USA
vTI	Johann Heinrich von Thünen-Institut, Bundesforschungsinstitut für Ländliche Räume, Wald und Fischerei Institut für Seefischerei Palmaille 9 22767 Hamburg Germany

A.2 FAHRTTEILNEHMER / CRUISE PARTICIPANTS

Name	First Name	Institute	Profession	Nationality
Arndt	Stefanie	AWI	Student, meteorology	Germany
Bakker	Karel	NIOZ	Engineer, chemistry	The Netherlands
Batta Lona	Paola	UC	Ph.D. stud., biology	Mexico
Bittig	Henry	IFM-GEOMAR	Ph.D. stud., chemistry	Germany
Boebel	Olaf	AWI	Oceanographer	Germany
Bombosch	Annette	AWI	Ph.D. stud., biology	Germany
Buldt	Klaus	DWD	Techn., meteorology	Germany
Bulsiewicz	Klaus	IUP	Techn., physics	Germany
Couture	Constance	UBC	Biologist	Canada
Degenhardt	Philipp	IUP	Student, physics	Germany
Dufour	Carolina	LEGI	Ph.D. stud., physics	France
Fahrbach	Eberhard	AWI	Oceanographer Chief scientist	Germany
Gall	Fabian	HeliService	Techn., helicopter	Germany
Gebauer	Manfred	DWD	Meteorologist	Germany
Hammrich	Klaus	HeliService	Pilot	Germany
Haraldsson	Matilda	vTI	PhD. stud., biology	Sweden
Heckmann	Markus	HeliService	Techn., helicopter	Germany
Hesse	Tilmann	AWI	Ph.D. stud., physics	Germany
Hoppe	Clara	AWI	Ph.D. stud., biology	Germany
Hoppema	Jan Marinus	AWI	Chemist	The Netherlands
Huhn	Oliver	IUP	Physicist	Germany
Jones	Elizabeth	NIOZ	Chemist	U.K.
Kindermann	Lars	AWI	Physicist	Germany
Klatt	Olaf	AWI	Physicist	Germany
Lehnert	Linn-Sophia	FTZ - Westküste	Ph.D. stud., biology	Germany
Lindner	Roland	HeliService	Pilot	Germany
Macrander	Andreas	AWI	Oceanographer	Germany
Martin	Maria	PIK	Ph.D. stud., physics	Germany
Menzel	Uta	AWI	Student, physics	Germany
Möller	Axel	HZG	Ph.D. stud., chemistry	Germany
Monsees	Matthias	AWI	Techn., oceanography	Germany
Mühlenhardt-Siegel	Ute	DZMB	Biologist	Germany
Payne	Christopher	UBC	Technician, biology	Canada
Pfeiffer	Madlene	AWI	Ph.D. stud., physics	Romania

Name	First Name	Institute	Profession	Nationality
Rettig	Stefanie	AWI	Eng., oceanography	Germany
Richter	Ulrike	AWI	Technician, chemistry	Austria
Risch	Denise	FTZ - Westküste	Ph. D. stud., biology	Germany
Rocholl	Carsten	FTZ - Westküste	Geographer	Germany
Rödel	Frank		Artist	Germany
Rohardt	Gerd	AWI	Oceanographer	Germany
Sander	Hendrik	Optimare	Physicist	Germany
Schwegmann	Sandra	AWI	Ph.D. stud., physics	Germany
Siegel	Volker	vTI	Biologist	Germany
Sologub	Denis	SIO	Ph. D. Stud., biology	Russia
Strothmann	Olaf	AWI	Techn., oceanography	Germany
Suer	Birgit	vTI	Technician, biology	Germany
Trimborn	Scarlett	AWI	Biologist	Germany
Uryupova	Katya	MSU	Biologist	Russia
Verdaat	Hans	FTZ - Westküste	Biologist	The Netherlands
Walter	Jörg	AWI	Techn., oceanography	Germany
Winkelmann	Ricarda	PIK	Ph.D. stud., physics	Germany
Wolschke	Hendrik	HZG	Stud., chemistry	Germany
Zitterbart	Daniel	AWI	Ph.D. stud., physics	USA

A.3 SCHIFFSBESATZUNG / SHIP'S CREW

Name	Rank
Wunderlich, Thomas	Master
Spielke, Steffen	1. Offc.
Krohn, Günter	Ch. Eng.
Fallei, Holger	2. Offc.
Janik, Michael	2. Offc.
Reinstädler, Marco	2. Offc.
Erich, Matthias	Doctor
Hecht, Andreas	R. Offc.
Minzlaff, Hans-Ulrich	2. Eng.
Ziemann, Olaf	2. Eng.
Farysch, Tim	3. Eng.
Scholz, Manfred	Elec. Eng.
Fröb, Martin	ELO
Himmel,Frank	ELO
Muhle, Helmut	ELO
Winter, Andreas	ELO
Loidl, Reiner	Boatsw.
Reise, Lutz	Carpenter
Bäcker, Andreas	A.B.
Brickmann, Peter	A.B.
Guse, Hartmut	A.B.
Hagemann, Manfred	A.B.
Pousada Martinez, Saturnio	A.B.
Scheel, Sebastian	A.B.
Schmidt, Uwe	A.B.
Wende, Uwe	A.B.
Winkler, Michael	A.B.
Preußner, Jörg	Storek.
Elsner, Klaus	Mot-man
Pinske, Lutz	Mot-man
Plehn, Markus	Mot-man
Teichert, Uwe	Mot-man
Voy, Bernd	Mot-man
Müller-Homburg, Ralf-Dieter	Cook
Martens, Michael	Cooksmate
Silinski, Frank	Cooksmate
Czyborra, Bärbel	1. Stwdess

Wöckener, Martina	Stwdess/N.
Arendt, René	2. Steward
Gaude, Hans-Jürgen	2. Steward
Hu, Guo Yong	2. Steward
Silinski, Carmen	2. Stwdess
Sun, Yong Sheng	2. Steward
Yu, Kwok Yuen	Laundrym.

A.4 STATIONSLISTE / STATION LIST PS77

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/13-1	30.11.2010	01:55	37° 5.60' S	12° 46.08' E	4826	CTD/RO	in the water	
PS77/13-1	30.11.2010	03:38	37° 5.74' S	12° 46.21' E	4795	CTD/RO	on ground/max depth	EL31 4944m
PS77/13-2	30.11.2010	03:44	37° 5.75' S	12° 46.22' E	4795	PIES	released	ANT3-2 R
PS77/13-1	30.11.2010	05:04	37° 5.78' S	12° 46.14' E	4793	CTD/RO	on deck	
PS77/13-3	30.11.2010	06:31	37° 5.84' S	12° 45.23' E	4904	PIES	slipped	ANT3-3 D
PS77/13-3	30.11.2010	07:40	37° 5.82' S	12° 45.47' E	4872	PIES	on ground/max depth	No Posidonia data
PS77/13-2	30.11.2010	09:00	37° 6.56' S	12° 45.51' E	4944	PIES	release failed	ANT3-2 R failed
PS77/14-1	01.12.2010	03:25	39° 12.85' S	11° 20.07' E	5126	CTD/RO	in the water	
PS77/14-1	01.12.2010	05:10	39° 12.58' S	11° 20.89' E	4920	CTD/RO	on ground/max depth	EL31 5017m
PS77/14-1	01.12.2010	06:47	39° 12.65' S	11° 21.40' E	4921	CTD/RO	on deck	
PS77/14-2	01.12.2010	07:35	39° 12.62' S	11° 20.39' E	5139	PIES	released	ANT4-1 R
PS77/14-2	01.12.2010	10:00	39° 12.67' S	11° 19.69' E	0	PIES	release failed	ANT4-1 R failed
PS77/14-3	01.12.2010	10:13	39° 12.71' S	11° 19.57' E	5139	PIES	slipped	ANT4-2 D
PS77/14-3	01.12.2010	11:39	39° 12.43' S	11° 19.96' E	0	PIES	on ground/max depth	Posidonia: PIES ascending
PS77/14-3	01.12.2010	12:44	39° 12.88' S	11° 19.79' E	0	PIES	at surface	
PS77/14-3	01.12.2010	13:14	39° 13.19' S	11° 20.57' E	5186	PIES	on deck	ANT4-2 D failed
PS77/15-1	02.12.2010	03:37	41° 7.38' S	9° 57.73' E	4716	CTD/RO	in the water	
PS77/15-1	02.12.2010	05:07	41° 7.48' S	9° 57.74' E	4716	CTD/RO	on ground/max depth	EL31 4776m
PS77/15-2	02.12.2010	05:53	41° 7.39' S	9° 57.76' E	4717	PIES	released	ANT5-2 R
PS77/15-1	02.12.2010	06:41	41° 7.21' S	9° 57.86' E	4713	CTD/RO	on deck	
PS77/15-2	02.12.2010	07:13	41° 7.23' S	9° 57.76' E	4714	PIES	at surface	
PS77/15-2	02.12.2010	07:30	41° 7.30' S	9° 57.89' E	4717	PIES	on deck	
PS77/15-3	02.12.2010	08:05	41° 9.77' S	9° 55.31' E	4624	PIES	slipped	ANT5-3 D
PS77/15-3	02.12.2010	09:30	41° 9.78' S	9° 55.17' E	4631	PIES	on ground/max depth	POS 41° 9.74' S 9° 55.34' E
PS77/15-4	02.12.2010	09:44	41° 9.73' S	9° 55.08' E	4603	AFLOAT	in the water	Float # 01

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/16-1	02.12.2010	22:17	42° 58.80' S	8° 30.15' E	3930	PIES	slipped	ANT6-1 D
PS77/16-2	02.12.2010	22:46	42° 58.92' S	8° 30.04' E	3930	CTD/RO	in the water	
PS77/16-1	02.12.2010	23:29	42° 58.94' S	8° 30.08' E	3930	PIES	on ground/max depth	POS 42° 58.76‘ S 08° 30.00‘ E
PS77/16-2	03.12.2010	00:04	42° 58.94' S	8° 30.08' E	3930	CTD/RO	on ground/max depth	EL31 3963m
PS77/16-2	03.12.2010	01:21	42° 58.69' S	8° 29.95' E	3930	CTD/RO	on deck	
PS77/16-3	03.12.2010	01:28	42° 58.89' S	8° 30.14' E	3929	AFLOAT	in the water	Float # 02
PS77/17-1	03.12.2010	14:06	44° 39.51' S	7° 6.38' E	4593	PIES	released	ANT7-3 R
PS77/17-1	03.12.2010	15:30	44° 39.57' S	7° 6.64' E	0	PIES	at surface	
PS77/17-1	03.12.2010	18:05	44° 38.15' S	7° 6.65' E	4639	PIES	on deck	
PS77/17-2	03.12.2010	18:37	44° 39.73' S	7° 5.15' E	4593	PIES	in the water	ANT7-4 D
PS77/17-3	03.12.2010	19:04	44° 40.16' S	7° 5.34' E	4587	CTD/RO	in the water	
PS77/17-2	03.12.2010	19:57	44° 40.18' S	7° 5.51' E	4587	PIES	on ground/max depth	POS 44° 39.65‘ S 07° 05.25‘ E
PS77/17-3	03.12.2010	20:36	44° 40.16' S	7° 5.52' E	4586	CTD/RO	on ground/max depth	EL31 4636m
PS77/17-3	03.12.2010	22:03	44° 40.12' S	7° 5.89' E	4589	CTD/RO	on deck	
PS77/17-4	03.12.2010	22:10	44° 40.10' S	7° 5.95' E	4591	AFLOAT	in the water	Float #03
PS77/18-1	04.12.2010	14:55	46° 12.97' S	5° 40.23' E	4786	PIES	slipped	ANT8-1 D
PS77/18-2	04.12.2010	15:22	46° 12.83' S	5° 40.99' E	4824	CTD/RO	in the water	
PS77/18-1	04.12.2010	16:48	46° 13.17' S	5° 40.94' E	4843	PIES	on ground/max depth	POS 46° 12.95' S 5° 40.17' E
PS77/18-2	04.12.2010	16:55	46° 13.17' S	5° 40.99' E	4851	CTD/RO	on ground/max depth	EL31 4868m
PS77/18-2	04.12.2010	18:35	46° 13.25' S	5° 41.23' E	4823	CTD/RO	on deck	
PS77/18-3	04.12.2010	18:42	46° 13.24' S	5° 41.25' E	4822	AFLOAT	in the water	Float #04
PS77/19-1	05.12.2010	08:02	47° 39.37' S	4° 15.78' E	4545	PIES	released	ANT9-2 R
PS77/19-1	05.12.2010	09:40	47° 39.15' S	4° 16.35' E	4545	PIES	at surface	
PS77/19-1	05.12.2010	09:49	47° 38.95' S	4° 16.18' E	4545	PIES	on deck	
PS77/19-2	05.12.2010	10:20	47° 39.87' S	4° 15.22' E	4541	PIES	slipped	ANT9-3 D
PS77/19-3	05.12.2010	10:47	47° 39.78' S	4° 15.38' E	4543	CTD/RO	in the water	

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/19-3	05.12.2010	12:26	47° 39.63' S	4° 15.33' E	0	CTD/RO	on ground/max depth	EL31 4595m
PS77/19-4	05.12.2010	13:50	47° 39.63' S	4° 15.35' E	4543	BUCKET	in the water	
PS77/19-4	05.12.2010	13:59	47° 39.64' S	4° 15.37' E	4543	BUCKET	on deck	
PS77/19-2	05.12.2010	14:32	47° 39.76' S	4° 15.36' E	4544	PIES	on ground/max depth	No Posidonia reception
PS77/19-3	05.12.2010	14:32	47° 39.76' S	4° 15.36' E	4544	CTD/RO	on deck	
PS77/19-5	05.12.2010	14:36	47° 39.81' S	4° 15.32' E	4543	AFLOAT	in the water	Float #05
PS77/20-1	06.12.2010	01:31	49° 0.69' S	2° 50.07' E	0	PIES	released	ANT10-1 R
PS77/20-2	06.12.2010	03:58	49° 0.77' S	2° 50.05' E	4056	PIES	slipped	ANT10-2 D
PS77/20-3	06.12.2010	04:27	49° 0.78' S	2° 50.03' E	4056	CTD/RO	in the water	
PS77/20-2	06.12.2010	05:08	49° 0.84' S	2° 49.92' E	4052	PIES	on ground/max depth	No Posidonia reception
PS77/20-3	06.12.2010	05:56	49° 0.87' S	2° 49.81' E	4050	CTD/RO	on ground/max depth	EL32 4079m
PS77/20-3	06.12.2010	07:12	49° 1.10' S	2° 50.03' E	4052	CTD/RO	on deck	
PS77/20-4	06.12.2010	07:18	49° 1.10' S	2° 50.12' E	4057	AFLOAT	in the water	Float #06
PS77/20-1	06.12.2010	07:18	49° 1.10' S	2° 50.12' E	4057	PIES	release failed	ANT10-1 R failed
PS77/21-1	06.12.2010	19:05	50° 15.50' S	1° 26.58' E	3876	PIES	released	ANT11-3 R
PS77/21-1	06.12.2010	20:33	50° 15.71' S	1° 26.43' E	3875	PIES	at surface	
PS77/21-1	06.12.2010	20:42	50° 15.57' S	1° 26.65' E	3875	PIES	on deck	
PS77/21-2	06.12.2010	20:55	50° 15.63' S	1° 26.76' E	3868	CTD/RO	in the water	
PS77/21-2	06.12.2010	22:28	50° 15.61' S	1° 26.64' E	3870	CTD/RO	on ground/max depth	EL31 3887m
PS77/21-2	06.12.2010	23:42	50° 15.61' S	1° 26.78' E	3867	CTD/RO	on deck	
PS77/21-3	07.12.2010	00:13	50° 15.45' S	1° 25.18' E	3901	PIES	slipped	ANT11-4 D
PS77/21-3	07.12.2010	01:22	50° 15.17' S	1° 24.97' E	3907	PIES	on ground/max depth	POS 50° 15.33' S 1° 25.00' E
PS77/21-4	07.12.2010	01:30	50° 15.34' S	1° 25.02' E	3904	AFLOAT	in the water	Float #07
PS77/22-1	07.12.2010	10:52	51° 25.15' S	0° 0.24' E	2713	PIES	slipped	ANT12-1 D
PS77/22-2	07.12.2010	11:20	51° 25.17' S	0° 0.36' E	2712	CTD/RO	in the water	
PS77/22-1	07.12.2010	11:42	51° 25.13' S	0° 0.28' E	2712	PIES	on ground/max depth	POS 51° 25.23' S 0° 0.42' E

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/22-2	07.12.2010	12:28	51° 25.17' S	0° 0.33' E	2711	CTD/RO	on ground/max depth	2703m
PS77/22-2	07.12.2010	13:26	51° 25.08' S	0° 0.27' E	2711	CTD/RO	on deck	
PS77/22-3	07.12.2010	13:31	51° 25.21' S	0° 0.52' E	2712	AFLOAT	in the water	Float #08
PS77/23-1	07.12.2010	16:45	51° 56.78' S	0° 0.06' W	2861	CTD/RO	in the water	
PS77/23-1	07.12.2010	17:48	51° 56.73' S	0° 0.22' W	2856	CTD/RO	on ground/max depth	SE32.1 2851m
PS77/23-1	07.12.2010	18:45	51° 56.65' S	0° 0.12' W	2851	CTD/RO	on deck	
PS77/24-1	07.12.2010	22:10	52° 28.27' S	0° 0.12' W	2590	CTD/RO	in the water	
PS77/24-1	07.12.2010	23:14	52° 28.22' S	0° 0.01' W	2595	CTD/RO	on ground/max depth	SE32.1 2583m
PS77/24-1	08.12.2010	00:12	52° 28.19' S	0° 0.27' W	2586	CTD/RO	on deck	
PS77/24-2	08.12.2010	00:18	52° 28.21' S	0° 0.12' E	2590	AFLOAT	in the water	Float #09
PS77/25-1	08.12.2010	03:47	53° 0.50' S	0° 0.01' E	2493	CTD/RO	in the water	
PS77/25-1	08.12.2010	04:42	53° 0.65' S	0° 0.01' W	2483	CTD/RO	on ground/max depth	SE32.1 2475m
PS77/25-1	08.12.2010	05:35	53° 0.71' S	0° 0.02' E	2482	CTD/RO	on deck	
PS77/26-1	08.12.2010	09:11	53° 30.97' S	0° 0.40' E	2645	PIES	released	ANT13-2 R
PS77/26-1	08.12.2010	10:08	53° 31.38' S	0° 0.64' E	0	PIES	at surface	
PS77/26-1	08.12.2010	10:51	53° 30.98' S	0° 1.01' E	2725	PIES	on deck	
PS77/26-2	08.12.2010	11:23	53° 31.22' S	0° 0.13' E	2642	PIES	slipped	ANT13-3 D
PS77/26-3	08.12.2010	11:47	53° 31.26' S	0° 0.22' E	2640	CTD/RO	in the water	
PS77/26-2	08.12.2010	12:09	53° 31.27' S	0° 0.24' E	2640	PIES	on ground/max depth	POS 53° 31.20' S 0° 0.23' E
PS77/26-3	08.12.2010	12:57	53° 31.20' S	0° 0.05' W	2642	CTD/RO	on ground/max depth	SE32.1 2628m
PS77/26-3	08.12.2010	13:54	53° 31.11' S	0° 0.39' W	2657	CTD/RO	on deck	
PS77/27-1	08.12.2010	17:25	54° 0.03' S	0° 0.00' W	2531	CTD/RO	in the water	
PS77/27-1	08.12.2010	18:57	54° 0.17' S	0° 0.18' W	2474	CTD/RO	on ground/max depth	SE32.1 2427m
PS77/27-1	08.12.2010	19:50	54° 0.28' S	0° 0.23' W	2409	CTD/RO	on deck	
PS77/27-2	08.12.2010	19:59	54° 0.52' S	0° 0.26' W	2459	AFLOAT	in the water	Float #10

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/28-1	08.12.2010	23:14	54° 30.63' S	0° 0.02' E	1669	CTD/RO	in the water	
PS77/28-1	09.12.2010	00:04	54° 30.61' S	0° 0.28' E	1685	CTD/RO	on ground/max depth	SE32.1 1655m
PS77/28-1	09.12.2010	00:44	54° 30.53' S	0° 0.09' E	1667	CTD/RO	on deck	
PS77/29-1	09.12.2010	04:10	55° 0.27' S	0° 0.01' E	1733	CTD/RO	in the water	
PS77/29-1	09.12.2010	04:54	55° 0.35' S	0° 0.04' W	1756	CTD/RO	on ground/max depth	SE32.1 1723m
PS77/29-1	09.12.2010	05:33	55° 0.36' S	0° 0.06' E	1739	CTD/RO	on deck	
PS77/29-2	09.12.2010	05:37	55° 0.33' S	0° 0.13' E	1734	AFLOAT	in the water	Float #11
PS77/30-1	09.12.2010	06:02	55° 3.62' S	0° 0.16' W	2582	IFISH	in the water	
PS77/30-1	09.12.2010	07:03	55° 8.55' S	0° 0.03' W	3345	IFISH	on deck	
PS77/31-1	09.12.2010	09:41	55° 30.06' S	0° 0.03' E	3785	CTD/RO	in the water	
PS77/31-1	09.12.2010	11:17	55° 30.04' S	0° 0.36' E	3790	CTD/RO	on ground/max depth	SE32.1 3793 m
PS77/31-1	09.12.2010	12:38	55° 29.99' S	0° 0.63' E	3782	CTD/RO	on deck	
PS77/31-2	09.12.2010	12:42	55° 30.05' S	0° 0.66' E	3779	AFLOAT	in the water	Float #12
PS77/32-1	09.12.2010	16:12	55° 59.91' S	0° 0.07' E	3781	CTD/RO	in the water	
PS77/32-1	09.12.2010	17:36	56° 0.02' S	0° 0.00' W	3863	CTD/RO	on ground/max depth	SE32.1 3787m
PS77/32-1	09.12.2010	18:49	56° 0.07' S	0° 0.24' E	3729	CTD/RO	on deck	
PS77/32-2	09.12.2010	18:56	56° 0.02' S	0° 0.10' E	3764	AFLOAT	in the water	Float #13
PS77/33-1	09.12.2010	22:14	56° 29.95' S	0° 0.09' W	5056	CTD/RO	in the water	
PS77/33-1	09.12.2010	23:50	56° 30.02' S	0° 0.06' E	4077	CTD/RO	on ground/max depth	SE32.1 4091m
PS77/33-1	10.12.2010	01:08	56° 30.17' S	0° 0.13' E	4105	CTD/RO	on deck	
PS77/34-1	10.12.2010	04:15	56° 55.71' S	0° 0.01' W	3673	PIES	slipped	ANT14-1 D
PS77/34-2	10.12.2010	04:40	56° 55.80' S	0° 0.02' E	3682	CTD/RO	in the water	
PS77/34-1	10.12.2010	05:26	56° 55.90' S	0° 0.01' W	3693	PIES	on ground/max depth	POS 56° 55.60' S 0° 0.10' W
PS77/34-2	10.12.2010	06:04	56° 55.98' S	0° 0.18' W	3698	CTD/RO	on ground/max depth	SE32.1 3694m
PS77/34-2	10.12.2010	07:22	56° 56.10' S	0° 0.57' W	3709	CTD/RO	on deck	

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/35-1	10.12.2010	11:20	57° 29.98' S	0° 0.54' W	4001	CTD/RO	in the water	
PS77/35-1	10.12.2010	12:45	57° 29.92' S	0° 0.86' W	3936	CTD/RO	on ground/max depth	SE32.1 3977m
PS77/35-1	10.12.2010	14:08	57° 29.61' S	0° 0.98' W	3940	CTD/RO	on deck	
PS77/35-2	10.12.2010	14:14	57° 29.53' S	0° 0.62' W	3914	NFLOAT	in the water	Float #14
PS77/36-1	10.12.2010	17:29	58° 0.01' S	0° 0.02' W	4536	CTD/RO	in the water	
PS77/36-1	10.12.2010	19:04	57° 59.79' S	0° 0.06' W	4541	CTD/RO	on ground/max depth	SE32.1 4541m
PS77/36-1	10.12.2010	20:30	57° 59.54' S	0° 0.09' E	4544	CTD/RO	on deck	
PS77/36-2	10.12.2010	20:36	57° 59.62' S	0° 0.40' E	4522	NFLOAT	in the water	Float #15
PS77/37-1	10.12.2010	23:53	58° 30.00' S	0° 0.04' W	4195	CTD/RO	in the water	
PS77/37-1	11.12.2010	01:19	58° 29.93' S	0° 0.38' E	4147	CTD/RO	on ground/max depth	SE32.1 4192m
PS77/37-1	11.12.2010	02:45	58° 29.88' S	0° 1.17' E	4017	CTD/RO	on deck	
PS77/38-1	11.12.2010	06:43	59° 2.32' S	0° 5.29' E	4645	PIES	released	ANT15-1 R
PS77/38-1	11.12.2010	08:06	59° 2.23' S	0° 5.19' E	4645	PIES	at surface	
PS77/38-1	11.12.2010	08:27	59° 2.12' S	0° 4.86' E	4641	PIES	on deck	
PS77/39-1	11.12.2010	08:56	59° 4.18' S	0° 4.59' E	4681	MOOR	Posidonia	AWI227-10 R
PS77/39-1	11.12.2010	09:41	59° 3.97' S	0° 4.45' E	4679	MOOR	released	AWI227-10 R
PS77/39-1	11.12.2010	12:10	59° 4.13' S	0° 4.55' E	4680	MOOR	on ground/max depth	AWI227-10 R failed
PS77/40-1	11.12.2010	13:40	59° 9.42' S	0° 2.21' W	4742	MOOR	on ground/max depth	MARU#1 R attempted
PS77/40-1	11.12.2010	15:10	59° 9.92' S	0° 1.31' E	4733	MOOR	on ground/max depth	MARU#1 R cancelled (ice)
PS77/41-1	11.12.2010	16:20	59° 1.25' S	0° 9.63' E	4585	MOOR	in the water	AWI227-11 D top floatation
PS77/41-1	11.12.2010	17:54	59° 3.36' S	0° 6.19' E	4658	MOOR	slipped	Anchor slipped
PS77/41-1	11.12.2010	18:28	59° 3.02' S	0° 6.63' E	4646	MOOR	on ground/max depth	Posidonia fixes uncertain
PS77/42-2	11.12.2010	18:51	59° 2.37' S	0° 5.29' E	4647	PIES	slipped	ANT15-2 D
PS77/42-2	11.12.2010	19:20	59° 2.33' S	0° 6.07' E	4639	CTD/RO	in the water	
PS77/42-2	11.12.2010	20:16	59° 2.30' S	0° 6.27' E	4635	PIES	on ground/max depth	POS 59° 2.39' S 0° 5.52' E
PS77/42-2	11.12.2010	20:48	59° 2.32' S	0° 6.34' E	4635	CTD/RO	on ground/max depth	SE32.1 4666m

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/42-2	11.12.2010	22:20	59° 2.02' S	0° 6.07' E	4626	CTD/RO	on deck	
PS77/42-3	11.12.2010	22:24	59° 1.98' S	0° 6.02' E	4632	NFLOAT	in the water	Float #16
PS77/43-1	11.12.2010	23:40	59° 10.06' S	0° 0.22' E	4768	TEST	in the water	Test SonoVault
PS77/43-1	12.12.2010	00:38	59° 10.09' S	0° 0.10' E	4746	TEST	on ground/max depth	SE32.2 1500m
PS77/43-2	12.12.2010	02:08	59° 10.05' S	0° 0.17' E	4748	MOOR	released	MARU#1 R
PS77/43-1	12.12.2010	02:44	59° 10.18' S	0° 0.51' E	4824	TEST	on deck	
PS77/43-2	12.12.2010	02:57	59° 10.23' S	0° 1.02' E	4763	MOOR	at surface	
PS77/43-2	12.12.2010	03:24	59° 10.36' S	0° 0.68' E	4853	MOOR	on deck	
PS77/44-1	12.12.2010	05:44	59° 30.80' S	0° 0.61' W	4688	CTD/RO	in the water	
PS77/44-1	12.12.2010	07:22	59° 31.30' S	0° 0.27' W	4639	CTD/RO	on ground/max depth	SE32.1 4696m
PS77/44-1	12.12.2010	08:54	59° 31.77' S	0° 0.58' E	4753	CTD/RO	on deck	
PS77/45-1	12.12.2010	12:04	60° 0.09' S	0° 0.05' E	5361	CTD/RO	in the water	
PS77/45-1	12.12.2010	13:52	59° 59.93' S	0° 0.07' E	5365	CTD/RO	on ground/max depth	SE32.1 5423m
PS77/45-1	12.12.2010	15:34	60° 0.39' S	0° 1.36' E	5383	CTD/RO	on deck	
PS77/45-2	12.12.2010	15:39	60° 0.56' S	0° 1.21' E	5380	NFLOAT	in the water	Float #17
PS77/46-1	12.12.2010	18:55	60° 30.18' S	0° 0.81' E	5370	CTD/RO	in the water	
PS77/46-1	12.12.2010	20:42	60° 30.04' S	0° 1.78' E	5375	CTD/RO	on ground/max depth	SE32.1 5432 m
PS77/46-1	12.12.2010	22:24	60° 29.84' S	0° 1.84' E	5364	CTD/RO	on deck	
PS77/47-1	13.12.2010	01:52	60° 59.90' S	0° 0.10' W	5390	CTD/RO	in the water	
PS77/47-1	13.12.2010	03:44	61° 0.43' S	0° 0.18' W	5390	CTD/RO	on ground/max depth	5453m
PS77/47-1	13.12.2010	05:28	61° 0.96' S	0° 0.39' W	5387	CTD/RO	on deck	
PS77/48-1	13.12.2010	08:44	61° 29.86' S	0° 0.20' E	5389	CTD/RO	in the water	
PS77/48-1	13.12.2010	10:25	61° 30.03' S	0° 0.28' E	5389	CTD/RO	on ground/max depth	EL31 5435 m
PS77/48-1	13.12.2010	12:10	61° 30.23' S	0° 1.13' E	5392	CTD/RO	on deck	
PS77/49-1	13.12.2010	15:55	61° 59.49' S	0° 0.38' W	5372	CTD/RO	in the water	
PS77/49-1	13.12.2010	17:47	61° 58.80' S	0° 1.45' E	5372	CTD/RO	on ground/max depth	EL31 5517m (!)

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/49-1	13.12.2010	19:36	61° 57.67' S	0° 2.38' E	5371	CTD/RO	on deck	
PS77/49-2	13.12.2010	19:43	61° 57.76' S	0° 2.54' E	5372	NFLOAT	in the water	Float #18
PS77/50-1	14.12.2010	00:04	62° 29.35' S	0° 0.68' E	5350	CTD/RO	in the water	
PS77/50-1	14.12.2010	02:02	62° 29.43' S	0° 4.16' E	5353	CTD/RO	on ground/max depth	5758m
PS77/50-1	14.12.2010	03:48	62° 28.91' S	0° 6.45' E	5351	CTD/RO	on deck	
PS77/51-1	14.12.2010	07:41	62° 59.47' S	0° 0.03' W	5315	CTD/RO	in the water	
PS77/51-1	14.12.2010	09:20	62° 59.45' S	0° 0.03' W	5315	CTD/RO	on ground/max depth	EL31 5360m
PS77/51-1	14.12.2010	11:02	62° 59.74' S	0° 0.36' W	5314	CTD/RO	on deck	
PS77/51-2	14.12.2010	11:07	62° 59.76' S	0° 0.43' W	5314	NFLOAT	in the water	Float #19
PS77/52-1	14.12.2010	15:36	63° 30.89' S	0° 0.62' W	5244	CTD/RO	in the water	
PS77/52-1	14.12.2010	17:29	63° 31.76' S	0° 1.17' W	5244	CTD/RO	on ground/max depth	EL31 5312m
PS77/52-1	14.12.2010	19:10	63° 32.83' S	0° 2.68' W	5241	CTD/RO	on deck	
PS77/53-1	14.12.2010	23:45	64° 0.70' S	0° 2.72' W	5201	PIES	slipped	ANT17-1 D
PS77/53-2	15.12.2010	00:20	64° 1.25' S	0° 1.72' W	5200	CTD/RO	in the water	
PS77/53-1	15.12.2010	01:32	64° 2.18' S	0° 0.88' W	5198	PIES	on ground/max depth	No Posidonia reception
PS77/53-2	15.12.2010	02:01	64° 2.43' S	0° 0.18' W	5196	CTD/RO	on ground/max depth	5417m
PS77/53-2	15.12.2010	03:43	64° 3.17' S	0° 2.40' E	5196	CTD/RO	on deck	
PS77/53-3	15.12.2010	03:51	64° 3.22' S	0° 2.44' E	5195	TEST	in the water	Test SonoVault
PS77/53-3	15.12.2010	04:16	64° 3.31' S	0° 2.43' E	5195	TEST	on ground/max depth	SE32.2 1000m
PS77/53-3	15.12.2010	04:58	64° 3.43' S	0° 2.61' E	5196	TEST	on deck	
PS77/53-4	15.12.2010	06:36	63° 58.18' S	0° 2.21' W	5209	MOOR	released	AWI229-8 R
PS77/53-4	15.12.2010	07:12	63° 58.32' S	0° 2.99' W	5209	MOOR	at surface	mooring partly under ice
PS77/53-4	15.12.2010	08:57	63° 58.75' S	0° 2.39' W	0	MOOR	on deck	ULS / Top floatation
PS77/53-4	15.12.2010	11:54	64° 0.66' S	0° 2.46' W	0	MOOR	on deck	complete mooring on deck
PS77/53-5	15.12.2010	13:08	63° 57.24' S	0° 3.32' W	5210	MOOR	in the water	AWI229-9 D Anchor first
PS77/53-5	15.12.2010	16:22	63° 59.57' S	0° 2.66' W	5204	MOOR	in the water	ULS / Top floatation

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/53-5	15.12.2010	16:29	63° 59.56' S	0° 2.65' W	5205	MOOR	depl. release slipped	No Posidonia reception
PS77/53-6	15.12.2010	16:41	63° 59.66' S	0° 2.97' W	5205	NFLOAT	in the water	Float #20
PS77/54-1	15.12.2010	17:15	64° 4.17' S	0° 4.72' W	5196	MOOR	on ground/max depth	MARU#2 R Posidonia contact
PS77/54-1	15.12.2010	17:44	64° 4.70' S	0° 5.03' W	0	MOOR	on ground/max depth	MARU#2 R cancelled (ice)
PS77/55-1	15.12.2010	20:56	64° 30.09' S	0° 0.04' W	4674	CTD/RO	in the water	
PS77/55-1	15.12.2010	22:38	64° 30.19' S	0° 0.31' W	4673	CTD/RO	on ground/max depth	EL31 4690m
PS77/55-1	16.12.2010	00:10	64° 30.96' S	0° 1.18' W	4671	CTD/RO	on deck	
PS77/56-1	16.12.2010	03:19	64° 59.99' S	0° 0.29' W	3743	CTD/RO	in the water	
PS77/56-1	16.12.2010	04:46	65° 0.52' S	0° 0.63' W	3766	CTD/RO	on ground/max depth	EL31 3760m
PS77/56-1	16.12.2010	06:01	65° 0.93' S	0° 0.31' W	3769	CTD/RO	on deck	
PS77/56-2	16.12.2010	06:11	65° 1.21' S	0° 0.88' W	3784	NFLOAT	in the water	Float #21
PS77/57-1	16.12.2010	09:10	65° 30.00' S	0° 0.13' E	3994	CTD/RO	in the water	
PS77/57-1	16.12.2010	10:36	65° 30.01' S	0° 0.03' E	3996	CTD/RO	on ground/max depth	EL31 4000m
PS77/57-1	16.12.2010	11:52	65° 29.98' S	0° 0.08' E	3994	CTD/RO	on deck	
PS77/58-1	16.12.2010	15:14	66° 1.49' S	0° 3.89' E	3615	MOOR	released	AWI230-6 R
PS77/58-1	16.12.2010	15:18	66° 1.32' S	0° 4.23' E	3615	MOOR	at surface	
PS77/58-1	16.12.2010	15:47	66° 1.06' S	0° 4.49' E	3627	MOOR	on deck	Top floatation
PS77/58-1	16.12.2010	17:04	66° 1.09' S	0° 3.54' E	3664	MOOR	on deck	complete mooring on deck
PS77/58-2	16.12.2010	18:21	66° 3.60' S	0° 0.15' W	3596	MOOR	in the water	AWI230-7 D Top float first
PS77/58-2	16.12.2010	19:35	66° 1.90' S	0° 3.25' E	3607	MOOR	slipped	Anchor slipped
PS77/58-2	16.12.2010	20:00	66° 1.73' S	0° 3.47' E	3611	MOOR	on ground/max depth	POS ~66° 2.02' S ~0° 2.88' E
PS77/58-3	16.12.2010	20:30	66° 0.76' S	0° 7.18' E	3546	CTD/RO	in the water	
PS77/58-3	16.12.2010	21:43	66° 0.80' S	0° 7.30' E	3543	CTD/RO	on ground/max depth	EL31 3533m
PS77/58-3	16.12.2010	22:58	66° 0.65' S	0° 7.58' E	3542	CTD/RO	on deck	
PS77/58-4	16.12.2010	23:05	66° 0.46' S	0° 7.27' E	3558	NFLOAT	in the water	Float #22

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/59-1	17.12.2010	02:45	66° 29.97' S	0° 0.32' W	4539	CTD/RO	in the water	
PS77/59-1	17.12.2010	04:25	66° 29.87' S	0° 0.39' W	4534	CTD/RO	on ground/max depth	EL31 4553m
PS77/59-1	17.12.2010	05:55	66° 29.86' S	0° 0.77' W	4531	CTD/RO	on deck	
PS77/59-2	17.12.2010	06:21	66° 30.57' S	0° 2.87' W	4579	MOOR	released	AWI231-8 R
PS77/59-2	17.12.2010	06:24	66° 30.60' S	0° 2.62' W	4579	MOOR	at surface	
PS77/59-2	17.12.2010	06:50	66° 30.77' S	0° 1.93' W	4555	MOOR	on deck	ULS / Top floatation
PS77/59-2	17.12.2010	08:20	66° 30.74' S	0° 1.89' W	4553	MOOR	on deck	complete mooring on deck
PS77/59-3	17.12.2010	09:25	66° 31.37' S	0° 10.44' W	4559	MOOR	in the water	AWI231-9 D Top float first
PS77/59-3	17.12.2010	11:22	66° 30.71' S	0° 1.54' W	4538	MOOR	slipped	Anchor slipped
PS77/59-3	17.12.2010	11:58	66° 30.60' S	0° 0.64' W	4526	MOOR	on ground/max depth	Posidonia fixes uncertain
PS77/60-1	17.12.2010	13:12	66° 38.73' S	0° 0.13' W	0	IFISH	in the water	
PS77/60-1	17.12.2010	22:50	67° 1.60' S	0° 2.91' E	0	IFISH	on deck	
PS77/61-1	17.12.2010	23:10	67° 0.05' S	0° 0.03' W	4713	CTD/RO	in the water	
PS77/61-1	18.12.2010	00:46	67° 0.11' S	0° 0.23' E	4713	CTD/RO	on ground/max depth	EL31 4735m
PS77/61-1	18.12.2010	02:19	67° 0.13' S	0° 0.12' E	4713	CTD/RO	on deck	
PS77/61-2	18.12.2010	02:24	67° 0.12' S	0° 0.47' E	4713	NFLOAT	in the water	Float #23
PS77/62-1	18.12.2010	05:28	67° 30.06' S	0° 0.04' E	4637	CTD/RO	in the water	
PS77/62-1	18.12.2010	06:56	67° 29.77' S	0° 0.31' E	4636	CTD/RO	on ground/max depth	EL31 4568m
PS77/62-1	18.12.2010	08:24	67° 29.42' S	0° 0.19' E	4637	CTD/RO	on deck	
PS77/63-1	18.12.2010	11:35	68° 0.06' S	0° 0.17' E	4517	CTD/RO	in the water	
PS77/63-1	18.12.2010	13:08	68° 0.06' S	0° 0.08' W	4517	CTD/RO	on ground/max depth	EL31 4532m
PS77/63-1	18.12.2010	14:37	68° 0.16' S	0° 0.19' E	4517	CTD/RO	on deck	
PS77/63-2	18.12.2010	14:41	68° 0.20' S	0° 0.46' E	4517	NFLOAT	in the water	Float #24
PS77/64-1	18.12.2010	17:46	68° 30.14' S	0° 0.19' E	4265	CTD/RO	in the water	
PS77/64-1	18.12.2010	19:09	68° 30.08' S	0° 0.12' E	4266	CTD/RO	on ground/max depth	EL31 4277m
PS77/64-1	18.12.2010	20:34	68° 30.23' S	0° 0.87' E	4263	CTD/RO	on deck	

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/65-1	18.12.2010	22:17	68° 44.97' S	0° 0.07' E	3624	CTD/RO	in the water	
PS77/65-1	18.12.2010	23:37	68° 45.00' S	0° 0.03' W	3637	CTD/RO	on ground/max depth	EL31 3637m
PS77/65-1	19.12.2010	00:54	68° 44.65' S	0° 0.38' E	3573	CTD/RO	on deck	
PS77/66-1	19.12.2010	02:42	69° 1.02' S	0° 0.78' E	3386	CTD/RO	in the water	
PS77/66-1	19.12.2010	03:55	69° 0.94' S	0° 0.21' E	3381	CTD/RO	on ground/max depth	EL31 3369m
PS77/66-1	19.12.2010	05:06	69° 0.97' S	0° 0.06' E	3378	CTD/RO	on deck	
PS77/66-2	19.12.2010	05:40	68° 59.95' S	0° 0.04' W	3414	MOOR	released	AWI232-9 R
PS77/66-2	19.12.2010	05:43	68° 59.95' S	0° 0.04' W	3414	MOOR	at surface	
PS77/66-2	19.12.2010	06:21	68° 59.78' S	0° 0.04' W	3424	MOOR	on deck	ULS / Top floatation
PS77/66-2	19.12.2010	07:27	69° 0.36' S	0° 0.77' W	3378	MOOR	on deck	complete mooring on deck
PS77/66-3	19.12.2010	08:27	69° 1.87' S	0° 4.85' W	3273	MOOR	in the water	AWI232-10 D,Top float first
PS77/66-3	19.12.2010	09:50	69° 0.11' S	0° 0.11' W	3404	MOOR	slipped	Anchor slipped
PS77/66-3	19.12.2010	10:25	69° 0.13' S	0° 0.55' E	3404	MOOR	on ground/max depth	Posidonia fixes uncertain
PS77/66-4	19.12.2010	10:27	69° 0.16' S	0° 0.34' E	3404	NFLOAT	in the water	Float #25
NaN	20.12.2010	10:00	70° 30.74' S	8° 11.31' W	NaN	NaN	Shelf ice edge	begin supply Neumayer
NaN	22.12.2010	18:00	70° 30.74' S	8° 11.31' W	NaN	NaN	Shelf ice edge	end supply Neumayer
PS77/67-1	22.12.2010	19:11	70° 31.29' S	8° 5.80' W	227	CTD/RO	in the water	
PS77/67-1	22.12.2010	19:23	70° 31.32' S	8° 5.81' W	225	CTD/RO	on ground/max depth	EL31 214m
PS77/67-1	22.12.2010	19:30	70° 31.36' S	8° 5.87' W	226	CTD/RO	on deck	
PS77/68-1	23.12.2010	06:17	68° 59.83' S	6° 56.37' W	0	MOOR	released	ANT244-1 R
PS77/68-1	23.12.2010	06:26	68° 59.80' S	6° 56.35' W	0	MOOR	at surface	
PS77/68-1	23.12.2010	06:58	68° 59.81' S	6° 57.19' W	2942	MOOR	on deck	Top floatation
PS77/68-1	23.12.2010	07:49	68° 59.84' S	6° 57.02' W	2931	MOOR	on deck	complete mooring on deck
PS77/68-2	23.12.2010	09:14	69° 1.27' S	7° 2.09' W	2935	MOOR	in the water	AWI244-2 D Top float first
PS77/68-2	23.12.2010	10:04	69° 0.30' S	6° 58.89' W	2950	MOOR	slipped	Anchor slipped

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/68-3	23.12.2010	10:27	68° 59.75' S	6° 56.88' W	2863	CTD/RO	in the water	
PS77/68-2	23.12.2010	10:27	68° 59.75' S	6° 56.88' W	2863	MOOR	on ground/max depth	POS ~69° 0.64' S ~6° 59.42' W
PS77/68-3	23.12.2010	11:12	68° 59.78' S	6° 56.72' W	2935	CTD/RO	on ground/max depth	EL31 2081m
PS77/68-3	23.12.2010	11:50	68° 59.91' S	6° 56.86' W	2919	CTD/RO	on deck	
PS77/68-4	23.12.2010	11:55	68° 59.97' S	6° 57.18' W	2922	NFLOAT	in the water	Float #26
PS77/69-1	24.12.2010	03:30	71° 6.48' S	11° 26.20' W	356	CTD/RO	in the water	
PS77/69-1	24.12.2010	03:45	71° 6.51' S	11° 26.56' W	333	CTD/RO	on ground/max depth	EL31 315m
PS77/69-1	24.12.2010	04:03	71° 6.49' S	11° 26.94' W	316	CTD/RO	on deck	
PS77/70-1	24.12.2010	05:14	71° 0.23' S	11° 45.57' W	819	CTD/RO	in the water	
PS77/70-1	24.12.2010	05:39	71° 0.39' S	11° 45.80' W	832	CTD/RO	on ground/max depth	EL31 808m
PS77/70-1	24.12.2010	06:01	71° 0.52' S	11° 46.03' W	841	CTD/RO	on deck	
PS77/71-1	24.12.2010	06:46	70° 56.48' S	11° 57.33' W	1530	CTD/RO	in the water	
PS77/71-1	24.12.2010	07:23	70° 56.49' S	11° 57.72' W	1536	CTD/RO	on ground/max depth	EL31 1507m
PS77/71-1	24.12.2010	07:59	70° 56.53' S	11° 58.01' W	1539	CTD/RO	on deck	
PS77/72-1	24.12.2010	09:35	70° 46.32' S	12° 27.81' W	2079	CTD/RO	in the water	
PS77/72-1	24.12.2010	10:27	70° 46.36' S	12° 27.74' W	2078	CTD/RO	on ground/max depth	EL31 2046m
PS77/72-1	24.12.2010	11:12	70° 46.39' S	12° 27.71' W	2076	CTD/RO	on deck	
PS77/73-1	24.12.2010	12:28	70° 39.82' S	12° 47.42' W	2365	CTD/RO	in the water	
PS77/73-1	24.12.2010	13:26	70° 39.84' S	12° 47.46' W	2367	CTD/RO	on ground/max depth	EL31 2341m
PS77/73-1	24.12.2010	14:20	70° 39.85' S	12° 47.32' W	2364	CTD/RO	on deck	
PS77/74-1	25.12.2010	09:55	70° 25.83' S	13° 29.41' W	2785	CTD/RO	in the water	
PS77/74-1	25.12.2010	11:00	70° 25.84' S	13° 29.37' W	2784	CTD/RO	on ground/max depth	EL31 2760m
PS77/74-1	25.12.2010	12:00	70° 25.60' S	13° 29.74' W	2795	CTD/RO	on deck	
PS77/75-1	25.12.2010	13:18	70° 18.30' S	13° 51.75' W	4389	CTD/RO	in the water	
PS77/75-1	25.12.2010	14:50	70° 18.27' S	13° 51.71' W	4389	CTD/RO	on ground/max depth	EL31 4398m
PS77/75-1	25.12.2010	16:12	70° 18.40' S	13° 51.57' W	4388	CTD/RO	on deck	

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/76-1	26.12.2010	07:57	70° 5.14' S	14° 30.26' W	4739	CTD/RO	in the water	
PS77/76-1	26.12.2010	09:37	70° 5.27' S	14° 30.11' W	4698	CTD/RO	on ground/max depth	EL31 4761m
PS77/76-1	26.12.2010	11:12	70° 5.34' S	14° 30.05' W	4689	CTD/RO	on deck	
PS77/76-2	26.12.2010	11:24	70° 5.37' S	14° 30.37' W	4741	NFLOAT	in the water	Float #27
PS77/77-1	26.12.2010	16:00	69° 34.43' S	15° 58.89' W	4151	CTD/RO	in the water	
PS77/77-1	26.12.2010	17:28	69° 34.13' S	15° 59.52' W	4762	CTD/RO	on ground/max depth	EL31 4785m
PS77/77-1	26.12.2010	18:59	69° 33.67' S	15° 59.77' W	4755	CTD/RO	on deck	
PS77/78-1	27.12.2010	00:38	69° 2.87' S	17° 29.70' W	4779	CTD/RO	in the water	
PS77/78-1	27.12.2010	02:07	69° 2.71' S	17° 30.02' W	4779	CTD/RO	on ground/max depth	EL31 4805m
PS77/78-1	27.12.2010	03:37	69° 2.12' S	17° 29.60' W	4780	CTD/RO	on deck	
PS77/78-2	27.12.2010	06:08	69° 3.57' S	17° 26.35' W	0	MOOR	released	AWI245-1 R
PS77/78-2	27.12.2010	06:15	69° 3.57' S	17° 26.43' W	0	MOOR	at surface	
PS77/78-2	27.12.2010	06:45	69° 3.63' S	17° 26.29' W	4778	MOOR	on deck	Top floatation
PS77/78-2	27.12.2010	08:18	69° 3.45' S	17° 29.21' W	4778	MOOR	on deck	complete mooring on deck
PS77/78-3	27.12.2010	09:02	69° 3.33' S	17° 20.23' W	4779	MOOR	in the water	AWI245-2D Anchor first
PS77/78-3	27.12.2010	11:03	69° 3.52' S	17° 23.03' W	4778	MOOR	in the water	Top floatation
PS77/78-3	27.12.2010	11:06	69° 3.52' S	17° 23.05' W	4778	MOOR	depl. release slipped	
PS77/78-3	27.12.2010	12:00	69° 3.51' S	17° 22.95' W	0	MOOR	on ground/max depth	Posidonia fixes uncertain
PS77/78-4	27.12.2010	12:01	69° 3.52' S	17° 22.98' W	4778	NFLOAT	in the water	Float #28
PS77/79-1	27.12.2010	18:17	68° 32.65' S	18° 43.07' W	4800	CTD/RO	in the water	
PS77/79-1	27.12.2010	19:42	68° 32.30' S	18° 44.32' W	4803	CTD/RO	on ground/max depth	EL31 4870m
PS77/79-1	27.12.2010	21:12	68° 32.15' S	18° 45.33' W	4805	CTD/RO	on deck	
PS77/80-1	28.12.2010	01:53	68° 1.85' S	19° 57.08' W	4909	CTD/RO	in the water	
PS77/80-1	28.12.2010	03:27	68° 1.31' S	19° 58.62' W	4909	CTD/RO	on ground/max depth	EL31 4960m
PS77/80-1	28.12.2010	05:02	68° 0.86' S	19° 59.30' W	4910	CTD/RO	on deck	
PS77/80-2	28.12.2010	05:08	68° 0.79' S	19° 59.54' W	4910	NFLOAT	in the water	Float #29

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/81-1	28.12.2010	09:52	67° 40.68' S	21° 47.43' W	4917	CTD/RO	in the water	
PS77/81-1	28.12.2010	11:27	67° 40.64' S	21° 47.52' W	4918	CTD/RO	on ground/max depth	EL31 4940m
PS77/81-1	28.12.2010	12:58	67° 40.62' S	21° 47.87' W	4917	CTD/RO	on deck	
PS77/82-1	28.12.2010	17:55	67° 19.32' S	23° 36.48' W	4884	CTD/RO	in the water	
PS77/82-1	28.12.2010	19:21	67° 19.64' S	23° 36.67' W	4889	CTD/RO	on ground/max depth	EL31 4907m
PS77/82-1	28.12.2010	20:57	67° 19.63' S	23° 36.37' W	4886	CTD/RO	on deck	
PS77/82-2	28.12.2010	21:03	67° 19.72' S	23° 36.55' W	4887	NFLOAT	in the water	Float #30
PS77/83-1	29.12.2010	01:30	66° 58.04' S	25° 22.04' W	4871	CTD/RO	in the water	
PS77/83-1	29.12.2010	03:01	66° 58.05' S	25° 22.21' W	4856	CTD/RO	on ground/max depth	EL31 4879m
PS77/83-1	29.12.2010	04:33	66° 58.17' S	25° 21.90' W	4849	CTD/RO	on deck	
PS77/84-1	29.12.2010	09:03	66° 36.73' S	27° 6.88' W	4876	MOOR	released	AWI209-5 R
PS77/84-1	29.12.2010	09:06	66° 36.77' S	27° 6.83' W	4876	MOOR	at surface	
PS77/84-1	29.12.2010	09:26	66° 37.00' S	27° 6.80' W	4876	MOOR	on deck	Top floatation
PS77/84-1	29.12.2010	11:03	66° 36.80' S	27° 5.93' W	4877	MOOR	on deck	complete mooring on deck
PS77/84-2	29.12.2010	12:24	66° 34.13' S	27° 7.27' W	4879	MOOR	in the water	AWI209-6D Top float first
PS77/84-2	29.12.2010	14:06	66° 36.70' S	27° 7.31' W	4877	MOOR	slipped	Anchor slipped
PS77/84-2	29.12.2010	15:05	66° 36.58' S	27° 7.26' W	4876	MOOR	on ground/max depth	Posidonia fixes uncertain
PS77/84-3	29.12.2010	15:21	66° 37.72' S	27° 6.18' W	4898	CTD/RO	in the water	
PS77/84-3	29.12.2010	16:57	66° 37.69' S	27° 6.02' W	4875	CTD/RO	on ground/max depth	EL31 4897m
PS77/84-3	29.12.2010	18:28	66° 37.56' S	27° 5.53' W	4875	CTD/RO	on deck	
PS77/84-4	29.12.2010	18:34	66° 37.54' S	27° 5.37' W	4875	NFLOAT	in the water	Float #31
PS77/85-1	29.12.2010	22:21	66° 26.80' S	28° 39.97' W	4861	CTD/RO	in the water	
PS77/85-1	29.12.2010	23:53	66° 26.83' S	28° 39.92' W	4861	CTD/RO	on ground/max depth	EL31 4882m
PS77/85-1	30.12.2010	01:32	66° 26.76' S	28° 39.73' W	4861	CTD/RO	on deck	
PS77/86-1	30.12.2010	04:44	66° 18.52' S	29° 59.80' W	4820	CTD/RO	in the water	
PS77/86-1	30.12.2010	06:16	66° 18.49' S	29° 59.57' W	4820	CTD/RO	on ground/max depth	EL31 4838m

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/86-1	30.12.2010	07:49	66° 18.47' S	29° 59.41' W	4820	CTD/RO	on deck	
PS77/86-2	30.12.2010	07:54	66° 18.46' S	29° 59.41' W	4820	NFLOAT	in the water	Float #32
PS77/87-1	30.12.2010	11:00	66° 10.19' S	31° 17.50' W	4819	CTD/RO	in the water	
PS77/87-1	30.12.2010	12:31	66° 10.51' S	31° 17.25' W	4819	CTD/RO	on ground/max depth	EL31 4855m
PS77/87-1	30.12.2010	14:06	66° 11.18' S	31° 16.99' W	4814	CTD/RO	on deck	
PS77/88-1	30.12.2010	17:30	66° 1.88' S	32° 34.53' W	4806	CTD/RO	in the water	
PS77/88-1	30.12.2010	19:03	66° 1.85' S	32° 34.67' W	4806	CTD/RO	on ground/max depth	EL31 4830m
PS77/88-1	30.12.2010	20:37	66° 1.77' S	32° 35.03' W	4805	CTD/RO	on deck	
PS77/89-1	30.12.2010	23:56	65° 53.73' S	33° 51.31' W	4802	CTD/RO	in the water	
PS77/89-1	31.12.2010	01:28	65° 54.04' S	33° 51.58' W	4800	CTD/RO	on ground/max depth	EL31 4828m
PS77/89-1	31.12.2010	03:00	65° 54.18' S	33° 51.69' W	4800	CTD/RO	on deck	
PS77/89-2	31.12.2010	03:05	65° 54.18' S	33° 51.69' W	4800	NFLOAT	in the water	Float #33
PS77/90-1	31.12.2010	07:09	65° 45.19' S	35° 7.91' W	4792	CTD/RO	in the water	
PS77/90-1	31.12.2010	08:39	65° 45.25' S	35° 7.99' W	4791	CTD/RO	on ground/max depth	EL31 4812m
PS77/90-1	31.12.2010	10:11	65° 45.26' S	35° 7.85' W	4790	CTD/RO	on deck	
PS77/91-1	01.01.2011	06:04	65° 36.93' S	36° 24.47' W	0	MOOR	released	AWI208-5 R
PS77/91-1	01.01.2011	06:06	65° 36.96' S	36° 24.45' W	0	MOOR	under ice floe	POS: mooring ascending
PS77/91-1	01.01.2011	11:50	65° 37.44' S	36° 24.04' W	0	MOOR	at surface	located after POS survey
PS77/91-1	01.01.2011	12:29	65° 37.34' S	36° 24.20' W	0	MOOR	on deck	4 Benthos
PS77/91-1	01.01.2011	14:16	65° 37.91' S	36° 24.63' W	4781	MOOR	on deck	complete mooring on deck
PS77/91-2	01.01.2011	15:15	65° 36.89' S	36° 24.57' W	4783	MOOR	in the water	AWI208-6D Anchor first
PS77/91-2	01.01.2011	17:44	65° 37.03' S	36° 25.24' W	4783	MOOR	in the water	ULS / deployment release
PS77/91-2	01.01.2011	17:49	65° 37.04' S	36° 25.28' W	4784	MOOR	depl. release slipped	No Posidonia reception
PS77/91-3	01.01.2011	18:09	65° 36.94' S	36° 22.60' W	4787	CTD/RO	in the water	
PS77/91-3	01.01.2011	19:38	65° 37.12' S	36° 23.08' W	4783	CTD/RO	on ground/max depth	EL31 4807m
PS77/91-3	01.01.2011	21:13	65° 37.41' S	36° 23.38' W	4782	CTD/RO	on deck	

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/92-1	02.01.2011	01:57	65° 26.49' S	37° 46.32' W	4743	CTD/RO	in the water	
PS77/92-1	02.01.2011	03:27	65° 26.50' S	37° 46.54' W	4743	CTD/RO	on ground/max depth	EL31 4759m
PS77/92-1	02.01.2011	04:58	65° 26.39' S	37° 47.14' W	4744	CTD/RO	on deck	
PS77/93-1	02.01.2011	07:34	65° 33.63' S	37° 11.39' W	0	MOOR	release from helicopter	AWI242-1 R
PS77/93-1	02.01.2011	07:43	65° 33.94' S	37° 10.36' W	0	MOOR	at surface	at 65°34.3'S 037°07.4'W
PS77/93-1	02.01.2011	08:38	65° 34.34' S	37° 7.40' W	4755	MOOR	on deck	Top floatation
PS77/93-1	02.01.2011	10:00	65° 34.03' S	37° 7.63' W	4754	MOOR	on deck	complete mooring on deck
PS77/94-1	02.01.2011	17:55	65° 16.09' S	39° 7.59' W	4777	CTD/RO	in the water	
PS77/94-1	02.01.2011	19:23	65° 16.23' S	39° 6.44' W	4778	CTD/RO	on ground/max depth	EL31 4834m
PS77/94-1	02.01.2011	21:00	65° 16.20' S	39° 5.81' W	4779	CTD/RO	on deck	
PS77/95-1	03.01.2011	01:54	65° 5.28' S	40° 30.98' W	4772	CTD/RO	in the water	
PS77/95-1	03.01.2011	03:26	65° 5.61' S	40° 31.46' W	4770	CTD/RO	on ground/max depth	EL31 4791m
PS77/95-1	03.01.2011	05:05	65° 5.97' S	40° 31.18' W	4770	CTD/RO	on deck	
PS77/95-1	03.01.2011	05:10	65° 5.96' S	40° 31.08' W	4770	NFLOAT	in the water	Float #34
PS77/96-1	03.01.2011	08:32	64° 56.63' S	41° 30.44' W	4752	CTD/RO	in the water	
PS77/96-1	03.01.2011	10:07	64° 56.72' S	41° 30.40' W	4750	CTD/RO	on ground/max depth	EL31 4768m
PS77/96-1	03.01.2011	11:38	64° 56.82' S	41° 30.57' W	4750	CTD/RO	on deck	
PS77/97-1	03.01.2011	14:44	64° 48.96' S	42° 26.76' W	4717	RMT	in the water	
PS77/97-1	03.01.2011	15:03	64° 48.19' S	42° 27.03' W	4719	RMT	profile start	
PS77/97-1	03.01.2011	15:30	64° 47.08' S	42° 27.32' W	4721	RMT	profile end	
PS77/97-1	03.01.2011	15:36	64° 46.94' S	42° 27.36' W	4721	RMT	on deck	
PS77/97-2	03.01.2011	16:10	64° 48.92' S	42° 29.24' W	4719	CTD/RO	in the water	
PS77/97-2	03.01.2011	17:43	64° 48.83' S	42° 29.53' W	4718	CTD/RO	on ground/max depth	EL31 4737m
PS77/97-2	03.01.2011	19:21	64° 48.83' S	42° 29.29' W	4719	CTD/RO	on deck	
PS77/98-1	03.01.2011	21:42	64° 42.79' S	43° 19.76' W	4671	CTD/RO	in the water	
PS77/98-1	03.01.2011	23:14	64° 42.81' S	43° 19.78' W	4679	CTD/RO	on ground/max depth	EL31 4686m

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/98-1	04.01.2011	00:45	64° 42.80' S	43° 19.75' W	4671	CTD/RO	on deck	
PS77/99-1	04.01.2011	03:12	64° 36.82' S	44° 10.67' W	4623	CTD/RO	in the water	
PS77/99-1	04.01.2011	04:42	64° 36.90' S	44° 10.99' W	4622	CTD/RO	on ground/max depth	EL31 4635m
PS77/99-1	04.01.2011	06:11	64° 36.91' S	44° 10.74' W	4622	CTD/RO	on deck	
PS77/100-1	04.01.2011	08:34	64° 29.98' S	45° 0.04' W	4487	CTD/RO	in the water	
PS77/100-1	04.01.2011	10:00	64° 30.02' S	44° 59.72' W	4485	CTD/RO	on ground/max depth	EL31 4495m
PS77/100-1	04.01.2011	11:37	64° 30.02' S	44° 59.97' W	4485	CTD/RO	on deck	
PS77/100-2	04.01.2011	11:40	64° 30.02' S	45° 0.01' W	4485	NFLOAT	in the water	Float #35
PS77/101-1	04.01.2011	13:43	64° 25.23' S	45° 42.56' W	0	MOOR	release from helicopter	AWI217-3 R
PS77/101-1	04.01.2011	13:52	64° 24.99' S	45° 45.93' W	0	MOOR	at surface	observed from Helicopter
PS77/101-1	04.01.2011	14:27	64° 23.70' S	45° 52.00' W	4466	MOOR	on deck	Top floatation
PS77/101-1	04.01.2011	15:30	64° 23.99' S	45° 51.97' W	4465	MOOR	on deck	complete mooring on deck
PS77/101-2	04.01.2011	16:16	64° 26.25' S	45° 50.56' W	4471	MOOR	in the water	AWI217-4 D Top float first
PS77/101-2	04.01.2011	17:25	64° 23.88' S	45° 51.95' W	4466	MOOR	slipped	Anchor slipped
PS77/101-2	04.01.2011	17:57	64° 23.73' S	45° 52.39' W	4465	MOOR	on ground/max depth	POS 64° 24.21' S 45° 51.59' W
PS77/101-3	04.01.2011	18:14	64° 22.96' S	45° 52.67' W	4465	CTD/RO	in the water	
PS77/101-3	04.01.2011	19:41	64° 22.84' S	45° 53.37' W	4463	CTD/RO	on ground/max depth	EL31 4475m
PS77/101-3	04.01.2011	21:06	64° 22.85' S	45° 53.84' W	4461	CTD/RO	on deck	
PS77/102-1	04.01.2011	23:28	64° 18.21' S	46° 40.93' W	4396	CTD/RO	in the water	
PS77/102-1	05.01.2011	00:53	64° 18.24' S	46° 41.08' W	4395	CTD/RO	on ground/max depth	EL31 4405m
PS77/102-1	05.01.2011	02:18	64° 18.10' S	46° 40.78' W	4394	CTD/RO	on deck	
PS77/103-1	05.01.2011	04:39	64° 11.41' S	47° 30.96' W	4210	CTD/RO	in the water	
PS77/103-1	05.01.2011	05:59	64° 11.45' S	47° 31.00' W	4210	CTD/RO	on ground/max depth	EL31 4213m
PS77/103-1	05.01.2011	07:20	64° 11.45' S	47° 31.23' W	4211	CTD/RO	on deck	

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/104-1	05.01.2011	09:30	64° 3.29' S	48° 17.27' W	3998	CTD/RO	in the water	
PS77/104-1	05.01.2011	10:47	64° 3.24' S	48° 17.37' W	3997	CTD/RO	on ground/max depth	EL31 3994m
PS77/104-1	05.01.2011	12:03	64° 3.25' S	48° 17.20' W	3998	CTD/RO	on deck	
PS77/105-1	05.01.2011	14:13	63° 54.28' S	49° 3.32' W	0	MOOR	released	AWI216-3 R
PS77/105-1	05.01.2011	14:49	63° 53.79' S	49° 4.94' W	0	MOOR	at surface	
PS77/105-1	05.01.2011	15:04	63° 54.02' S	49° 4.72' W	3525	MOOR	on deck	Top floatation
PS77/105-1	05.01.2011	15:15	63° 53.92' S	49° 4.74' W	3522	MOOR	on deck	complete mooring on deck
PS77/105-2	05.01.2011	15:27	63° 54.02' S	49° 4.69' W	3526	MOOR	in the water	AWI216-4 D Anchor first
PS77/105-2	05.01.2011	15:54	63° 54.03' S	49° 4.72' W	3526	MOOR	in the water	Top floatation+depl.release
PS77/105-2	05.01.2011	15:57	63° 54.03' S	49° 4.72' W	3526	MOOR	depl. release slipped	
PS77/105-3	05.01.2011	16:17	63° 53.60' S	49° 5.23' W	3510	CTD/RO	in the water	
PS77/105-2	05.01.2011	16:23	63° 53.64' S	49° 5.21' W	3511	MOOR	on ground/max depth	POS 63° 54.06' S 49° 4.80' W
PS77/105-3	05.01.2011	17:33	63° 53.74' S	49° 4.36' W	3517	CTD/RO	on ground/max depth	EL31 3531m
PS77/105-3	05.01.2011	18:53	63° 53.79' S	49° 3.88' W	3522	CTD/RO	on deck	
PS77/106-1	05.01.2011	20:19	63° 52.61' S	49° 31.91' W	3336	CTD/RO	in the water	
PS77/106-1	05.01.2011	21:25	63° 52.75' S	49° 31.81' W	3341	CTD/RO	on ground/max depth	EL31 3323m
PS77/106-1	05.01.2011	22:32	63° 52.86' S	49° 31.38' W	3347	CTD/RO	on deck	
PS77/106-2	05.01.2011	22:36	63° 52.93' S	49° 31.45' W	3348	NFLOAT	in the water	Float #36
PS77/107-1	06.01.2011	00:05	63° 50.97' S	50° 2.11' W	2915	CTD/RO	in the water	
PS77/107-1	06.01.2011	01:15	63° 50.95' S	50° 2.04' W	2915	CTD/RO	on ground/max depth	EL31 2898m
PS77/107-1	06.01.2011	02:17	63° 51.03' S	50° 2.14' W	2914	CTD/RO	on deck	
PS77/108-1	06.01.2011	03:33	63° 47.37' S	50° 26.26' W	2662	CTD/RO	in the water	
PS77/108-1	06.01.2011	04:33	63° 47.61' S	50° 26.41' W	2659	CTD/RO	on ground/max depth	EL31 2639m
PS77/108-1	06.01.2011	05:28	63° 47.75' S	50° 26.34' W	2658	CTD/RO	on deck	
PS77/109-1	06.01.2011	06:38	63° 43.11' S	50° 48.52' W	2562	CTD/RO	in the water	
PS77/109-1	06.01.2011	07:32	63° 43.01' S	50° 48.66' W	2561	CTD/RO	on ground/max depth	EL31 2536m

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/109-1	06.01.2011	08:28	63° 42.97' S	50° 48.73' W	2561	CTD/RO	on deck	
PS77/109-2	06.01.2011	08:29	63° 42.97' S	50° 48.73' W	2561	MOOR	released	AWI207-7 R
PS77/109-2	06.01.2011	08:33	63° 42.96' S	50° 48.79' W	2560	MOOR	at surface	
PS77/109-2	06.01.2011	08:59	63° 42.71' S	50° 50.56' W	2548	MOOR	on deck	Top floatation
PS77/109-2	06.01.2011	10:07	63° 43.21' S	50° 51.13' W	2543	MOOR	on deck	complete mooring on deck
PS77/109-3	06.01.2011	11:03	63° 44.29' S	50° 47.51' W	2573	MOOR	in the water	AWI207-8 D Top float first
PS77/109-3	06.01.2011	12:05	63° 43.07' S	50° 49.91' W	2552	MOOR	slipped	Anchor slipped
PS77/109-3	06.01.2011	12:28	63° 42.97' S	50° 50.62' W	2552	MOOR	on ground/max depth	POS 63° 43.19' S 50° 49.55' W
PS77/110-1	06.01.2011	14:14	63° 37.72' S	51° 20.68' W	2211	CTD/RO	in the water	
PS77/110-1	06.01.2011	15:11	63° 37.72' S	51° 20.86' W	2209	CTD/RO	on ground/max depth	EL31 2181m
PS77/110-1	06.01.2011	16:02	63° 37.65' S	51° 20.89' W	2207	CTD/RO	on deck	
PS77/111-1	06.01.2011	18:20	63° 29.09' S	52° 5.65' W	973	MOOR	released	AWI206-6 R
PS77/111-1	06.01.2011	18:24	63° 29.06' S	52° 5.83' W	973	MOOR	at surface	
PS77/111-1	06.01.2011	18:52	63° 28.82' S	52° 5.64' W	973	MOOR	on deck	Top floatation
PS77/111-1	06.01.2011	19:18	63° 29.03' S	52° 5.80' W	971	MOOR	on deck	complete mooring on deck
PS77/111-2	06.01.2011	20:04	63° 29.74' S	52° 6.71' W	968	MOOR	in the water	AWI206-7 D Top float first
PS77/111-2	06.01.2011	20:37	63° 28.84' S	52° 5.77' W	970	MOOR	slipped	Anchor slipped
PS77/111-2	06.01.2011	20:52	63° 28.44' S	52° 5.50' W	968	MOOR	on ground/max depth	POS 63° 28.93' S 52° 5.87' W
PS77/111-3	06.01.2011	21:15	63° 28.39' S	52° 3.33' W	1001	CTD/RO	in the water	
PS77/111-3	06.01.2011	21:44	63° 28.37' S	52° 3.09' W	1006	CTD/RO	on ground/max depth	EL31 976m
PS77/111-3	06.01.2011	22:08	63° 28.24' S	52° 3.09' W	1004	CTD/RO	on deck	
PS77/112-1	06.01.2011	23:23	63° 33.48' S	51° 43.61' W	1382	CTD/RO	in the water	
PS77/112-1	07.01.2011	00:04	63° 33.48' S	51° 43.47' W	1569	CTD/RO	on ground/max depth	EL31 1543m
PS77/112-1	07.01.2011	00:37	63° 33.45' S	51° 43.47' W	1566	CTD/RO	on deck	
PS77/113-1	07.01.2011	01:33	63° 40.52' S	51° 45.21' W	1787	CTD/RO	in the water	
PS77/113-1	07.01.2011	02:21	63° 40.52' S	51° 45.41' W	1768	CTD/RO	on ground/max depth	EL31 1758m

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/113-1	07.01.2011	03:00	63° 40.56' S	51° 45.08' W	1798	CTD/RO	on deck	
PS77/114-1	07.01.2011	04:05	63° 49.70' S	51° 44.26' W	1676	CTD/RO	in the water	
PS77/114-1	07.01.2011	04:52	63° 49.73' S	51° 44.26' W	1676	CTD/RO	on ground/max depth	EL31 1648m
PS77/114-1	07.01.2011	05:29	63° 49.72' S	51° 44.28' W	1676	CTD/RO	on deck	
PS77/115-1	07.01.2011	06:03	63° 52.89' S	51° 49.02' W	1577	CTD/RO	in the water	
PS77/115-1	07.01.2011	06:35	63° 52.99' S	51° 48.96' W	1574	CTD/RO	on ground/max depth	EL31 1546m
PS77/115-1	07.01.2011	07:19	63° 53.14' S	51° 48.87' W	1571	CTD/RO	on deck	
PS77/116-1	07.01.2011	07:52	63° 56.31' S	51° 54.15' W	1869	CTD/RO	in the water	
PS77/116-1	07.01.2011	08:36	63° 56.31' S	51° 54.02' W	1867	CTD/RO	on ground/max depth	EL31 1848m
PS77/116-1	07.01.2011	09:23	63° 56.31' S	51° 54.25' W	1872	CTD/RO	on deck	
PS77/117-1	07.01.2011	09:58	63° 59.46' S	51° 59.00' W	2098	CTD/RO	in the water	
PS77/117-1	07.01.2011	10:50	63° 59.50' S	51° 59.08' W	2100	CTD/RO	on ground/max depth	EL31 2071m
PS77/117-1	07.01.2011	11:37	63° 59.50' S	51° 58.93' W	2101	CTD/RO	on deck	
PS77/118-1	07.01.2011	12:28	64° 2.09' S	52° 3.58' W	2247	CTD/RO	in the water	
PS77/118-1	07.01.2011	13:22	64° 2.08' S	52° 3.66' W	2245	CTD/RO	on ground/max depth	EL31 2223m
PS77/118-1	07.01.2011	14:14	64° 2.24' S	52° 3.73' W	2258	CTD/RO	on deck	
PS77/119-1	07.01.2011	15:05	64° 5.90' S	52° 17.66' W	2309	CTD/RO	in the water	
PS77/119-1	07.01.2011	16:05	64° 6.12' S	52° 18.19' W	2309	CTD/RO	on ground/max depth	EL31 2290m
PS77/119-1	07.01.2011	16:57	64° 6.22' S	52° 18.25' W	2315	CTD/RO	on deck	
PS77/120-1	07.01.2011	21:44	63° 24.82' S	52° 32.08' W	533	CTD/RO	in the water	
PS77/120-1	07.01.2011	22:14	63° 24.89' S	52° 32.16' W	533	CTD/RO	on ground/max depth	EL31 509m
PS77/120-1	07.01.2011	22:31	63° 24.87' S	52° 32.29' W	533	CTD/RO	on deck	
PS77/121-1	08.01.2011	00:14	63° 18.98' S	53° 3.45' W	458	CTD/RO	in the water	
PS77/121-1	08.01.2011	00:35	63° 18.98' S	53° 3.43' W	458	CTD/RO	on ground/max depth	EL31 436m
PS77/121-1	08.01.2011	00:50	63° 18.97' S	53° 3.56' W	463	CTD/RO	on deck	

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/122-1	08.01.2011	02:53	63° 13.18' S	53° 42.44' W	306	CTD/RO	in the water	
PS77/122-1	08.01.2011	03:06	63° 13.15' S	53° 42.56' W	304	CTD/RO	on ground/max depth	EL31 282m
PS77/122-1	08.01.2011	03:20	63° 13.13' S	53° 42.61' W	303	CTD/RO	on deck	
PS77/123-1	08.01.2011	04:49	63° 8.90' S	54° 9.61' W	260	CTD/RO	in the water	
PS77/123-1	08.01.2011	05:01	63° 8.96' S	54° 9.74' W	260	CTD/RO	on ground/max depth	EL31 239m
PS77/123-1	08.01.2011	05:13	63° 9.01' S	54° 9.72' W	260	CTD/RO	on deck	
PS77/124-1	08.01.2011	20:50	62° 27.04' S	57° 59.44' W	1930	EBS	in the water	
PS77/124-1	08.01.2011	22:05	62° 27.67' S	58° 0.67' W	1910	EBS	on ground/max depth	GE52.2 3005m
PS77/124-1	08.01.2011	22:17	62° 27.80' S	58° 1.08' W	1910	EBS	hoisting	
PS77/124-1	08.01.2011	23:27	62° 27.88' S	58° 1.27' W	1911	EBS	on deck	
PS77/125-1	09.01.2011	09:32	63° 29.66' S	60° 28.16' W	688	RMT	in the water	
PS77/125-1	09.01.2011	09:46	63° 29.89' S	60° 28.89' W	674	RMT	profile start	GE72.1 321m
PS77/125-1	09.01.2011	10:07	63° 30.33' S	60° 30.55' W	562	RMT	profile end	
PS77/125-1	09.01.2011	10:08	63° 30.33' S	60° 30.57' W	561	RMT	on deck	
PS77/125-2	09.01.2011	10:28	63° 30.34' S	60° 30.53' W	561	CTD/RO	in the water	
PS77/125-2	09.01.2011	10:50	63° 30.35' S	60° 30.59' W	558	CTD/RO	on ground/max depth	EL31 537m
PS77/125-2	09.01.2011	11:07	63° 30.37' S	60° 30.62' W	555	CTD/RO	on deck	
PS77/126-1	09.01.2011	13:25	63° 14.29' S	60° 58.11' W	866	RMT	in the water	
PS77/126-1	09.01.2011	13:42	63° 14.66' S	60° 59.11' W	870	RMT	profile start	GE72.1 401m
PS77/126-1	09.01.2011	14:05	63° 15.27' S	61° 0.82' W	862	RMT	profile end	
PS77/126-1	09.01.2011	14:11	63° 15.28' S	61° 0.82' W	861	RMT	on deck	
PS77/126-2	09.01.2011	14:29	63° 14.99' S	61° 0.13' W	864	CTD/RO	in the water	
PS77/126-2	09.01.2011	15:02	63° 15.04' S	60° 59.94' W	851	CTD/RO	on ground/max depth	EL31 833m
PS77/126-2	09.01.2011	15:18	63° 15.07' S	60° 59.86' W	846	CTD/RO	on deck	
PS77/127-1	09.01.2011	17:36	62° 59.49' S	61° 28.28' W	458	RMT	in the water	
PS77/127-1	09.01.2011	17:56	62° 59.70' S	61° 29.73' W	473	RMT	profile start	GE72.1 467m

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/127-1	09.01.2011	18:29	63° 0.56' S	61° 31.74' W	505	RMT	profile end	
PS77/127-1	09.01.2011	18:32	63° 0.50' S	61° 31.58' W	502	RMT	on deck	
PS77/127-2	09.01.2011	18:41	63° 0.28' S	61° 31.00' W	488	CTD/RO	in the water	
PS77/127-2	09.01.2011	19:02	63° 0.31' S	61° 30.93' W	489	CTD/RO	on ground/max depth	EL31 467m
PS77/127-2	09.01.2011	19:11	63° 0.33' S	61° 30.89' W	489	CTD/RO	on deck	
PS77/128-1	09.01.2011	21:25	62° 44.90' S	61° 58.01' W	463	RMT	in the water	
PS77/128-1	09.01.2011	21:44	62° 45.48' S	61° 59.43' W	535	RMT	profile start	GE72.1 494m
PS77/128-1	09.01.2011	22:14	62° 46.26' S	62° 1.73' W	596	RMT	profile end	
PS77/128-1	09.01.2011	22:17	62° 46.28' S	62° 1.78' W	598	RMT	on deck	
PS77/128-2	09.01.2011	22:30	62° 46.21' S	62° 1.30' W	577	CTD/RO	in the water	
PS77/128-2	09.01.2011	22:51	62° 46.30' S	62° 1.40' W	582	CTD/RO	on ground/max depth	EL31 561m
PS77/128-2	09.01.2011	23:02	62° 46.33' S	62° 1.50' W	589	CTD/RO	on deck	
PS77/129-1	10.01.2011	01:22	62° 29.63' S	62° 27.97' W	821	RMT	in the water	
PS77/129-1	10.01.2011	01:37	62° 29.83' S	62° 29.11' W	877	RMT	profile start	GE72.1 416m
PS77/129-1	10.01.2011	02:02	62° 30.22' S	62° 31.18' W	889	RMT	profile end	
PS77/129-1	10.01.2011	02:08	62° 30.27' S	62° 31.41' W	874	RMT	on deck	
PS77/129-2	10.01.2011	02:20	62° 30.22' S	62° 31.26' W	896	CTD/RO	in the water	
PS77/129-2	10.01.2011	02:58	62° 30.23' S	62° 31.42' W	890	CTD/RO	on ground/max depth	EL31 904m
PS77/129-2	10.01.2011	03:15	62° 30.25' S	62° 31.53' W	893	CTD/RO	on deck	
PS77/130-1	10.01.2011	05:38	62° 14.65' S	62° 57.83' W	4725	RMT	in the water	
PS77/130-1	10.01.2011	05:57	62° 14.79' S	62° 59.20' W	4727	RMT	profile start	GE72.1 440m
PS77/130-1	10.01.2011	06:21	62° 14.98' S	63° 1.31' W	4728	RMT	profile end	
PS77/130-1	10.01.2011	06:27	62° 15.00' S	63° 1.59' W	4728	RMT	on deck	
PS77/130-2	10.01.2011	06:41	62° 14.93' S	63° 0.48' W	4728	CTD/RO	in the water	
PS77/130-2	10.01.2011	08:15	62° 15.13' S	63° 0.09' W	4729	CTD/RO	on ground/max depth	EL31 4764m
PS77/130-2	10.01.2011	09:58	62° 15.21' S	62° 59.65' W	4730	CTD/RO	on deck	

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/131-1	10.01.2011	12:28	62° 0.57' S	63° 28.33' W	4009	RMT	in the water	
PS77/131-1	10.01.2011	12:44	62° 0.20' S	63° 29.25' W	3919	RMT	profile start	GE72.1 435m
PS77/131-1	10.01.2011	13:10	61° 59.62' S	63° 31.17' W	3881	RMT	profile end	
PS77/131-1	10.01.2011	13:14	61° 59.56' S	63° 31.35' W	3870	RMT	on deck	
PS77/131-2	10.01.2011	13:29	61° 59.64' S	63° 30.93' W	3883	CTD/RO	in the water	
PS77/131-2	10.01.2011	14:49	61° 59.48' S	63° 31.00' W	3881	CTD/RO	on ground/max depth	EL31 3891m
PS77/131-2	10.01.2011	16:07	61° 59.41' S	63° 30.90' W	3880	CTD/RO	on deck	
PS77/132-1	10.01.2011	18:28	61° 45.65' S	63° 59.14' W	3619	RMT	in the water	
PS77/132-1	10.01.2011	18:44	61° 45.18' S	64° 0.04' W	3640	RMT	profile start	GE72.1 429m
PS77/132-1	10.01.2011	19:10	61° 44.37' S	64° 1.51' W	3567	RMT	profile end	
PS77/132-1	10.01.2011	19:21	61° 44.28' S	64° 1.54' W	3555	RMT	on deck	
PS77/132-2	10.01.2011	19:28	61° 44.28' S	64° 1.45' W	3559	CTD/RO	in the water	
PS77/132-2	10.01.2011	20:38	61° 44.22' S	64° 1.86' W	3549	CTD/RO	on ground/max depth	EL31 3547m
PS77/132-2	10.01.2011	21:53	61° 44.09' S	64° 1.89' W	3548	CTD/RO	on deck	
PS77/133-1	10.01.2011	23:52	61° 30.17' S	64° 25.94' W	3544	RMT	in the water	
PS77/133-1	11.01.2011	00:11	61° 29.96' S	64° 27.31' W	3488	RMT	profile start	GE72.1 423m
PS77/133-1	11.01.2011	00:36	61° 29.75' S	64° 29.35' W	3542	RMT	profile end	
PS77/133-1	11.01.2011	00:40	61° 29.72' S	64° 29.51' W	3545	RMT	on deck	
PS77/133-2	11.01.2011	00:49	61° 29.69' S	64° 29.49' W	3547	CTD/RO	in the water	
PS77/133-2	11.01.2011	02:05	61° 29.64' S	64° 28.86' W	3529	CTD/RO	on ground/max depth	EL31 3536m
PS77/133-2	11.01.2011	03:13	61° 29.75' S	64° 28.44' W	3508	CTD/RO	on deck	
PS77/133-3	11.01.2011	03:33	61° 29.76' S	64° 28.42' W	3506	EBS	in the water	
PS77/133-3	11.01.2011	05:48	61° 30.66' S	64° 29.90' W	3535	EBS	profile start	GE52.2 5300m
PS77/133-3	11.01.2011	05:58	61° 30.80' S	64° 30.15' W	3544	EBS	profile end	
PS77/133-3	11.01.2011	07:55	61° 31.11' S	64° 30.42' W	3549	EBS	on deck	

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/134-1	11.01.2011	13:00	62° 10.14' S	65° 25.62' W	3854	RMT	in the water	
PS77/134-1	11.01.2011	13:16	62° 10.20' S	65° 26.36' W	3840	RMT	profile start	GE72.1 360m
PS77/134-1	11.01.2011	13:37	62° 10.22' S	65° 27.32' W	3831	RMT	profile end	
PS77/134-1	11.01.2011	13:42	62° 10.23' S	65° 27.39' W	3830	RMT	on deck	
PS77/134-2	11.01.2011	13:53	62° 10.22' S	65° 27.65' W	3825	CTD/RO	in the water	
PS77/134-2	11.01.2011	15:25	62° 10.12' S	65° 26.59' W	3835	CTD/RO	on ground/max depth	EL31 3853m
PS77/134-2	11.01.2011	16:41	62° 10.34' S	65° 25.48' W	3865	CTD/RO	on deck	
PS77/135-1	11.01.2011	18:38	62° 24.41' S	65° 0.08' W	3804	RMT	in the water	
PS77/135-1	11.01.2011	18:56	62° 24.67' S	65° 1.93' W	3755	RMT	profile start	GE72.1 474m
PS77/135-1	11.01.2011	19:21	62° 25.09' S	65° 4.60' W	3706	RMT	profile end	
PS77/135-1	11.01.2011	19:26	62° 25.16' S	65° 4.86' W	3702	RMT	on deck	
PS77/135-2	11.01.2011	19:38	62° 25.20' S	65° 4.74' W	3712	CTD/RO	in the water	
PS77/135-2	11.01.2011	20:54	62° 25.64' S	65° 5.78' W	3718	CTD/RO	on ground/max depth	EL31 3732m
PS77/135-2	11.01.2011	22:18	62° 26.06' S	65° 7.06' W	3583	CTD/RO	on deck	
PS77/136-1	12.01.2011	00:46	62° 39.05' S	64° 26.61' W	3769	RMT	in the water	
PS77/136-1	12.01.2011	01:01	62° 38.96' S	64° 27.93' W	3728	RMT	profile start	GE72.1 401m
PS77/136-1	12.01.2011	01:25	62° 38.89' S	64° 30.09' W	3658	RMT	profile end	
PS77/136-1	12.01.2011	01:29	62° 38.88' S	64° 30.38' W	3652	RMT	on deck	
PS77/136-2	12.01.2011	01:38	62° 38.87' S	64° 30.58' W	3652	CTD/RO	in the water	
PS77/136-2	12.01.2011	02:52	62° 38.80' S	64° 30.89' W	3654	CTD/RO	on ground/max depth	EL31 3658m
PS77/136-2	12.01.2011	04:05	62° 38.39' S	64° 30.74' W	3679	CTD/RO	on deck	
PS77/137-1	12.01.2011	06:23	62° 53.95' S	64° 0.49' W	3697	RMT	in the water	
PS77/137-1	12.01.2011	06:41	62° 53.48' S	63° 59.04' W	3638	RMT	profile start	GE72.1 470m
PS77/137-1	12.01.2011	07:10	62° 52.75' S	63° 56.66' W	3735	RMT	profile end	
PS77/137-1	12.01.2011	07:17	62° 52.78' S	63° 56.67' W	3736	RMT	on deck	
PS77/137-2	12.01.2011	07:29	62° 52.88' S	63° 57.09' W	3727	CTD/RO	in the water	

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/137-2	12.01.2011	08:41	62° 52.70' S	63° 57.35' W	3718	CTD/RO	on ground/max depth	EL31 3732m
PS77/137-2	12.01.2011	09:49	62° 52.48' S	63° 56.99' W	3726	CTD/RO	on deck	
PS77/138-1	12.01.2011	12:00	63° 8.32' S	63° 29.56' W	508	RMT	in the water	
PS77/138-1	12.01.2011	12:20	63° 7.96' S	63° 28.12' W	432	RMT	profile start	GE72.1 433m
PS77/138-1	12.01.2011	12:45	63° 7.60' S	63° 26.27' W	448	RMT	profile end	
PS77/138-1	12.01.2011	12:50	63° 7.62' S	63° 26.18' W	450	RMT	on deck	
PS77/138-2	12.01.2011	12:59	63° 7.69' S	63° 26.15' W	451	CTD/RO	in the water	
PS77/138-2	12.01.2011	13:15	63° 7.73' S	63° 26.31' W	448	CTD/RO	on ground/max depth	EL31 431m
PS77/138-2	12.01.2011	13:25	63° 7.81' S	63° 26.29' W	449	CTD/RO	on deck	
PS77/139-1	12.01.2011	15:36	63° 22.48' S	62° 59.28' W	324	RMT	in the water	
PS77/139-1	12.01.2011	15:58	63° 22.20' S	62° 57.64' W	342	RMT	profile start	GE72.1 505m
PS77/139-1	12.01.2011	16:30	63° 21.73' S	62° 54.75' W	398	RMT	profile end	
PS77/139-1	12.01.2011	16:35	63° 21.73' S	62° 54.65' W	403	RMT	on deck	
PS77/139-2	12.01.2011	16:47	63° 21.86' S	62° 54.92' W	394	CTD/RO	in the water	
PS77/139-2	12.01.2011	17:05	63° 21.83' S	62° 54.93' W	395	CTD/RO	on ground/max depth	EL31 371m
PS77/139-2	12.01.2011	17:14	63° 21.83' S	62° 54.97' W	394	CTD/RO	on deck	
PS77/140-1	12.01.2011	19:32	63° 37.65' S	62° 30.58' W	320	RMT	in the water	
PS77/140-1	12.01.2011	19:52	63° 37.51' S	62° 28.47' W	315	RMT	profile start	GE72.1 534m
PS77/140-1	12.01.2011	20:22	63° 37.21' S	62° 25.77' W	320	RMT	profile end	
PS77/140-1	12.01.2011	20:28	63° 37.23' S	62° 25.70' W	321	RMT	on deck	
PS77/140-2	12.01.2011	20:38	63° 37.32' S	62° 26.09' W	323	CTD/RO	in the water	
PS77/140-2	12.01.2011	20:53	63° 37.28' S	62° 26.13' W	323	CTD/RO	on ground/max depth	EL31 297m
PS77/140-2	12.01.2011	21:00	63° 37.27' S	62° 26.09' W	321	CTD/RO	on deck	
PS77/141-1	12.01.2011	22:59	63° 49.26' S	62° 3.22' W	343	RMT	in the water	
PS77/141-1	12.01.2011	23:18	63° 49.08' S	62° 1.22' W	358	RMT	profile start	GE72.1 495m

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/141-1	12.01.2011	23:43	63° 48.87' S	61° 58.64' W	372	RMT	profile end	
PS77/141-1	12.01.2011	23:47	63° 48.85' S	61° 58.34' W	372	RMT	on deck	
PS77/141-2	12.01.2011	23:58	63° 48.91' S	61° 58.32' W	371	CTD/RO	in the water	
PS77/141-2	13.01.2011	00:13	63° 48.93' S	61° 58.12' W	365	CTD/RO	on ground/max depth	EL31 349m
PS77/141-2	13.01.2011	00:22	63° 48.93' S	61° 57.97' W	365	CTD/RO	on deck	
PS77/142-1	13.01.2011	14:37	64° 34.03' S	62° 34.82' W	510	RMT	in the water	
PS77/142-1	13.01.2011	14:55	64° 33.64' S	62° 33.28' W	851	RMT	profile start	GE72.1 404m
PS77/142-1	13.01.2011	15:19	64° 33.03' S	62° 30.68' W	826	RMT	profile end	
PS77/142-1	13.01.2011	15:24	64° 32.97' S	62° 30.43' W	836	RMT	on deck	
PS77/142-2	13.01.2011	15:34	64° 32.95' S	62° 30.30' W	833	CTD/RO	in the water	
PS77/142-2	13.01.2011	16:06	64° 32.81' S	62° 29.53' W	812	CTD/RO	on ground/max depth	EL31 796m
PS77/142-2	13.01.2011	16:20	64° 32.81' S	62° 29.44' W	812	CTD/RO	on deck	
PS77/143-1	13.01.2011	18:41	64° 18.79' S	61° 50.14' W	1060	RMT	in the water	
PS77/143-1	13.01.2011	18:56	64° 18.17' S	61° 50.56' W	894	RMT	profile start	GE72.1 403m
PS77/143-1	13.01.2011	19:19	64° 17.13' S	61° 50.96' W	1146	RMT	profile end	
PS77/143-1	13.01.2011	19:24	64° 17.05' S	61° 50.98' W	1130	RMT	on deck	
PS77/143-2	13.01.2011	19:36	64° 17.18' S	61° 50.82' W	1150	CTD/RO	in the water	
PS77/143-2	13.01.2011	20:10	64° 17.10' S	61° 50.85' W	1138	CTD/RO	on ground/max depth	EL31 1120m
PS77/143-2	13.01.2011	20:31	64° 17.15' S	61° 50.75' W	1149	CTD/RO	on deck	
PS77/144-1	14.01.2011	02:27	64° 10.33' S	63° 22.65' W	321	RMT	in the water	
PS77/144-1	14.01.2011	02:45	64° 9.89' S	63° 21.48' W	323	RMT	profile start	402m
PS77/144-1	14.01.2011	03:07	64° 9.25' S	63° 19.69' W	378	RMT	profile end	
PS77/144-1	14.01.2011	03:50	64° 9.42' S	63° 19.96' W	308	RMT	on deck	
PS77/144-2	14.01.2011	03:58	64° 9.41' S	63° 20.01' W	294	CTD/RO	in the water	
PS77/144-2	14.01.2011	04:13	64° 9.37' S	63° 20.10' W	314	CTD/RO	on ground/max depth	EL31 290m
PS77/144-2	14.01.2011	04:19	64° 9.34' S	63° 20.15' W	299	CTD/RO	on deck	

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/145-1	14.01.2011	06:35	63° 56.80' S	63° 56.57' W	436	RMT	in the water	
PS77/145-1	14.01.2011	06:52	63° 56.58' S	63° 55.03' W	436	RMT	profile start	GE52.2 401m
PS77/145-1	14.01.2011	07:13	63° 56.25' S	63° 53.14' W	477	RMT	profile end	
PS77/145-1	14.01.2011	07:17	63° 56.26' S	63° 53.08' W	480	RMT	on deck	
PS77/145-2	14.01.2011	07:28	63° 56.40' S	63° 53.41' W	488	CTD/RO	in the water	
PS77/145-2	14.01.2011	07:47	63° 56.45' S	63° 53.53' W	492	CTD/RO	on ground/max depth	EL31 467m
PS77/145-2	14.01.2011	07:58	63° 56.47' S	63° 53.50' W	490	CTD/RO	on deck	
PS77/146-1	14.01.2011	10:20	63° 43.05' S	64° 29.84' W	361	RMT	in the water	
PS77/146-1	14.01.2011	10:36	63° 42.76' S	64° 28.68' W	358	RMT	profile start	GE52.2 402m
PS77/146-1	14.01.2011	10:59	63° 42.39' S	64° 26.99' W	357	RMT	profile end	
PS77/146-1	14.01.2011	11:02	63° 42.39' S	64° 26.93' W	356	RMT	on deck	
PS77/146-2	14.01.2011	11:14	63° 42.38' S	64° 26.94' W	355	CTD/RO	in the water	
PS77/146-2	14.01.2011	11:28	63° 42.36' S	64° 26.81' W	356	CTD/RO	on ground/max depth	EL31 338m
PS77/146-2	14.01.2011	11:35	63° 42.37' S	64° 26.77' W	355	CTD/RO	on deck	
PS77/147-1	14.01.2011	13:58	63° 29.60' S	65° 0.77' W	2433	RMT	in the water	
PS77/147-1	14.01.2011	14:15	63° 29.07' S	65° 0.55' W	2421	RMT	profile start	GE52.2 400m
PS77/147-1	14.01.2011	14:39	63° 28.10' S	65° 0.40' W	2463	RMT	profile end	
PS77/147-1	14.01.2011	14:44	63° 27.97' S	65° 0.34' W	2446	RMT	on deck	
PS77/147-2	14.01.2011	14:54	63° 28.01' S	65° 0.48' W	2459	CTD/RO	in the water	
PS77/147-2	14.01.2011	16:04	63° 28.07' S	65° 0.54' W	2468	CTD/RO	on ground/max depth	EL31 2454m
PS77/147-2	14.01.2011	16:51	63° 28.03' S	65° 0.28' W	2450	CTD/RO	on deck	
PS77/148-1	14.01.2011	19:05	63° 15.66' S	65° 33.40' W	2797	RMT	in the water	
PS77/148-1	14.01.2011	19:22	63° 15.32' S	65° 32.19' W	2793	RMT	profile start	GE52.2 404m
PS77/148-1	14.01.2011	19:46	63° 14.78' S	65° 30.30' W	2792	RMT	profile end	
PS77/148-1	14.01.2011	19:50	63° 14.77' S	65° 30.18' W	2791	RMT	on deck	

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/148-2	14.01.2011	19:59	63° 14.81' S	65° 30.23' W	2790	CTD/RO	in the water	
PS77/148-2	14.01.2011	20:58	63° 14.90' S	65° 30.29' W	2790	CTD/RO	on ground/max depth	EL31 2777m
PS77/148-2	14.01.2011	21:55	63° 14.74' S	65° 30.19' W	2791	CTD/RO	on deck	
PS77/149-1	15.01.2011	00:18	63° 1.72' S	66° 5.72' W	3300	RMT	in the water	
PS77/149-1	15.01.2011	00:32	63° 1.50' S	66° 4.73' W	3313	RMT	profile start	GE52.2 403m
PS77/149-1	15.01.2011	00:57	63° 1.09' S	66° 3.11' W	3325	RMT	profile end	
PS77/149-1	15.01.2011	01:00	63° 1.06' S	66° 3.01' W	3325	RMT	on deck	
PS77/149-2	15.01.2011	01:09	63° 1.08' S	66° 3.02' W	3325	CTD/RO	in the water	
PS77/149-2	15.01.2011	02:26	63° 1.16' S	66° 3.06' W	3325	CTD/RO	on ground/max depth	EL31 3321m
PS77/149-2	15.01.2011	03:30	63° 1.11' S	66° 2.78' W	3325	CTD/RO	on deck	
PS77/150-1	15.01.2011	05:50	62° 47.66' S	66° 36.84' W	3450	RMT	in the water	
PS77/150-1	15.01.2011	06:05	62° 47.20' S	66° 35.52' W	3451	RMT	profile start	GE52.2 401m
PS77/150-1	15.01.2011	06:27	62° 46.43' S	66° 33.25' W	3466	RMT	profile end	
PS77/150-1	15.01.2011	06:30	62° 46.38' S	66° 33.10' W	3466	RMT	on deck	
PS77/150-2	15.01.2011	06:40	62° 46.39' S	66° 32.96' W	3466	CTD/RO	in the water	
PS77/150-2	15.01.2011	07:50	62° 45.66' S	66° 31.28' W	3470	CTD/RO	on ground/max depth	EL31 3488m
PS77/150-2	15.01.2011	08:57	62° 44.90' S	66° 29.67' W	3478	CTD/RO	on deck	
PS77/151-1	15.01.2011	11:19	62° 33.36' S	67° 6.11' W	3677	EBS	in the water	
PS77/151-1	15.01.2011	13:41	62° 32.34' S	67° 4.40' W	3704	EBS	profile start	GE52.2 5503m
PS77/151-1	15.01.2011	13:50	62° 32.23' S	67° 4.19' W	3705	EBS	profile end	
PS77/151-1	15.01.2011	15:48	62° 32.25' S	67° 3.05' W	3704	EBS	on deck	
PS77/151-2	15.01.2011	16:07	62° 32.73' S	67° 3.41' W	3701	CTD/RO	in the water	
PS77/151-2	15.01.2011	17:26	62° 32.43' S	67° 3.12' W	3703	CTD/RO	on ground/max depth	EL31 3709m
PS77/151-2	15.01.2011	18:40	62° 32.48' S	67° 2.33' W	3701	CTD/RO	on deck	
PS77/151-3	15.01.2011	18:52	62° 32.40' S	67° 2.11' W	3701	RMT	in the water	
PS77/151-3	15.01.2011	19:08	62° 31.78' S	67° 1.45' W	3700	RMT	profile start	GE52.2 401m

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/151-3	15.01.2011	19:31	62° 30.78' S	67° 0.47' W	3591	RMT	profile end	
PS77/151-3	15.01.2011	19:35	62° 30.72' S	67° 0.38' W	3569	RMT	on deck	
PS77/152-1	16.01.2011	01:33	63° 10.73' S	68° 15.84' W	3735	RMT	in the water	
PS77/152-1	16.01.2011	01:48	63° 10.47' S	68° 14.82' W	3761	RMT	profile start	GE52.2 400m
PS77/152-1	16.01.2011	02:10	63° 10.05' S	68° 13.12' W	3800	RMT	profile end	
PS77/152-1	16.01.2011	02:15	63° 9.98' S	68° 12.85' W	3805	RMT	on deck	
PS77/152-2	16.01.2011	02:23	63° 9.98' S	68° 12.77' W	3806	CTD/RO	in the water	
PS77/152-2	16.01.2011	03:42	63° 9.65' S	68° 12.64' W	3822	CTD/RO	on ground/max depth	EL31 3835m
PS77/152-2	16.01.2011	05:00	63° 9.65' S	68° 12.09' W	3829	CTD/RO	on deck	
PS77/153-1	16.01.2011	07:16	63° 23.83' S	67° 44.05' W	3547	RMT	in the water	
PS77/153-1	16.01.2011	07:31	63° 23.53' S	67° 42.88' W	3559	RMT	profile start	GE52.2 400m
PS77/153-1	16.01.2011	07:54	63° 23.00' S	67° 40.93' W	3621	RMT	profile end	
PS77/153-1	16.01.2011	07:58	63° 22.98' S	67° 40.79' W	3624	RMT	on deck	
PS77/153-2	16.01.2011	08:09	63° 22.99' S	67° 40.81' W	3622	CTD/RO	in the water	
PS77/153-2	16.01.2011	09:21	63° 22.97' S	67° 41.11' W	3622	CTD/RO	on ground/max depth	EL31 2635m
PS77/153-2	16.01.2011	10:34	63° 23.05' S	67° 40.89' W	3616	CTD/RO	on deck	
PS77/154-1	16.01.2011	12:48	63° 38.33' S	67° 11.74' W	3375	RMT	in the water	
PS77/154-1	16.01.2011	13:03	63° 38.04' S	67° 10.31' W	3378	RMT	profile start	GE52.2 401m
PS77/154-1	16.01.2011	13:25	63° 37.53' S	67° 8.11' W	3380	RMT	profile end	
PS77/154-1	16.01.2011	13:27	63° 37.50' S	67° 7.97' W	3379	RMT	on deck	
PS77/154-2	16.01.2011	13:37	63° 37.49' S	67° 7.68' W	3378	CTD/RO	in the water	
PS77/154-2	16.01.2011	14:47	63° 37.10' S	67° 6.45' W	3382	CTD/RO	on ground/max depth	EL31 3392m
PS77/154-2	16.01.2011	15:55	63° 36.86' S	67° 5.44' W	3385	CTD/RO	on deck	
PS77/155-1	16.01.2011	18:11	63° 51.14' S	66° 37.77' W	3138	RMT	in the water	
PS77/155-1	16.01.2011	18:25	63° 50.72' S	66° 36.40' W	3199	RMT	profile start	GE52.2 402m

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/155-1	16.01.2011	18:49	63° 50.02' S	66° 33.97' W	3262	RMT	profile end	
PS77/155-1	16.01.2011	18:55	63° 49.92' S	66° 33.64' W	3271	RMT	on deck	
PS77/155-2	16.01.2011	19:02	63° 49.87' S	66° 33.51' W	3275	CTD/RO	in the water	
PS77/155-2	16.01.2011	20:10	63° 49.51' S	66° 33.55' W	3247	CTD/RO	on ground/max depth	EL31 3253m
PS77/155-2	16.01.2011	21:17	63° 49.16' S	66° 33.06' W	3228	CTD/RO	on deck	
PS77/156-1	16.01.2011	23:37	64° 5.60' S	66° 3.76' W	453	RMT	in the water	
PS77/156-1	16.01.2011	23:52	64° 5.08' S	66° 3.33' W	458	RMT	profile start	GE52.2 402m
PS77/156-1	17.01.2011	00:16	64° 4.24' S	66° 2.57' W	462	RMT	profile end	
PS77/156-1	17.01.2011	00:19	64° 4.17' S	66° 2.52' W	460	RMT	on deck	
PS77/156-2	17.01.2011	00:29	64° 4.13' S	66° 2.50' W	460	CTD/RO	in the water	
PS77/156-2	17.01.2011	00:47	64° 4.12' S	66° 2.51' W	460	CTD/RO	on ground/max depth	EL31 443m
PS77/156-2	17.01.2011	01:00	64° 4.14' S	66° 2.53' W	460	CTD/RO	on deck	
PS77/157-1	17.01.2011	03:03	64° 17.17' S	65° 31.03' W	614	RMT	in the water	
PS77/157-1	17.01.2011	03:20	64° 17.63' S	65° 29.97' W	623	RMT	profile start	GE52.2
PS77/157-1	17.01.2011	03:41	64° 18.18' S	65° 28.67' W	598	RMT	profile end	
PS77/157-1	17.01.2011	03:46	64° 18.28' S	65° 28.44' W	595	RMT	on deck	
PS77/157-2	17.01.2011	03:54	64° 18.35' S	65° 28.37' W	594	CTD/RO	in the water	
PS77/157-2	17.01.2011	04:17	64° 18.45' S	65° 28.40' W	594	CTD/RO	on ground/max depth	EL31 574m
PS77/157-2	17.01.2011	04:36	64° 18.52' S	65° 28.48' W	594	CTD/RO	on deck	
PS77/158-1	17.01.2011	06:45	64° 30.66' S	64° 55.87' W	589	RMT	in the water	
PS77/158-1	17.01.2011	07:01	64° 31.17' S	64° 54.76' W	585	RMT	profile start	GE52.2 400m
PS77/158-1	17.01.2011	07:23	64° 31.83' S	64° 53.45' W	582	RMT	profile end	
PS77/158-1	17.01.2011	07:30	64° 31.91' S	64° 53.30' W	582	RMT	on deck	
PS77/158-2	17.01.2011	07:38	64° 31.91' S	64° 53.34' W	582	CTD/RO	in the water	
PS77/158-2	17.01.2011	08:01	64° 31.89' S	64° 53.53' W	580	CTD/RO	on ground/max depth	EL31 561m
PS77/158-2	17.01.2011	08:22	64° 31.89' S	64° 53.72' W	582	CTD/RO	on deck	

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/159-1	17.01.2011	09:48	64° 44.00' S	64° 59.61' W	458	RMT	in the water	
PS77/159-1	17.01.2011	10:04	64° 44.68' S	64° 59.97' W	440	RMT	profile start	GE52.2 402m
PS77/159-1	17.01.2011	10:28	64° 45.63' S	65° 0.14' W	446	RMT	profile end	
PS77/159-1	17.01.2011	10:32	64° 45.73' S	65° 0.14' W	448	RMT	on deck	
PS77/159-2	17.01.2011	10:42	64° 45.72' S	65° 0.11' W	448	CTD/RO	in the water	
PS77/159-2	17.01.2011	11:01	64° 45.73' S	65° 0.26' W	444	CTD/RO	on ground/max depth	EL31 425m
PS77/159-2	17.01.2011	11:10	64° 45.73' S	65° 0.27' W	444	CTD/RO	on deck	
PS77/160-1	17.01.2011	14:28	65° 4.40' S	65° 53.42' W	174	RMT	in the water	
PS77/160-1	17.01.2011	14:39	65° 4.53' S	65° 54.42' W	169	RMT	profile start	GE52.2
PS77/160-1	17.01.2011	14:53	65° 4.72' S	65° 55.78' W	184	RMT	profile end	
PS77/160-1	17.01.2011	14:58	65° 4.76' S	65° 56.10' W	185	RMT	on deck	
PS77/160-2	17.01.2011	15:11	65° 4.75' S	65° 56.17' W	185	CTD/RO	in the water	
PS77/160-2	17.01.2011	15:20	65° 4.75' S	65° 56.20' W	185	CTD/RO	on ground/max depth	EL31 169m
PS77/160-2	17.01.2011	15:26	65° 4.75' S	65° 56.22' W	184	CTD/RO	on deck	
PS77/161-1	17.01.2011	17:43	64° 52.65' S	66° 34.14' W	456	RMT	in the water	
PS77/161-1	17.01.2011	18:00	64° 52.44' S	66° 32.43' W	350	RMT	profile start	GE52.2 401m
PS77/161-1	17.01.2011	18:24	64° 52.11' S	66° 29.85' W	671	RMT	profile end	
PS77/161-1	17.01.2011	18:28	64° 52.09' S	66° 29.61' W	682	RMT	on deck	
PS77/161-2	17.01.2011	18:40	64° 52.11' S	66° 29.49' W	688	CTD/RO	in the water	
PS77/161-2	17.01.2011	19:06	64° 52.10' S	66° 29.30' W	693	CTD/RO	on ground/max depth	EL31 677m
PS77/161-2	17.01.2011	19:20	64° 52.10' S	66° 29.24' W	694	CTD/RO	on deck	
PS77/162-1	17.01.2011	21:40	64° 40.12' S	67° 8.98' W	472	RMT	in the water	
PS77/162-1	17.01.2011	21:56	64° 39.55' S	67° 7.61' W	480	RMT	profile start	GE52.2 401m
PS77/162-1	17.01.2011	22:19	64° 38.90' S	67° 6.12' W	470	RMT	profile end	
PS77/162-1	17.01.2011	22:22	64° 38.84' S	67° 5.99' W	469	RMT	on deck	
PS77/162-2	17.01.2011	22:32	64° 38.82' S	67° 5.89' W	471	CTD/RO	in the water	

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/162-2	17.01.2011	22:50	64° 38.81' S	67° 5.86' W	470	CTD/RO	on ground/max depth	EL31 453m
PS77/162-2	17.01.2011	23:00	64° 38.80' S	67° 5.83' W	471	CTD/RO	on deck	
PS77/163-1	18.01.2011	01:18	64° 27.15' S	67° 43.50' W	1541	RMT	in the water	
PS77/163-1	18.01.2011	01:34	64° 26.58' S	67° 42.79' W	1766	RMT	profile start	GE52.2 401m
PS77/163-1	18.01.2011	01:56	64° 25.75' S	67° 41.68' W	1972	RMT	profile end	
PS77/163-1	18.01.2011	01:58	64° 25.70' S	67° 41.61' W	1990	RMT	on deck	
PS77/163-2	18.01.2011	02:08	64° 25.62' S	67° 41.51' W	2007	CTD/RO	in the water	
PS77/163-2	18.01.2011	03:04	64° 25.27' S	67° 41.00' W	2094	CTD/RO	on ground/max depth	EL31 2123m
PS77/163-2	18.01.2011	03:40	64° 24.95' S	67° 40.51' W	2143	CTD/RO	on deck	
PS77/164-1	18.01.2011	05:54	64° 13.85' S	68° 19.72' W	2725	RMT	in the water	
PS77/164-1	18.01.2011	06:10	64° 13.46' S	68° 18.81' W	2701	RMT	profile start	GE52.2 400m
PS77/164-1	18.01.2011	06:35	64° 12.88' S	68° 17.42' W	2649	RMT	profile end	
PS77/164-1	18.01.2011	06:40	64° 12.88' S	68° 17.46' W	2651	RMT	on deck	
PS77/164-2	18.01.2011	06:46	64° 12.88' S	68° 17.53' W	2656	CTD/RO	in the water	
PS77/164-2	18.01.2011	07:43	64° 13.08' S	68° 18.53' W	2691	CTD/RO	on ground/max depth	EL31 2676m
PS77/164-2	18.01.2011	08:31	64° 13.20' S	68° 19.24' W	2706	CTD/RO	on deck	
PS77/165-1	18.01.2011	10:43	64° 0.27' S	68° 53.01' W	2996	RMT	in the water	
PS77/165-1	18.01.2011	10:57	63° 59.89' S	68° 52.01' W	3006	RMT	profile start	GE52.2 402 m
PS77/165-1	18.01.2011	11:23	63° 59.30' S	68° 49.90' W	3039	RMT	profile end	
PS77/165-1	18.01.2011	11:25	63° 59.28' S	68° 49.84' W	3040	RMT	on deck	
PS77/165-2	18.01.2011	11:32	63° 59.23' S	68° 49.84' W	3042	CTD/RO	in the water	
PS77/165-2	18.01.2011	12:50	63° 58.79' S	68° 49.81' W	3055	CTD/RO	on ground/max depth	EL31 3046m
PS77/165-2	18.01.2011	13:42	63° 58.57' S	68° 49.70' W	3062	CTD/RO	on deck	
PS77/166-1	18.01.2011	16:01	63° 47.20' S	69° 27.31' W	3513	RMT	in the water	
PS77/166-1	18.01.2011	16:17	63° 46.95' S	69° 25.79' W	3495	RMT	profile start	402m
PS77/166-1	18.01.2011	16:40	63° 46.51' S	69° 23.69' W	3469	RMT	profile end	

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/166-1	18.01.2011	16:44	63° 46.46' S	69° 23.49' W	3467	RMT	on deck	
PS77/166-2	18.01.2011	16:51	63° 46.42' S	69° 23.40' W	3466	CTD/RO	in the water	
PS77/166-2	18.01.2011	18:03	63° 45.70' S	69° 22.79' W	3460	CTD/RO	on ground/max depth	EL31 3486m
PS77/166-2	18.01.2011	19:21	63° 45.18' S	69° 22.78' W	3464	CTD/RO	on deck	
PS77/167-1	19.01.2011	00:48	64° 22.18' S	70° 41.23' W	3431	EBS	in the water	
PS77/167-1	19.01.2011	02:59	64° 22.20' S	70° 38.35' W	3419	EBS	profile start	GE52.2 5106m
PS77/167-1	19.01.2011	03:09	64° 22.11' S	70° 37.90' W	3419	EBS	profile end	
PS77/167-1	19.01.2011	05:03	64° 21.90' S	70° 37.73' W	3421	EBS	on deck	
PS77/167-2	19.01.2011	05:20	64° 22.01' S	70° 38.60' W	3420	CTD/RO	in the water	
PS77/167-2	19.01.2011	06:31	64° 21.69' S	70° 37.73' W	3423	CTD/RO	on ground/max depth	EL31 3426m
PS77/167-2	19.01.2011	07:38	64° 21.30' S	70° 37.33' W	3429	CTD/RO	on deck	
PS77/167-3	19.01.2011	07:47	64° 21.19' S	70° 36.92' W	3430	RMT	in the water	
PS77/167-3	19.01.2011	08:03	64° 20.87' S	70° 35.36' W	3425	RMT	profile start	GE52.2 400m
PS77/167-3	19.01.2011	08:28	64° 20.35' S	70° 32.81' W	3410	RMT	profile end	
PS77/167-3	19.01.2011	08:31	64° 20.32' S	70° 32.69' W	3410	RMT	on deck	
PS77/168-1	19.01.2011	10:57	64° 36.03' S	70° 4.93' W	3190	RMT	in the water	
PS77/168-1	19.01.2011	11:13	64° 35.18' S	70° 4.39' W	3189	RMT	profile start	GE52.2 400m
PS77/168-1	19.01.2011	11:37	64° 33.90' S	70° 3.61' W	3203	RMT	profile end	
PS77/168-1	19.01.2011	11:39	64° 33.82' S	70° 3.60' W	3204	RMT	on deck	
PS77/168-2	19.01.2011	12:04	64° 33.33' S	70° 3.50' W	3216	CTD/RO	in the water	
PS77/168-2	19.01.2011	13:26	64° 32.55' S	70° 4.15' W	3220	CTD/RO	on ground/max depth	EL31 3217m
PS77/168-2	19.01.2011	14:22	64° 32.12' S	70° 4.58' W	3222	CTD/RO	on deck	
PS77/169-1	19.01.2011	16:45	64° 47.69' S	69° 31.24' W	2815	RMT	in the water	
PS77/169-1	19.01.2011	17:01	64° 48.14' S	69° 30.23' W	2806	RMT	profile start	GE52.2
PS77/169-1	19.01.2011	17:23	64° 48.85' S	69° 28.70' W	2788	RMT	profile end	
PS77/169-1	19.01.2011	17:28	64° 48.97' S	69° 28.46' W	2784	RMT	on deck	

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/169-2	19.01.2011	17:38	64° 49.06' S	69° 28.36' W	2782	CTD/RO	in the water	
PS77/169-2	19.01.2011	18:40	64° 49.28' S	69° 28.60' W	2783	CTD/RO	on ground/max depth	EL31 2767m
PS77/169-2	19.01.2011	19:30	64° 49.53' S	69° 29.20' W	2787	CTD/RO	on deck	
PS77/170-1	19.01.2011	21:37	65° 1.69' S	68° 54.13' W	2324	RMT	in the water	
PS77/170-1	19.01.2011	21:52	65° 1.19' S	68° 52.91' W	2452	RMT	profile start	GE52.2 401m
PS77/170-1	19.01.2011	22:13	65° 0.53' S	68° 51.38' W	2508	RMT	profile end	
PS77/170-1	19.01.2011	22:16	65° 0.46' S	68° 51.24' W	2507	RMT	on deck	
PS77/170-2	19.01.2011	22:26	65° 0.40' S	68° 51.20' W	2508	CTD/RO	in the water	
PS77/170-2	19.01.2011	23:24	65° 0.30' S	68° 51.32' W	2510	CTD/RO	on ground/max depth	EL31 2494m
PS77/170-2	20.01.2011	00:06	65° 0.29' S	68° 51.29' W	2512	CTD/RO	on deck	
PS77/171-1	20.01.2011	02:17	65° 12.81' S	68° 16.46' W	899	RMT	in the water	
PS77/171-1	20.01.2011	02:33	65° 13.48' S	68° 16.32' W	445	RMT	profile start	GE52.2 403m
PS77/171-1	20.01.2011	02:55	65° 14.49' S	68° 16.26' W	439	RMT	profile end	
PS77/171-1	20.01.2011	03:00	65° 14.65' S	68° 16.27' W	438	RMT	on deck	
PS77/171-2	20.01.2011	03:10	65° 14.71' S	68° 16.32' W	436	CTD/RO	in the water	
PS77/171-2	20.01.2011	03:29	65° 14.85' S	68° 16.39' W	436	CTD/RO	on ground/max depth	EL31 414m
PS77/171-2	20.01.2011	03:38	65° 14.87' S	68° 16.41' W	436	CTD/RO	on deck	
PS77/172-1	20.01.2011	05:45	65° 25.08' S	67° 38.39' W	478	RMT	in the water	
PS77/172-1	20.01.2011	06:01	65° 25.68' S	67° 38.50' W	239	RMT	profile start	GE52.2 401m
PS77/172-1	20.01.2011	06:26	65° 26.72' S	67° 38.68' W	230	RMT	profile end	
PS77/172-1	20.01.2011	06:30	65° 26.84' S	67° 38.70' W	227	RMT	on deck	
PS77/172-2	20.01.2011	06:43	65° 26.85' S	67° 38.65' W	228	CTD/RO	in the water	
PS77/172-2	20.01.2011	06:55	65° 26.80' S	67° 38.60' W	228	CTD/RO	on ground/max depth	EL31 215m
PS77/172-2	20.01.2011	07:03	65° 26.81' S	67° 38.57' W	227	CTD/RO	on deck	
PS77/173-1	20.01.2011	09:09	65° 38.50' S	67° 2.72' W	170	RMT	in the water	
PS77/173-1	20.01.2011	09:19	65° 38.71' S	67° 1.96' W	170	RMT	profile start	GE52.2 271m

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/173-1	20.01.2011	09:34	65° 39.08' S	67° 0.85' W	166	RMT	profile end	
PS77/173-1	20.01.2011	09:39	65° 39.16' S	67° 0.61' W	169	RMT	on deck	
PS77/173-2	20.01.2011	09:48	65° 39.14' S	67° 0.56' W	170	CTD/RO	in the water	
PS77/173-2	20.01.2011	09:56	65° 39.11' S	67° 0.54' W	172	CTD/RO	on ground/max depth	EL31 158m
PS77/173-2	20.01.2011	10:00	65° 39.09' S	67° 0.56' W	171	CTD/RO	on deck	
PS77/174-1	20.01.2011	14:20	66° 11.14' S	68° 6.03' W	426	RMT	in the water	
PS77/174-1	20.01.2011	14:37	66° 11.66' S	68° 7.15' W	434	RMT	profile start	GE52.2 400m
PS77/174-1	20.01.2011	15:01	66° 12.43' S	68° 8.88' W	442	RMT	profile end	
PS77/174-1	20.01.2011	15:05	66° 12.54' S	68° 9.12' W	444	RMT	on deck	
PS77/174-2	20.01.2011	15:15	66° 12.68' S	68° 9.40' W	450	CTD/RO	in the water	
PS77/174-2	20.01.2011	15:31	66° 12.70' S	68° 9.36' W	452	CTD/RO	on ground/max depth	EL31 431m
PS77/174-2	20.01.2011	15:40	66° 12.72' S	68° 9.35' W	452	CTD/RO	on deck	
NaN	21.01.2011	12:00	67° 34.20' S	68° 7.50' W	NaN	NaN	begin supply Rothera	
NaN	22.01.2011	01:00	67° 34.20' S	68° 7.50' W	NaN	NaN	end supply Rothera	
PS77/175-1	22.01.2011	05:58	68° 16.58' S	69° 36.11' W	571	RMT	in the water	
PS77/175-1	22.01.2011	06:16	68° 16.35' S	69° 34.22' W	713	RMT	profile start	GE52.2 399m
PS77/175-1	22.01.2011	06:37	68° 16.01' S	69° 32.01' W	713	RMT	profile end	
PS77/175-1	22.01.2011	06:44	68° 15.95' S	69° 31.65' W	677	RMT	on deck	
PS77/175-2	22.01.2011	06:57	68° 16.01' S	69° 31.80' W	716	CTD/RO	in the water	
PS77/175-2	22.01.2011	07:26	68° 16.15' S	69° 32.20' W	703	CTD/RO	on ground/max depth	EL31 684m
PS77/175-2	22.01.2011	07:39	68° 16.17' S	69° 32.28' W	685	CTD/RO	on deck	
PS77/176-1	22.01.2011	09:50	68° 9.81' S	70° 18.23' W	809	RMT	in the water	
PS77/176-1	22.01.2011	10:07	68° 9.60' S	70° 16.10' W	641	RMT	profile start	GE52.2 401m
PS77/176-1	22.01.2011	10:31	68° 9.35' S	70° 13.15' W	438	RMT	profile end	
PS77/176-1	22.01.2011	10:36	68° 9.34' S	70° 12.91' W	427	RMT	on deck	
PS77/176-2	22.01.2011	10:58	68° 9.35' S	70° 12.49' W	433	CTD/RO	in the water	

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/176-2	22.01.2011	11:18	68° 9.29' S	70° 12.66' W	426	CTD/RO	on ground/max depth	EL31 405m
PS77/176-2	22.01.2011	11:29	68° 9.25' S	70° 12.79' W	423	CTD/RO	on deck	
PS77/177-1	22.01.2011	14:00	67° 59.53' S	71° 3.55' W	795	RMT	in the water	
PS77/177-1	22.01.2011	14:15	67° 59.16' S	71° 2.37' W	763	RMT	profile start	GE52.2 400m
PS77/177-1	22.01.2011	14:39	67° 58.53' S	71° 0.46' W	685	RMT	profile end	
PS77/177-1	22.01.2011	14:42	67° 58.48' S	71° 0.32' W	683	RMT	on deck	
PS77/177-2	22.01.2011	14:50	67° 58.44' S	71° 0.36' W	682	CTD/RO	in the water	
PS77/177-2	22.01.2011	15:08	67° 58.43' S	71° 0.40' W	685	CTD/RO	on ground/max depth	EL31 322m
PS77/177-2	22.01.2011	15:18	67° 58.40' S	71° 0.39' W	342	CTD/RO	on deck	
PS77/178-1	22.01.2011	17:51	67° 47.79' S	71° 49.69' W	344	RMT	in the water	
PS77/178-1	22.01.2011	18:07	67° 47.94' S	71° 48.08' W	348	RMT	profile start	GE52.2 400m
PS77/178-1	22.01.2011	18:29	67° 48.20' S	71° 45.59' W	348	RMT	profile end	
PS77/178-1	22.01.2011	18:33	67° 48.24' S	71° 45.32' W	348	RMT	on deck	
PS77/178-2	22.01.2011	18:42	67° 48.31' S	71° 45.41' W	348	CTD/RO	in the water	
PS77/178-2	22.01.2011	18:54	67° 48.33' S	71° 45.44' W	348	CTD/RO	on ground/max depth	EL31 328m
PS77/178-2	22.01.2011	19:03	67° 48.34' S	71° 45.47' W	347	CTD/RO	on deck	
PS77/179-1	22.01.2011	21:35	67° 37.11' S	72° 32.58' W	378	RMT	in the water	
PS77/179-1	22.01.2011	21:51	67° 37.30' S	72° 30.99' W	369	RMT	profile start	GE52.2 400m
PS77/179-1	22.01.2011	22:16	67° 37.62' S	72° 28.14' W	361	RMT	profile end	
PS77/179-1	22.01.2011	22:21	67° 37.64' S	72° 28.01' W	359	RMT	on deck	
PS77/179-2	22.01.2011	22:29	67° 37.66' S	72° 28.14' W	358	CTD/RO	in the water	
PS77/179-2	22.01.2011	22:44	67° 37.68' S	72° 28.18' W	360	CTD/RO	on ground/max depth	EL31 349m
PS77/179-2	22.01.2011	22:57	67° 37.75' S	72° 28.15' W	358	CTD/RO	on deck	
PS77/180-1	24.01.2011	03:18	67° 26.39' S	73° 18.06' W	378	RMT	in the water	
PS77/180-1	24.01.2011	03:35	67° 26.17' S	73° 16.14' W	372	RMT	profile start	GE52.2 400m
PS77/180-1	24.01.2011	03:58	67° 25.78' S	73° 13.46' W	360	RMT	profile end	

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/180-1	24.01.2011	04:02	67° 25.75' S	73° 13.17' W	358	RMT	on deck	
PS77/180-2	24.01.2011	04:20	67° 25.76' S	73° 13.15' W	357	CTD/RO	in the water	
PS77/180-2	24.01.2011	04:38	67° 25.72' S	73° 13.18' W	357	CTD/RO	on ground/max depth	EL31 343m
PS77/180-2	24.01.2011	04:46	67° 25.70' S	73° 13.24' W	358	CTD/RO	on deck	
PS77/181-1	24.01.2011	07:20	67° 15.18' S	73° 58.63' W	3209	RMT	in the water	
PS77/181-1	24.01.2011	07:35	67° 15.03' S	73° 56.91' W	3294	RMT	profile start	GE52.2 400m
PS77/181-1	24.01.2011	08:00	67° 14.76' S	73° 53.92' W	3312	RMT	profile end	
PS77/181-1	24.01.2011	08:04	67° 14.74' S	73° 53.70' W	3316	RMT	on deck	
PS77/181-2	24.01.2011	08:11	67° 14.78' S	73° 53.81' W	3316	CTD/RO	in the water	
PS77/181-2	24.01.2011	09:17	67° 14.64' S	73° 53.60' W	3315	CTD/RO	on ground/max depth	EL31 3311m
PS77/181-2	24.01.2011	10:22	67° 14.45' S	73° 52.62' W	3317	CTD/RO	on deck	
PS77/182-1	24.01.2011	12:58	67° 4.11' S	74° 40.25' W	2956	RMT	in the water	
PS77/182-1	24.01.2011	13:12	67° 3.82' S	74° 38.84' W	2967	RMT	profile start	GE52.2 400m
PS77/182-1	24.01.2011	13:35	67° 3.33' S	74° 36.64' W	2962	RMT	profile end	
PS77/182-1	24.01.2011	13:38	67° 3.27' S	74° 36.45' W	2962	RMT	on deck	
PS77/182-2	24.01.2011	13:38	67° 3.27' S	74° 36.45' W	2962	CTD/RO	in the water	
PS77/182-2	24.01.2011	13:57	67° 3.23' S	74° 36.34' W	2962	CTD/RO	on ground/max depth	ca. 200m, Fluorometer defect
PS77/182-2	24.01.2011	14:00	67° 3.22' S	74° 36.30' W	2962	CTD/RO	on deck	
PS77/182-2	24.01.2011	14:03	67° 3.21' S	74° 36.27' W	2962	CTD/RO	in the water	
PS77/182-2	24.01.2011	15:10	67° 3.02' S	74° 36.06' W	2964	CTD/RO	on ground/max depth	EL31 2954m
PS77/182-2	24.01.2011	16:06	67° 2.94' S	74° 36.26' W	2966	CTD/RO	on deck	
PS77/183-1	24.01.2011	18:33	66° 51.65' S	75° 19.11' W	3161	CTD/RO	in the water	
PS77/183-1	24.01.2011	19:44	66° 51.86' S	75° 19.10' W	3153	CTD/RO	on ground/max depth	EL31 3149m
PS77/183-1	24.01.2011	20:54	66° 52.10' S	75° 18.99' W	3147	CTD/RO	on deck	
PS77/183-2	24.01.2011	21:04	66° 51.93' S	75° 19.00' W	3153	RMT	in the water	
PS77/183-2	24.01.2011	21:20	66° 51.28' S	75° 19.37' W	3179	RMT	profile start	GE52.2 400m

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/183-2	24.01.2011	21:43	66° 50.24' S	75° 19.93' W	3209	RMT	profile end	
PS77/183-2	24.01.2011	21:47	66° 50.13' S	75° 19.97' W	3212	RMT	on deck	
PS77/183-3	24.01.2011	21:56	66° 49.94' S	75° 19.97' W	3216	IFISH	in the water	
PS77/183-3	25.01.2011	00:29	66° 35.83' S	75° 4.06' W	3393	IFISH	on deck	
PS77/184-1	25.01.2011	04:19	66° 6.92' S	74° 35.32' W	3938	EBS	in the water	
PS77/184-1	25.01.2011	06:46	66° 8.76' S	74° 36.00' W	3962	EBS	profile start	GE52.2 5757m
PS77/184-1	25.01.2011	06:56	66° 8.97' S	74° 35.88' W	3969	EBS	profile end	
PS77/184-1	25.01.2011	09:01	66° 10.33' S	74° 34.96' W	3998	EBS	on deck	
PS77/184-2	25.01.2011	09:51	66° 6.12' S	74° 33.51' W	3939	CTD/RO	in the water	
PS77/184-2	25.01.2011	11:07	66° 6.32' S	74° 32.43' W	3930	CTD/RO	on ground/max depth	EL31 3959m
PS77/184-2	25.01.2011	12:23	66° 6.39' S	74° 31.41' W	3918	CTD/RO	on deck	
PS77/184-3	25.01.2011	12:40	66° 6.29' S	74° 33.55' W	3940	RMT	in the water	
PS77/184-3	25.01.2011	12:55	66° 6.81' S	74° 34.23' W	3932	RMT	profile start	GE52.2 400m
PS77/184-3	25.01.2011	13:18	66° 7.62' S	74° 35.34' W	3940	RMT	profile end	
PS77/184-3	25.01.2011	13:23	66° 7.73' S	74° 35.51' W	3943	RMT	on deck	
PS77/184-4	25.01.2011	13:33	66° 7.77' S	74° 35.56' W	3944	CTD/RO	in the water	
PS77/184-4	25.01.2011	13:38	66° 7.76' S	74° 35.53' W	3942	CTD/RO	on ground/max depth	EL31 87m
PS77/184-4	25.01.2011	13:43	66° 7.76' S	74° 35.51' W	3942	CTD/RO	on deck	
PS77/185-1	25.01.2011	16:04	66° 18.39' S	73° 54.12' W	3886	RMT	in the water	
PS77/185-1	25.01.2011	16:20	66° 18.90' S	73° 55.25' W	3874	RMT	profile start	GE52.2 401m
PS77/185-1	25.01.2011	16:44	66° 19.83' S	73° 56.94' W	3873	RMT	profile end	
PS77/185-1	25.01.2011	16:48	66° 19.91' S	73° 57.09' W	3874	RMT	on deck	
PS77/185-2	25.01.2011	16:59	66° 19.88' S	73° 57.06' W	3874	CTD/RO	in the water	
PS77/185-2	25.01.2011	18:21	66° 20.00' S	73° 56.09' W	3865	CTD/RO	on ground/max depth	EL31 3888m
PS77/185-2	25.01.2011	19:35	66° 20.13' S	73° 55.04' W	3862	CTD/RO	on deck	

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/186-1	25.01.2011	21:47	66° 30.63' S	73° 14.15' W	3743	RMT	in the water	
PS77/186-1	25.01.2011	22:03	66° 31.14' S	73° 15.26' W	3693	RMT	profile start	GE52.2 401m
PS77/186-1	25.01.2011	22:26	66° 31.95' S	73° 17.03' W	3678	RMT	profile end	
PS77/186-1	25.01.2011	22:30	66° 32.02' S	73° 17.15' W	3674	RMT	on deck	
PS77/186-2	25.01.2011	22:39	66° 32.03' S	73° 17.08' W	3673	CTD/RO	in the water	
PS77/186-2	25.01.2011	23:54	66° 32.17' S	73° 16.19' W	3659	CTD/RO	on ground/max depth	EL31 3679m
PS77/186-2	26.01.2011	01:04	66° 32.34' S	73° 15.89' W	3660	CTD/RO	on deck	
PS77/187-1	26.01.2011	03:12	66° 41.57' S	72° 32.64' W	3429	RMT	in the water	
PS77/187-1	26.01.2011	03:28	66° 42.04' S	72° 33.66' W	3438	RMT	profile start	GE52.2 400m
PS77/187-1	26.01.2011	03:52	66° 42.68' S	72° 35.58' W	3427	RMT	profile end	
PS77/187-1	26.01.2011	03:56	66° 42.75' S	72° 35.78' W	3422	RMT	on deck	
PS77/187-2	26.01.2011	04:03	66° 42.73' S	72° 35.70' W	3423	CTD/RO	in the water	
PS77/187-2	26.01.2011	05:13	66° 42.58' S	72° 34.81' W	3432	CTD/RO	on ground/max depth	EL31 3437m
PS77/187-2	26.01.2011	06:23	66° 42.69' S	72° 34.52' W	3431	CTD/RO	on deck	
PS77/188-1	26.01.2011	08:37	66° 54.32' S	71° 52.12' W	886	RMT	in the water	
PS77/188-1	26.01.2011	08:53	66° 54.73' S	71° 53.48' W	883	RMT	profile start	GE52.2 400m
PS77/188-1	26.01.2011	09:18	66° 55.25' S	71° 55.89' W	843	RMT	profile end	
PS77/188-1	26.01.2011	09:22	66° 55.27' S	71° 56.03' W	850	RMT	on deck	
PS77/188-2	26.01.2011	09:31	66° 55.22' S	71° 55.89' W	426	CTD/RO	in the water	
PS77/188-2	26.01.2011	09:50	66° 55.26' S	71° 55.71' W	426	CTD/RO	on ground/max depth	EL31 407m
PS77/188-2	26.01.2011	10:07	66° 55.30' S	71° 55.56' W	426	CTD/RO	on deck	
PS77/189-1	26.01.2011	12:21	67° 5.17' S	71° 10.59' W	444	RMT	in the water	
PS77/189-1	26.01.2011	12:37	67° 5.64' S	71° 11.94' W	446	RMT	profile start	GE52.2 400m
PS77/189-1	26.01.2011	13:01	67° 6.41' S	71° 13.94' W	447	RMT	profile end	
PS77/189-1	26.01.2011	13:04	67° 6.48' S	71° 14.13' W	450	RMT	on deck	
PS77/189-2	26.01.2011	13:13	67° 6.52' S	71° 14.21' W	447	CTD/RO	in the water	

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/189-2	26.01.2011	13:32	67° 6.55' S	71° 14.28' W	450	CTD/RO	on ground/max depth	EL31 430m
PS77/189-2	26.01.2011	13:48	67° 6.62' S	71° 14.43' W	449	CTD/RO	on deck	
PS77/190-1	26.01.2011	16:07	67° 16.02' S	70° 27.57' W	566	RMT	in the water	
PS77/190-1	26.01.2011	16:24	67° 16.46' S	70° 29.29' W	559	RMT	profile start	GE52.2 400m
PS77/190-1	26.01.2011	16:46	67° 17.07' S	70° 31.36' W	574	RMT	profile end	
PS77/190-1	26.01.2011	16:51	67° 17.17' S	70° 31.69' W	575	RMT	on deck	
PS77/190-2	26.01.2011	17:01	67° 17.23' S	70° 31.89' W	578	CTD/RO	in the water	
PS77/190-2	26.01.2011	17:25	67° 17.23' S	70° 32.10' W	579	CTD/RO	on ground/max depth	EL31 559m
PS77/190-2	26.01.2011	17:44	67° 17.21' S	70° 32.09' W	579	CTD/RO	on deck	
PS77/191-1	26.01.2011	20:00	67° 26.98' S	69° 45.79' W	180	RMT	in the water	
PS77/191-1	26.01.2011	20:11	67° 27.29' S	69° 46.67' W	175	RMT	profile start	GE52.2 283m
PS77/191-1	26.01.2011	20:28	67° 27.79' S	69° 48.05' W	174	RMT	profile end	
PS77/191-1	26.01.2011	20:32	67° 27.85' S	69° 48.20' W	173	RMT	on deck	
PS77/191-2	26.01.2011	20:44	67° 27.74' S	69° 48.10' W	174	CTD/RO	in the water	
PS77/191-2	26.01.2011	20:52	67° 27.72' S	69° 48.11' W	173	CTD/RO	on ground/max depth	EL31 158m
PS77/191-2	26.01.2011	21:03	67° 27.65' S	69° 48.04' W	174	CTD/RO	on deck	
PS77/192-1	27.01.2011	01:50	66° 43.42' S	69° 15.80' W	264	RMT	in the water	
PS77/192-1	27.01.2011	02:05	66° 44.03' S	69° 16.78' W	237	RMT	profile start	GE52.2 401m
PS77/192-1	27.01.2011	02:28	66° 44.93' S	69° 18.31' W	215	RMT	profile end	
PS77/192-1	27.01.2011	02:31	66° 45.02' S	69° 18.47' W	217	RMT	on deck	
PS77/192-2	27.01.2011	02:39	66° 45.10' S	69° 18.62' W	221	CTD/RO	in the water	
PS77/192-2	27.01.2011	02:49	66° 45.11' S	69° 18.63' W	222	CTD/RO	on ground/max depth	EL31 409m
PS77/192-2	27.01.2011	02:54	66° 45.10' S	69° 18.60' W	224	CTD/RO	on deck	
PS77/193-1	27.01.2011	05:03	66° 32.51' S	69° 54.01' W	481	RMT	in the water	
PS77/193-1	27.01.2011	05:19	66° 32.69' S	69° 55.57' W	492	RMT	profile start	GE52.2 400m
PS77/193-1	27.01.2011	05:41	66° 32.93' S	69° 57.93' W	495	RMT	profile end	

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/193-1	27.01.2011	05:46	66° 32.97' S	69° 58.31' W	494	RMT	on deck	
PS77/193-2	27.01.2011	05:54	66° 32.99' S	69° 58.41' W	494	CTD/RO	in the water	
PS77/193-2	27.01.2011	06:16	66° 33.04' S	69° 58.40' W	493	CTD/RO	on ground/max depth	EL31 477m
PS77/193-2	27.01.2011	06:25	66° 33.10' S	69° 58.48' W	485	CTD/RO	on deck	
PS77/194-1	27.01.2011	08:33	66° 21.08' S	70° 37.05' W	551	RMT	in the water	
PS77/194-1	27.01.2011	08:49	66° 21.55' S	70° 38.34' W	548	RMT	profile start	GE52.2 400m
PS77/194-1	27.01.2011	09:12	66° 22.27' S	70° 40.18' W	566	RMT	profile end	
PS77/194-1	27.01.2011	09:16	66° 22.35' S	70° 40.41' W	569	RMT	on deck	
PS77/194-2	27.01.2011	09:39	66° 22.67' S	70° 41.21' W	572	CTD/RO	in the water	
PS77/194-2	27.01.2011	09:58	66° 22.65' S	70° 41.20' W	573	CTD/RO	on ground/max depth	EL31 557m
PS77/194-2	27.01.2011	10:09	66° 22.64' S	70° 41.21' W	572	CTD/RO	on deck	
PS77/195-1	27.01.2011	12:12	66° 9.54' S	71° 15.28' W	2934	RMT	in the water	
PS77/195-1	27.01.2011	12:28	66° 9.59' S	71° 16.88' W	2969	RMT	profile start	GE52.2 400m
PS77/195-1	27.01.2011	12:51	66° 9.63' S	71° 19.16' W	3013	RMT	profile end	
PS77/195-1	27.01.2011	12:55	66° 9.64' S	71° 19.41' W	3029	RMT	on deck	
PS77/195-2	27.01.2011	13:04	66° 9.65' S	71° 19.46' W	3035	CTD/RO	in the water	
PS77/195-2	27.01.2011	14:07	66° 9.61' S	71° 19.12' W	3011	CTD/RO	on ground/max depth	EL31 3039m
PS77/195-2	27.01.2011	15:06	66° 9.61' S	71° 19.17' W	3014	CTD/RO	on deck	
PS77/196-1	27.01.2011	17:02	65° 58.29' S	71° 55.19' W	3384	RMT	in the water	
PS77/196-1	27.01.2011	17:18	65° 57.84' S	71° 56.66' W	3270	RMT	profile start	GE52.2 401m
PS77/196-1	27.01.2011	17:39	65° 57.29' S	71° 58.62' W	3261	RMT	profile end	
PS77/196-1	27.01.2011	17:44	65° 57.18' S	71° 59.00' W	3255	RMT	on deck	
PS77/196-2	27.01.2011	17:55	65° 57.19' S	71° 59.20' W	3246	CTD/RO	in the water	
PS77/196-2	27.01.2011	19:12	65° 57.69' S	71° 59.67' W	3212	CTD/RO	on ground/max depth	EL31 3226m
PS77/196-2	27.01.2011	20:42	65° 57.87' S	71° 59.90' W	3204	CTD/RO	on deck	

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/197-1	27.01.2011	22:54	65° 45.40' S	72° 38.27' W	3271	RMT	in the water	
PS77/197-1	27.01.2011	23:10	65° 45.55' S	72° 36.11' W	3267	RMT	profile start	GE52.2 400m
PS77/197-1	27.01.2011	23:32	65° 45.81' S	72° 33.34' W	3255	RMT	profile end	
PS77/197-1	27.01.2011	23:35	65° 45.84' S	72° 33.01' W	3255	RMT	on deck	
PS77/197-2	27.01.2011	23:44	65° 45.83' S	72° 32.77' W	3258	CTD/RO	in the water	
PS77/197-2	28.01.2011	00:51	65° 45.78' S	72° 32.10' W	3266	CTD/RO	on ground/max depth	EL31 3263m
PS77/197-2	28.01.2011	01:56	65° 45.93' S	72° 31.72' W	3255	CTD/RO	on deck	
PS77/198-1	28.01.2011	04:22	65° 33.04' S	73° 13.44' W	3544	EBS	in the water	
PS77/198-1	28.01.2011	06:32	65° 34.81' S	73° 12.82' W	3528	EBS	profile start	GE52.2 5200m
PS77/198-1	28.01.2011	06:43	65° 34.99' S	73° 12.57' W	3525	EBS	profile end	
PS77/198-1	28.01.2011	08:40	65° 35.56' S	73° 13.45' W	3526	EBS	on deck	
PS77/198-2	28.01.2011	09:11	65° 33.04' S	73° 13.26' W	3542	CTD/RO	in the water	Polarstern-CTD
PS77/198-2	28.01.2011	10:21	65° 33.08' S	73° 13.07' W	3540	CTD/RO	on ground/max depth	SE32.1 3550m
PS77/198-2	28.01.2011	11:28	65° 33.15' S	73° 12.99' W	3539	CTD/RO	on deck	
PS77/198-3	28.01.2011	11:54	65° 32.34' S	73° 15.29' W	3552	RMT	in the water	
PS77/198-3	28.01.2011	12:10	65° 32.81' S	73° 14.07' W	3549	RMT	profile start	GE52.2 400m
PS77/198-3	28.01.2011	12:34	65° 33.44' S	73° 11.98' W	3531	RMT	profile end	
PS77/198-3	28.01.2011	12:38	65° 33.49' S	73° 11.81' W	3528	RMT	on deck	
PS77/198-4	28.01.2011	12:59	65° 33.17' S	73° 12.99' W	3539	CTD/RO	in the water	
PS77/198-4	28.01.2011	14:13	65° 33.49' S	73° 12.88' W	3534	CTD/RO	on ground/max depth	EL31 3536m
PS77/198-4	28.01.2011	15:55	65° 33.82' S	73° 11.31' W	3523	CTD/RO	on deck	
PS77/199-1	28.01.2011	20:40	64° 58.22' S	71° 56.13' W	3677	RMT	in the water	
PS77/199-1	28.01.2011	20:54	64° 57.57' S	71° 55.39' W	3684	RMT	profile start	GE52.2 402m
PS77/199-1	28.01.2011	21:18	64° 56.49' S	71° 54.20' W	3693	RMT	profile end	

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/199-1	28.01.2011	21:21	64° 56.40' S	71° 54.10' W	3696	RMT	on deck	
PS77/199-2	28.01.2011	21:29	64° 56.33' S	71° 54.08' W	3696	CTD/RO	in the water	
PS77/199-2	28.01.2011	22:43	64° 55.95' S	71° 54.31' W	3698	CTD/RO	on ground/max depth	EL31 3707m
PS77/199-2	28.01.2011	23:53	64° 55.81' S	71° 54.64' W	3701	CTD/RO	on deck	
PS77/200-1	29.01.2011	02:10	65° 11. 20' S	71° 20.75' W	3278	RMT	in the water	
PS77/200-1	29.01.2011	02:25	65° 10.73' S	71° 19.43' W	3275	RMT	profile start	GE52.2 401m
PS77/200-1	29.01.2011	02:47	65° 10.24' S	71° 17.31' W	3282	RMT	profile end	
PS77/200-1	29.01.2011	02:50	65° 10.18' S	71° 17.11' W	3283	RMT	on deck	
PS77/200-2	29.01.2011	02:58	65° 10.12' S	71° 17.10' W	3285	CTD/RO	in the water	
PS77/200-2	29.01.2011	04:11	65° 9.07' S	71° 16.81' W	3308	CTD/RO	on ground/max depth	EL31 3318m
PS77/200-2	29.01.2011	05:52	65° 7.91' S	71° 16.46' W	3330	CTD/RO	on deck	
PS77/201-1	29.01.2011	08:17	65° 23.50' S	70° 43.81' W	3287	RMT	in the water	
PS77/201-1	29.01.2011	08:31	65° 23.31' S	70° 42.46' W	3267	RMT	profile start	GE52.2 400m
PS77/201-1	29.01.2011	08:53	65° 22.98' S	70° 40.41' W	3245	RMT	profile end	
PS77/201-1	29.01.2011	08:57	65° 22.96' S	70° 40.34' W	3244	RMT	on deck	
PS77/201-2	29.01.2011	09:04	65° 23.00' S	70° 40.68' W	3249	CTD/RO	in the water	
PS77/201-2	29.01.2011	10:12	65° 23.00' S	70° 41.48' W	3256	CTD/RO	on ground/max depth	EL31 3251m
PS77/201-2	29.01.2011	11:17	65° 22.99' S	70° 41.83' W	3259	CTD/RO	on deck	
PS77/202-1	29.01.2011	13:30	65° 36.27' S	70° 6.03' W	2643	RMT	in the water	
PS77/202-1	29.01.2011	13:46	65° 35.70' S	70° 4.79' W	2760	RMT	profile start	GE52.2 401m
PS77/202-1	29.01.2011	14:07	65° 34.88' S	70° 3.40' W	2842	RMT	profile end	
PS77/202-1	29.01.2011	14:12	65° 34.81' S	70° 3.25' W	2852	RMT	on deck	
PS77/202-2	29.01.2011	14:21	65° 34.78' S	70° 3.22' W	2858	CTD/RO	in the water	
PS77/202-2	29.01.2011	15:28	65° 34.40' S	70° 3.04' W	2863	CTD/RO	on ground/max depth	EL31 2898m
PS77/202-2	29.01.2011	16:59	65° 33.76' S	70° 2.78' W	2889	CTD/RO	on deck	

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/203-1	29.01.2011	19:24	65° 48.66' S	69° 27.16' W	433	RMT	in the water	
PS77/203-1	29.01.2011	19:40	65° 48.09' S	69° 26.03' W	427	RMT	profile start	GE52.2 401m
PS77/203-1	29.01.2011	20:03	65° 47.23' S	69° 24.43' W	398	RMT	profile end	
PS77/203-1	29.01.2011	20:06	65° 47.18' S	69° 24.35' W	395	RMT	on deck	
PS77/203-2	29.01.2011	20:16	65° 47.20' S	69° 24.44' W	397	CTD/RO	in the water	
PS77/203-2	29.01.2011	20:30	65° 47.18' S	69° 24.51' W	395	CTD/RO	on ground/max depth	EL31 376m
PS77/203-2	29.01.2011	20:44	65° 47.16' S	69° 24.61' W	395	CTD/RO	on deck	
PS77/204-1	29.01.2011	22:54	66° 0.65' S	68° 48.68' W	337	RMT	in the water	
PS77/204-1	29.01.2011	23:10	66° 0.21' S	68° 47.59' W	333	RMT	profile start	GE52.2 401m
PS77/204-1	29.01.2011	23:32	65° 59.49' S	68° 46.12' W	333	RMT	profile end	
PS77/204-1	29.01.2011	23:34	65° 59.47' S	68° 46.07' W	334	RMT	on deck	
PS77/204-2	29.01.2011	23:47	65° 59.50' S	68° 46.07' W	331	CTD/RO	in the water	
PS77/204-2	30.01.2011	00:01	65° 59.48' S	68° 46.02' W	332	CTD/RO	on ground/max depth	EL31 316m
PS77/204-2	30.01.2011	00:12	65° 59.48' S	68° 46.01' W	333	CTD/RO	on deck	
PS77/205-1	30.01.2011	16:50	64° 58.56' S	63° 24.44' W	493	RMT	in the water	
PS77/205-1	30.01.2011	17:06	64° 57.86' S	63° 23.21' W	522	RMT	profile start	EL31 400m
PS77/205-1	30.01.2011	17:27	64° 56.73' S	63° 21.87' W	432	RMT	profile end	
PS77/205-1	30.01.2011	17:31	64° 56.58' S	63° 21.70' W	400	RMT	on deck	
PS77/205-2	30.01.2011	17:53	64° 56.17' S	63° 21.39' W	345	CTD/RO	in the water	Polarstern-CTD
PS77/205-2	30.01.2011	18:08	64° 56.06' S	63° 21.36' W	330	CTD/RO	on ground/max depth	SE32.1 326m
PS77/205-2	30.01.2011	18:16	64° 55.98' S	63° 21.31' W	307	CTD/RO	on deck	
PS77/206-1	01.02.2011	21:10	59° 53.91' S	62° 53.47' W	3791	CTD/RO	in the water	Polarstern-CTD
PS77/206-1	01.02.2011	22:53	59° 53.72' S	62° 53.25' W	3836	CTD/RO	on ground/max depth	SE32.1 3891m
PS77/206-1	02.02.2011	00:05	59° 53.91' S	62° 53.39' W	3776	CTD/RO	on deck	

Station	Date [UTC]	Time [UTC]	Position Lat (GPS)	Position Lon (GPS)	Depth [m]	Gear	Action	Comment
PS77/206-2	02.02.2011	00:10	59° 53.86' S	62° 53.41' W	3804	AFLOAT	in the water	Float #37
PS77/207-1	02.02.2011	10:33	58° 19.93' S	63° 33.06' W	3813	CTD/RO	in the water	Polarstern-CTD
PS77/207-1	02.02.2011	12:03	58° 20.30' S	63° 29.79' W	3533	CTD/RO	on ground/max depth	SE32.1 3564m
PS77/207-1	02.02.2011	13:10	58° 20.62' S	63° 27.95' W	3725	CTD/RO	on deck	
PS77/207-2	02.02.2011	13:18	58° 20.56' S	63° 28.18' W	3816	AFLOAT	in the water	Float #38

Notes

Station list compiled from DShip station book.

Depth [m]: uncorrected depths calculated with sound velocity 1500 m/s from DWS echo sounder. “0” values may occur when DWS is switched off during Posidonia operations.

Gear abbreviations

AFLOAT	Apex Float
BUCKET	Bucket for surface water sampling
CTD/RO	Conductivity-Temperature-Depth / Rosette water sampler
EBS	Epibenthos Sledge
IFISH	Iron-Fish
MOOR	Mooring (recovery)
MOOR	Mooring (deployment)
NaN	Logistics (Neumayer and Rothera)
NFLOAT	Nemo Float
PIES	Pressure Inverted Echo Sounder (recovery)
PIES	Pressure Inverted Echo Sounder (deployment)
RMT	Rectangular Midwater Trawl
TEST	Test deployment of equipment

Comment abbreviations

D	(after mooring name): Deployment of mooring
EL31	Single conductor winch EL31 (and maximal wire length)
SE32.1	Single conductor winch SE32.1 (and maximal wire length)
SE32.2	Hydrographic winch SE32.2 (and maximal wire length)
GE52.2	Friction winch GE52.2 (and maximal wire length)
GE72.1	Friction winch GE72.1 with coaxial cable (and maximal wire length)
(no comment)	OZE CTD/RO from observing oceanography section, AWI, used.
Polarstern-CTD	Polarstern CTD/RO used. All other stations: OZE CTD/RO.
POS	Posidonia (position estimates at ground from post-processed Posidonia data)
R	(after mooring name): Recovery of Mooring
ULS	Upward Looking Sonar

A. 5 POSIDONIA OPERATIONS DURING ANT-XXVII/2

Andreas Macrander, Matthias Monsees, and Gerd Rohardt (AWI)

1. Overview

The underwater acoustic Posidonia system of *Polarstern* was operated for underwater location and tracking of PIES and "standard" moorings; the latter were also released by acoustic commands transmitted via the Posidonia system.

In contrast to a hydrophone lowered over the side of the vessel, the Posidonia system allows a relatively stable two-way communication with acoustic releases and transponders considered the high noise levels produced by *Polarstern*. Furthermore, the arrangement of 4 transducers / receivers allows determining the absolute position of an underwater device via short-baseline navigation.

Polarstern is permanently equipped with a Posidonia array protected from ice by a protective plastic "window" in the ship's bottom (El Naggar et al., 2010). Additionally, an "open" Posidonia array can be lowered through the ship's moon pool. While not suitable for fast sailing speeds and ice, the "open" array may have better acoustic capabilities, not being affected by shadowing and reflections in a chamber in the hull.

During ANT-XXVII/2 it turned out that in some cases the fixed Posidonia device got no contact to the underwater transponder. Further, large scatter in the positions makes the assessment of the actual mooring position uncertain, particularly, as the Posidonia positions usually remain for extended periods in a coherent "cloud" before suddenly "jumping" to another area. Postprocessing of all Posidonia data, combined with current estimates from the vessel-mounted Acoustic Doppler Current Profiler (vmADCP) allows obtaining the most likely position of the moorings in most, but not all cases. However, this manual assessment is too time-consuming to be applied in real time. Normally, the horizontal displacement of the moorings is rather small; hence, the ship's GPS position during deployment will already give a rather accurate position estimate sufficient for future recovery, except in cases with narrow leads and sea-ice coverage.

In this report, Posidonia characteristics of all 53 mooring operations (in the following referred to as "events") during ANT-XXVII/2 are summarized (Table 1).

2. Results and discussion

2.1 Return rate, state of the sea and ice conditions

Generally, Posidonia was operated in a 10 seconds interval, i.e. in optimal conditions, 6 acoustic position fixes of a mooring transponder, and 6 corresponding GPS ship position estimates are obtained per minute. Depending on the acoustic conditions, the actual rate may be lower. Fig. 1 shows the absolute number of ship and transponder position fixes. The smallest return rates were observed in the beginning of the cruise (PIES moorings in the ACC), especially in rough sea conditions. Return rates became significantly better with event #21, when *Polarstern* entered calm areas partially covered with loose sea ice. At the end of the cruise (event # 43 and 48-53), the open array was used, which gave consistently high return rates.

Fig. 2 depicts the return rate in relation to the heave motion of *Polarstern* – return rates (size of the dots in Fig. 2) generally become smaller when ship heave exceeds 4 m. Considering the scatter of the position fixes (colour of the dots in Fig. 2), the best results are obtained by the open array (triangles in Fig. 2). Using the fixed array, normally less than 30% of all transponder fixes are closer than 100 m to the nominal position, whereas the open array achieves values of >60% (the low values of event # 43 can be attributed to a long search phase when the mooring was blocked below an ice flow, which meant considerable displacement with the drifting sea ice, and extremely difficult acoustic communication at nearly horizontal angle).

At 13 moorings, no fixes were obtained. In 7 of these cases, the moorings were not surfacing at all (events # 1, 3, 13, 37, 39), or Posidonia operation was unnecessary as the mooring was released by helicopter (# 45, 46). For the remaining 6 moorings which operated properly but where no fixes were obtained, the reason is unclear (# 12, 14, 27, 28, 29, 44).

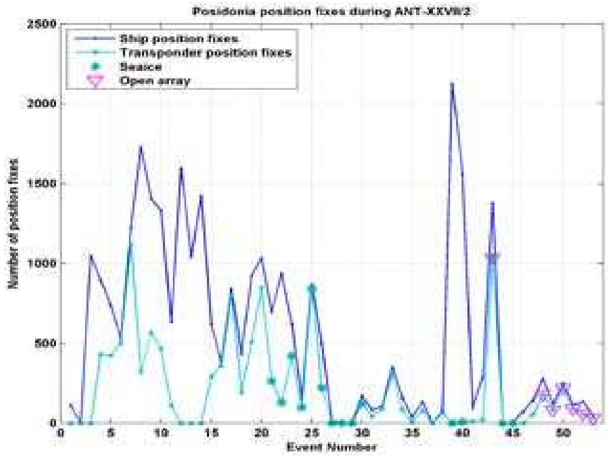

Fig. 1: Absolute number of Ship GPS fixes (blue line) and transponder Posidonia fixes (cyan lines) for all 53 mooring operations. The different values correspond to different duration of the Posidonia operations (360 equals 1 hour). Note that the open array at the end of the cruise (▽ signs) generally gives the best return rates.

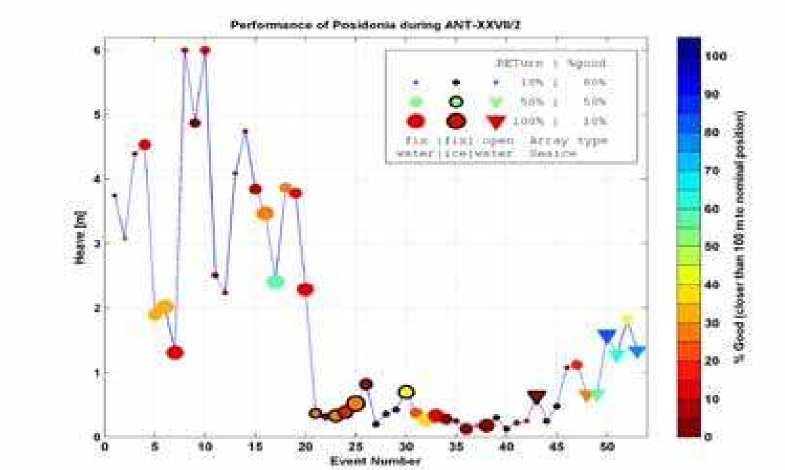

Fig. 2: Performance of Posidonia operations. The blue line shows maximum heave motion of Polarstern. Round dots refer to fixed, triangles to the open array. The bigger symbols indicate better return rate. Blue and green colour refers to little scatter in positions.

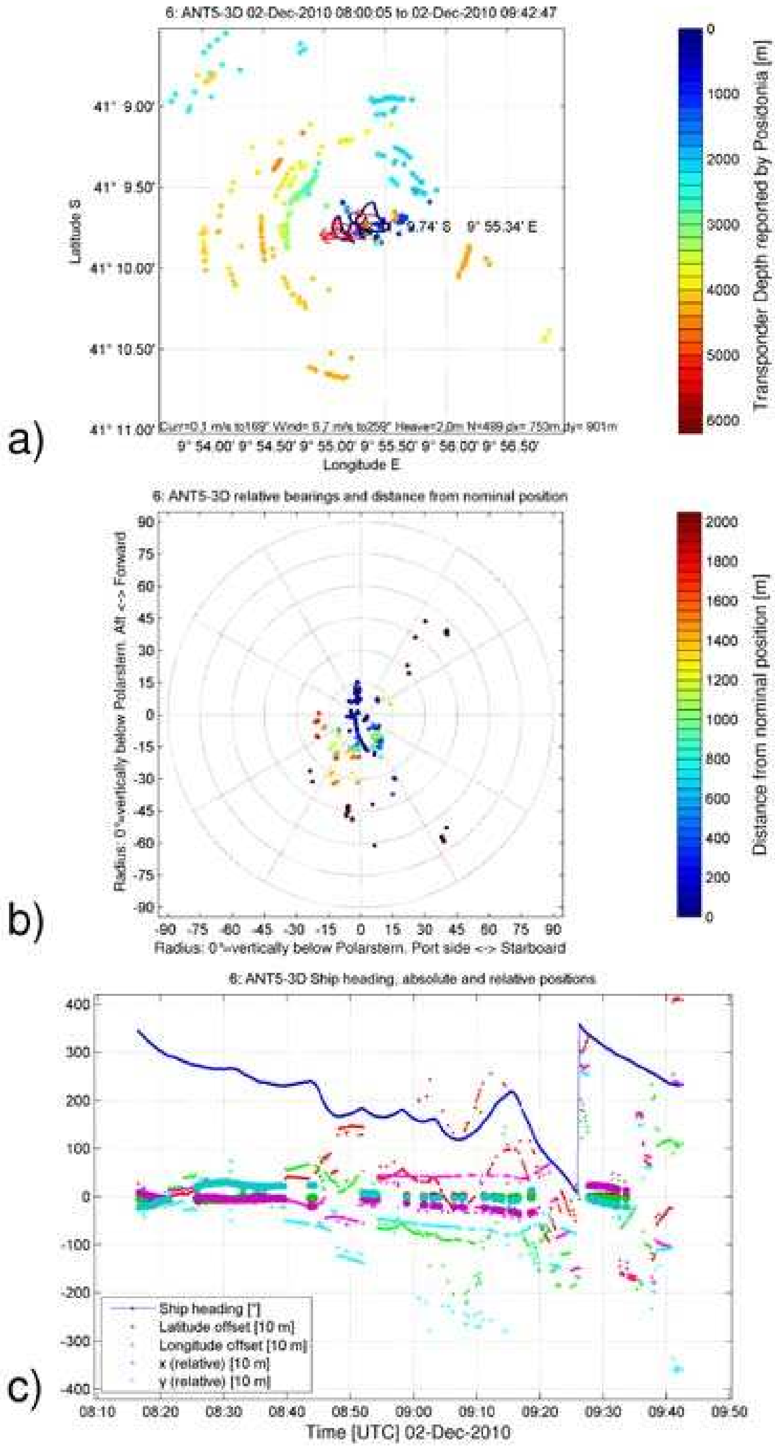

Fig. 3: (a) Map of absolute position fixes. Note the concentric circles around the actual position in the centre. Colour refers to depth of transponder. (b) bearings relative to Polarstern. 0° in the centre means vertically below the ship, 90° at the edge horizontal. Forward is up, starboard to the right etc. Colour refers to deviation from nominal position. (c) Ship heading (blue line) and absolute position errors in latitude (red) and longitude (green). Position relative to ship: x (positive to starboard, magenta), y (positive to forward, cyan). Heavy dots mark correct fixes, small dots indicate false fixes.

2.2 Scatter of position fixes

A major problem of the fixed array are scattered positions, which on the map often appear as concentric circles around the actual position (Fig. 3, and figures in appendix). Additionally, apparently consistent “clouds” of fixes occur, when over several minutes, all fixes are contained within one “cloud”, before suddenly the positions “jump” to another cloud, which appears equally convincing.

An evaluation of the apparent mooring positions in both absolute positions and relative bearings to the ship reveals (example from event #6: Fig. 3) that “clouds” occur when the ship remains at the same position and heading. “Circles” are produced during turns of the ship. In relative bearings, also the circles show up as “clouds” with more or less constant relative bearings (red and orange dots in Fig. 3b). Correct positions are evident as “clouds” in the map, but “lines” in relative bearings (blue dots in Fig. 3b), when the ship is sailing. Plotted over time, false positions are closely following changes of ship heading (Fig. 3c).

In case of doubtful fixes, turning of the vessel would produce concentric circles on the map, with the most likely mooring position in the centre (“nominal position”). A similar behaviour is evident during an “8” shaped cruise track for calibration of the Posidonia device (El Naggar et al., 2010). Also sailing at constant heading directly across the actual position improves the likelihood to obtain correct positions (e.g. at event # 7).

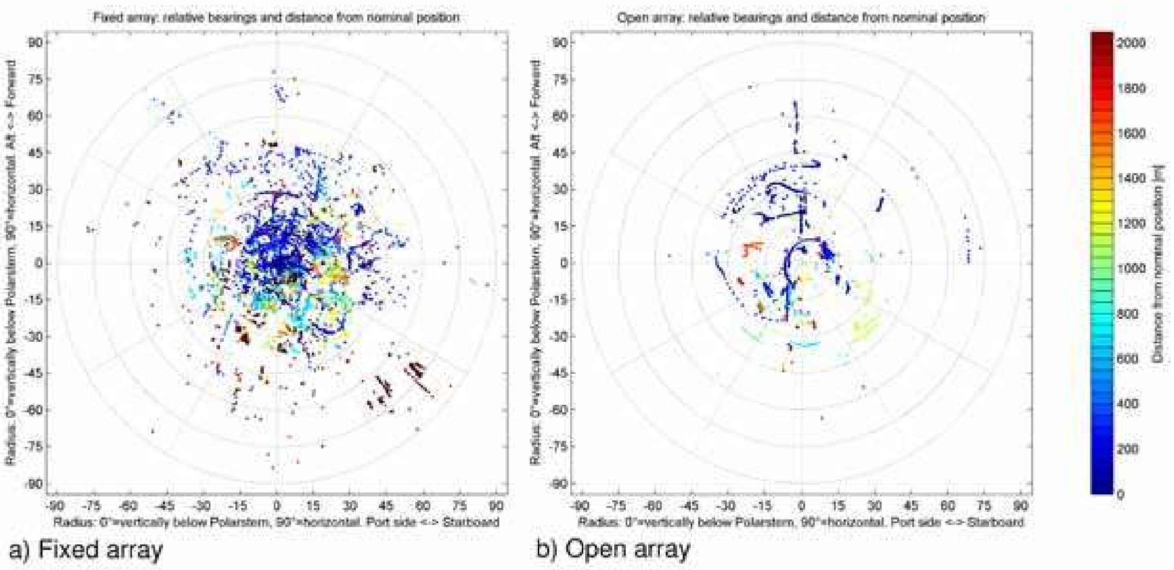

Fig. 4: Bearing in degrees of transponder fixes relative to ship. 0° in the centre refers to vertically below the ship, 90° at the edge to horizontal direction. Starboard is to the right, forward is up. The colour of the dots refers to the position deviation from the nominal mooring position in m. Left: Fixed Posidonia array. Right: Open Posidonia array. The non-blue dots all stem from event #43, where a mooring was blocked under an ice floe.

The relative bearings of the false fixes are not significantly concentrated at specific angles (however, the *difference*s between expected and actual bearing angles show such clustering, see later). Obviously, the combination of different angles of the incoming actual sound signal, possible reflections inside the hull chamber of the fixed system, and other disturbances may produce any (false) relative bearing. An evaluation of all mooring operations only reveals that the fixed array delivers good positions (error < 100 m, dark blue dots in Fig. 4a) mostly only when the mooring transponder is almost vertically below the ship (angle < 15°). The open array delivers good positions even at angles of 30° up to 45° (note the dark blue dots in Fig. 5b; the non-blue dots in all stem from the exceptional event # 43, where a mooring drifting at the underside of a sea ice floe was tracked).

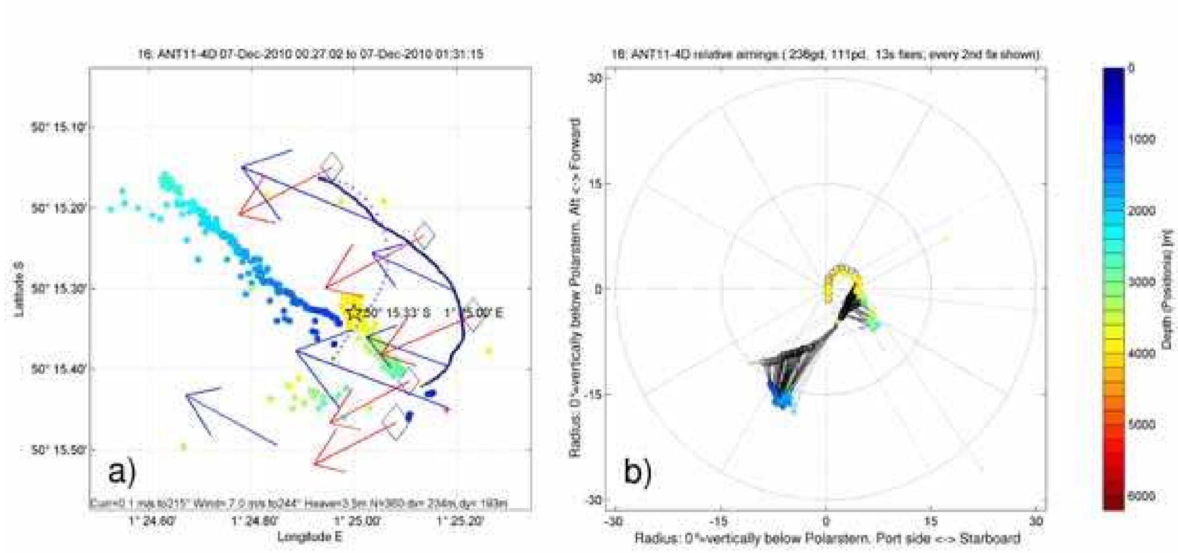

*Fig. 5: Example of Posidonia readings from PIES ANT11-4 deployment. (a) Map of absolute positions. Dark blue circles show ship position, coloured dots transponder position and depth. Blue arrows indicate the current measured by vmADCP between 100 and 200 m; the length of the arrows is equivalent to the horizontal displacement during 1 hour. Red arrows indicate wind direction and speed (1 hour displacement * 0.01). The actual deployment position is marked with a red "+", the final position at the bottom with a black star. During the first part of the descent, Posidonia fixes are unrealistically offset to the north-west. (b) Relative bearings (in °) of the Posidonia fixes (coloured dots), and corrected bearings assuming the mooring to be vertically above the final position (black circles). The false fixes are those dots which are outside the first 15° circle. Correct positions were only retrieved when the mooring was less than 15° away from vertical direction below the ship. See also figures for event #16 in appendix.*

2.3 Depth errors

During deployment or recovery, the changing depth of the transponder can induce a horizontal displacement in the map, when the relative bearing is at a false, but constant angle (example from event #16: Fig. 5). In this example, Posidonia reported the transponder at an angle of 15° / azimuth of 210°. Only after the mooring reached a depth of > 2000 m, the angle was correctly determined at < 10°.

The depth estimates are normally quite reliable provided the ship is more or less above the mooring. In this case the depth estimate depends primarily on travel time, which is less prone to errors than the bearing determination. Depending on the angle, corresponding depth errors are evident in some plots (see appendix, also for event # 16).

2.4 Bearing angle errors

Approximate bearing angle errors can be calculated from the Posidonia fixes and *Polarstern* positions, assuming slant range to be correct, and assuming that the actual position of the transponder is exactly at the – rather well determined – nominal position. This method neglects horizontal displacement due to currents, which is normally much smaller (typically less than 250 m) than the position deviations reported by Posidonia (>1000 m).

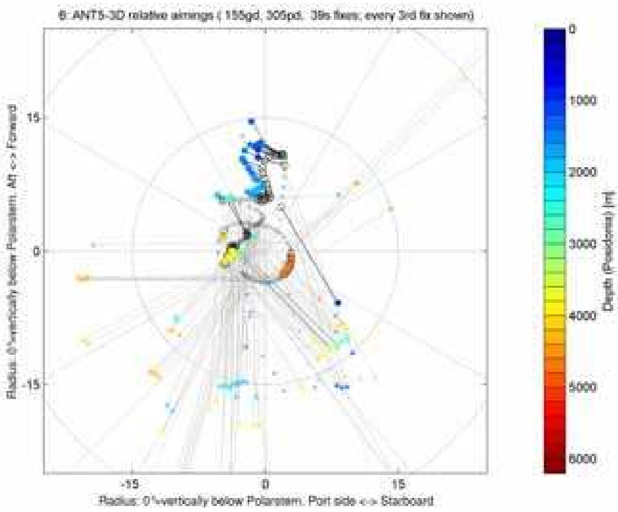

Fig. 6: Bearing angles (in °) relative to Polarstern for PIES ANT5-3 deployment. Vertically below the ship is in the centre, forward is up, starboard to the right etc. Fixes reported by Posidonia shown as coloured dots (colour = depth reported by Posidonia). These are connected with lines to the expected bearing if the mooring were exactly at the nominal position (with same slant range as observed by Posidonia). There are 155 "good deep" fixes (position deviation <250 m, depth >1000 m, bold dots, with expected positions shown by black circles close by), and 305 "poor deep" dots (paler dots). Shallow fixes (depth <1000 m) are shown with small palest dots, as the positioning assumption is least accurate here. See also figures in appendix for event #6.

Fig. 6 shows an example from event #6 (deployment of PIES ANT5-3; see also figures in appendix). Whereas the ship was more or less vertically above the mooring during the entire deployment (angle <15° to vertical, see black circles in Fig. 6), only about one third of all fixes were "good", i.e. closer than 250 m to the nominal position. Two thirds of the fixes showed large errors (Fig. 6 pale dots, connected to expected nominal position with grey lines).

As a further evaluation it was investigated if certain angles of incoming sound signals are projected systematically into certain false bearings. The incoming angle is calculated assuming the mooring to be exactly at the nominal position, which is roughly fulfilled when the mooring is deeper than 1000 m. Further, ship pitch and roll angles are corrected for. The analysis reveals, that indeed sound incoming in specific angles is often mapped to a single (or several) specific different angles (Fig. 7).

However, because of the positioning uncertainty, it is impossible to determine from these data an exact mapping function which would correct recorded bearings into absolute bearings.

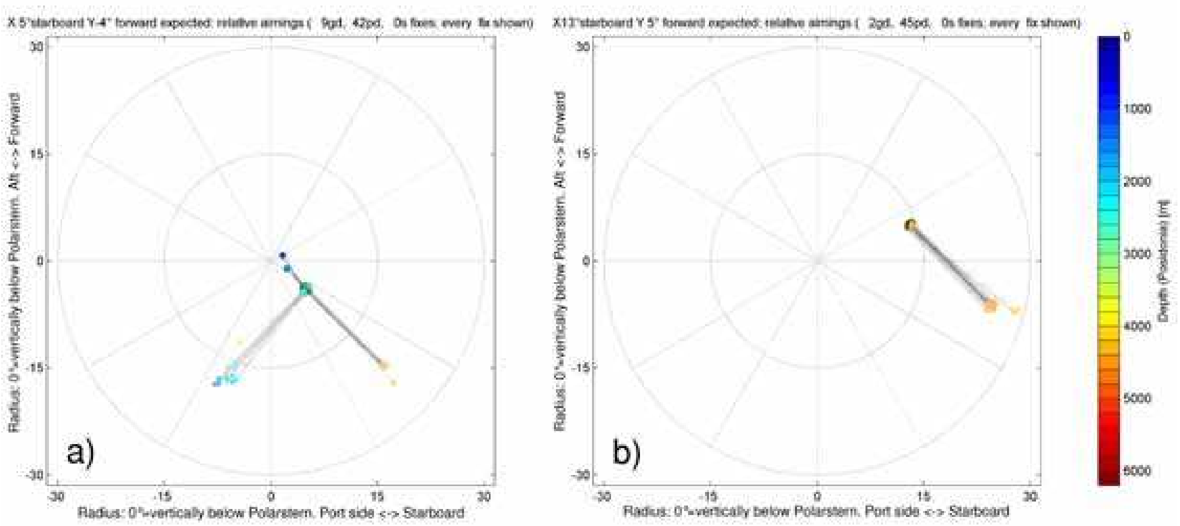

Fig. 7: Two examples of projection of expected aiming angles (black circles, calculated from nominal mooring positions), and actual aiming angles observed by Posidonia (coloured dots, from Posidonia fixes). Figures compiled from all fixed-array Posidonia data, which "belong" to a specific correct bearing. In some expected angles, Posidonia data are widely scattered into different "clouds" (e.g. left panel for 5° starboard, -4° forward), in others most data are reported from a single specific direction (right panel, 13° starboard, 5° forward). Pitch and roll angles have been corrected for.

2.5 Slant range, signal-to-noise ratio, and bearing angle error

Fig. 8 shows the position error as function of slant range. Positions which are likely to be correct have deviations of less than 250 m corresponding to an angle error of max. a few degrees. Many unrealistic fixes, however, are concentrated at angle errors of ≈15°, ≈22°, ≈36° and more. Although the assumption that the mooring is vertically above its nominal position is rather coarse, it appears that the concentration of false fixes at specific angles is caused by the geometry of the hull chamber and the transducers.

The absolute strength of the transponder signal, and the signal-to-noise ratio (SNR) may influence the location performance of the system, too. SNR is displayed by the Abyss software during operation of Posidonia, but apparently it is not stored in the archived data (c.f. Ixsea, 2007). For a qualitative assessment, a linear relation between slant range (which is a rather reliable quantity, being determined just by travel time) and assumed signal strength in dB has been calculated, with values arbitrarily set to 20 dB at 5000 m distance. Figure 6, however, reveals that the percentage of "good" positions is rather constant over the full range of slant ranges from 0 to 6000 m. Lower SNRs which were observed on the Abyss display during the operation of the system were often correlated with poor positions or no positions at all – this may indicate that the actual SNR may be lower than the values resulting from using a simple slant range-to-SNR relation. Possibly, larger angles lead to partial reflection of the incoming sound signal before reaching the Posidonia transducers inside the hull chamber. This effect, however, can not be validated without original SNR values.

3. Conclusions

Evaluation of the Posidonia data from ANT-XXVII/2 reveals that the open moon pool array is clearly superior to the fixed array mounted permanently in a plexiglass covered hull chamber.

The fixed array performs relatively well, when *Polarstern* heave movement is < 4 m, and the mooring transponder is almost vertically below the ship (angle < 15°). The open array copes easily with angles of 30° to 45°, possibly even more.

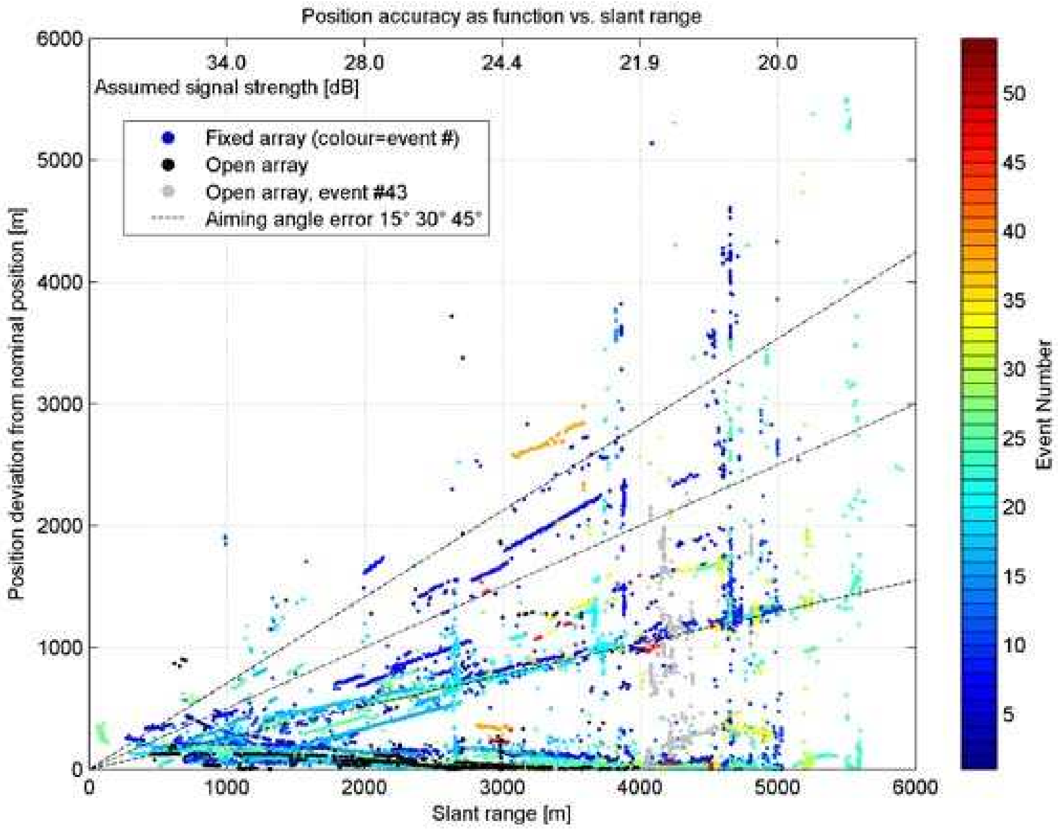

Fig. 8: Slant range vs. deviation from nominal position (y-axis). Colour denotes reported transponder depth. The black dots refer to the – rather good – position fixes of the open array (regardless of transponder depth), the grey dots to event #43, where a mooring drifting far away from its nominal position under an ice floe was tracked. The slanted black lines indicate an aiming error of 15°, 30° and 45°, respectively.

When the ship is turning, the fixed array typically produces concentric “circles” in absolute positions, which are related to constant bearings in relative angles to the ship. In case of the ship not moving, constant bearings produce position “clouds” both in relative and absolute coordinates. When the mooring is descending or ascending, “streaks” in absolute coordinates can be the result of false constant bearings.

There are some indications that specific angles of incoming sound are projected into specific false bearings, but a specific mapping function to correct this effect can not be defined without independent exact position data of the transponder.

Suggested methods to identify false fixes, and retrieve the actual position of a mooring:

- When using the fixed array: - at sea -
- Position the ship almost vertically above the mooring (angle < 10°).
- Turn the ship to get concentric “circles” on the map. The circles are better to distinguish on the screen than stationary “clouds”, and the actual position is always in the centre of the circles.
- Postprocessing of all Posidonia and DShip data as done in this report may give the best possible position estimate of all moorings. At the present stage, the Matlab program used for this task is not capable of real-time processing.

The optimum solution will be, however, to use an open array without possible acoustic reflections etc. – either the moon pool device, which is not capable for fast sailing or ice, or a modified fixed array with transducers outside of the ship’s hull.

Acknowledgements

We thank electronic engineer Helmut Muhle for his support in Posidonia operation, and captain and entire crew of R/V *Polarstern* for all mooring work during ANT-XXVII/2.

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A1 Statistics for all 53 mooring operations during ANT-XXVII/2

Mooring ID Station # running #	**Deploy-ment date/time [UTC]**	**Deployment position (GPS) Depth (DWS)**	**Final position (best estimate from Posidonia)**	**Posidonia Statistics Wind, vmADPC Ship heave, array/ice**	**Remarks (Posidonia) Remarks (Mooring)**
ANT3-2Rf PS77/13-2 1	30.11.2010 released @ 03:44	37° 5.75' S 12° 46.22' E 4795 m	no reception	# 0 (0%) +/-NaN m Wind 9.7 m/s to 42° Curr 0.03 m/s to 196° Heave 3.8 m FW	No reception. PIES likely lost.
ANT3-3D PS77/013-3 2	30.11.2010 slipped @ 06:31	37° 5.84' S 12° 45.23' E 4904 m	37° 05.80‘ S 12° 45.48‘ E 5000 m @07:40	# 0 (NaN%) +/-NaN m Wind 7.8 m/s to 47° Curr 0.03 m/s to 233° Heave 3.1 m FW	No log file saved (!). Posidonia position uncertain. PIES D 1.18 m/s.

Mooring ID Station # running #	Deploy-ment date/time [UTC]	Deployment position (GPS) Depth (DWS)	Final position (best estimate from Posidonia)	Posidonia Statistics Wind, vmADPC Ship heave, array/ice	Remarks (Posidonia) Remarks (Mooring)
ANT4-1Rf PS77/14-2 3	01.12.2010 released @ 07:35	39° 12.62' S 11° 20.39' E 5139 m	no reception	# 0 (0%) +/- NaN m Wind 14.3 m/s to 319° Curr NaN m/s to NaN° Heave 4.4 m FW	No reception. PIES likely lost.
ANT4-2Df PS77/014-3 4	01.12.2010 slipped @ 10:13	39° 12.71' S 11° 19.57' E 5139 m	39° 12.81' S 11° 19.88' E 4438 m @ 11:32	# 432 (48%) +/- 519 m Wind 13.9 m/s to 316° Curr NaN m/s to NaN° Heave 4.5 m FW	Stable positions from de-scent/ ascent, also many concentrically scattered fixes. Releaser failed, recovered @13:14. PIES D 1.25 m/s. R -1.04 m/s.
ANT5-2R PS77/15-2 5	02.12.2010 released @ 05:53	41° 7.39' S 9° 57.76' E 4717 m	41° 7.39' S 9° 57.70' E 4660 m @ 05:53	# 424 (57%) +/- 2332 m Wind 7.4 m/s to 281° Curr NaN m/s to NaN° Heave 1.9 m FW	Good positions @ground exactly at nominal pos. Later scattered fixes only. Leave bottom @06:07. PIES R -1.19 m/s.
ANT5-3D PS77/015-3 6	02.12.2010 slipped @ 08:05	41° 9.77' S 9° 55.31' E 4624 m	41° 9.74' S 9° 55.34' E 4601 m @09:29	# 499 (95%) +/- 1174 m Wind 6.7 m/s to 259° Curr 0.08 m/s to 169° Heave 2.0 m FW	Good positions,+ lots of concentric-ally scattered fixes C-PIES without DCS. D 0.91 m/s.
ANT6-1D PS77/016-1 7	02.12.2010 slipped @ 22:17	42° 58.80' S 8° 30.15' E 3930 m	42° 58.76‘ S 08° 30.00‘ E 3871 m @01:00	#1122 (92%) +/-1201m Wind 11.9 m/s to 181° Curr 0.05 m/s to 198° Heave 1.3 m FW	Large scatter. Consistent positions only during first part of descent, and later when Polarstern sailed across position. Posidonia time axis error: Fixes after 00:00 assigned 24 h ear-lier. PIES D 0.86 m/s.
ANT7-3R PS77/17-1 8	03.12.2010 released @ 14:06	44° 39.51' S 7° 6.38' E 4593 m	44° 38.87' S 7° 6.22' E 4561 m	# 319 (18%) +/- 849 m Wind 14.7 m/s to 90° Curr 0.15 m/s to 18° Heave 6.0 m FW	Consistent positions 0.7 nm north of nominal position. Some random scatter. Pick up position 3 hours later agrees with vmADCP. ET861 trans-ponder might have turned upside down. Leave bot-tom @14:29 C-PIES R -1.28 m/s.

Mooring ID Station # running #	**Deploy-ment date/time [UTC]**	**Deployment position (GPS) Depth (DWS)**	**Final position (best estimate from Posidonia)**	**Posidonia Statistics Wind, vmADPC Ship heave, array/ice**	**Remarks (Posidonia) Remarks (Mooring)**
ANT7-4D PS77/017-2 9	03.12.2010 slipped @ 18:37	44° 39.73' S 7° 5.15' E 4593 m	44° 39.65‘ S 07° 05.25‘ E 4500 m @22:20	# 566 (40%) +/- 938 m Wind 15.8 m/s to 86° Curr 0.14 m/s to 57° Heave 4.9 m FW	Consistent positions + some concentrically scat-tered fixes. PIES D 1.03 m/s.
ANT8-1D PS77/018-1 10	04.12.2010 slipped @ 14:55	46° 12.97' S 5° 40.23' E 4786 m	46° 12.95' S 5° 40.17' E 4760 m @17:40	# 466 (35%) +/- 884 m Wind 14.0 m/s to 46° Curr 0.11 m/s to 261° Heave 6.0 m FW	Consistent positions only on ground; second group of fixes 0.8 nm north unlikely. PIES D 0.95 m/s.
ANT9-2R PS77/19-1 11	05.12.2010 released @ 08:02	47° 39.37' S 4° 15.78' E 4545 m	47° 39.24' S 4° 15.81' E 4545 m	# 110 (17%) +/- 555 m Wind 10.6 m/s to 118° Curr 0.21 m/s to 38° Heave 2.5 m FW	Two different positions on ground 0.15 nm apart. Northern position agrees better with vmADCP and surfacing position. Some random scatter. PIES R -0.91 m/s.
ANT9-3D PS77/019-2 12	05.12.2010 slipped @ 10:20	47° 39.87' S 4° 15.22' E 4541 m	no reception	# 0 (0%) +/- NaN m Wind 9.3 m/s to 146° Curr 0.10 m/s to 59° Heave 2.2 m FW	No reception. PIES D.
ANT10-1Rf PS77/20-1 13	06.12.2010 released @ 01:31	49° 0.69' S 2° 50.07' E 4057 m	no reception	# 0 (0%) +/- NaN m Wind 18.5 m/s to 157° Curr 0.14 m/s to 96° Heave 4.1 m FW	No reception. PIES likely lost. PopUp data until 30.12.2009.
ANT10-2D PS77/020-2 14	06.12.2010 slipped @ 03:58	49° 0.77' S 2° 50.05' E 4056 m	no reception	# 0 (0%) +/- NaN m Wind 16.4 m/s to 140° Curr 0.13 m/s to 120° Heave 4.7 m FW	No reception. PIES D.

Mooring ID Station # running #	**Deploy-ment date/time [UTC]**	**Deployment position (GPS) Depth (DWS)**	**Final position (best estimate from Posidonia)**	**Posidonia Statistics Wind, vmADPC Ship heave, array/ice**	**Remarks (Posidonia) Remarks (Mooring)**
ANT11-3R PS77/21-1 15	06.12.2010 released @ 19:05	50° 15.50' S 1° 26.58' E 3876 m	50° 15.61' S 1° 26.76' E 3822 m	# 292 (47%) +/- 848 m Wind 3.8 m/s to 314° Curr 0.05 m/s to 30° Heave 3.9 m FW	Stable position at ground, during ascent positions inconsistent with later pick-up position. Some scatter. PIES R -0.77 m/s.
ANT11-4D PS77/021-3 16	07.12.2010 slipped @ 00:13	50° 15.45' S 1° 25.18' E 3901 m	50° 15.33' S 1° 25.00' E 3846 m @ 01:22	# 360 (94%) +/- 303 m Wind 7.0 m/s to 244° Curr 0.11 m/s to 215° Heave 3.5 m FW	Persistingly wrong positions, later fixes consistent with slip position and current to NW. PIES D 0.93 m/s.
ANT12-1D PS77/022-1 17	07.12.2010 slipped @ 10:52	51° 25.15' S 0° 0.24' E 2713 m	51° 25.23' S 0° 0.42' E 2654 m @ 11:41	# 802 (95%) +/- 337 m Wind 13.3 m/s to 220° Curr 0.19 m/s to 151° Heave 2.4 m FW	Depth estimates good, lat/lon jumping several times between different positions, range 0.2 nm. PIES D 0.90 m/s.
ANT13-2R PS77/26-1 18	08.12.2010 released @ 09:11	53° 30.97' S 0° 0.40' E 2645 m	53° 31.21' S 0° 0.13' E 2645 m	# 192 (44%) +/- 386 m Wind 16.5 m/s to 107° Curr 0.11 m/s to 130° Heave 3.9 m FW	Relatively good positions, but beginning not before 15 min after release. Some random scatter. PIES R -0.93 m/s.
ANT13-3D PS77/026-2 19	08.12.2010 slipped @ 11:23	53° 31.22' S 0° 0.13' E 2642 m	53° 31.20' S 0° 0.23' E 2585 m @ 12:09	# 510 (55%) +/- 485 m Wind 17.4 m/s to 102° Curr 0.01 m/s to 345° Heave 3.8 m FW	Relatively good positions during descent and at ground. Consistent displacement 0.07 nm to ENE widely agreeing with vmADCP. PIES D 0.94 m/s.
ANT14-1D PS77/034-1 20	10.12.2010 slipped @ 04:15	56° 55.71' S 0° 0.01' W 3673 m	56° 55.60' S 0° 0.10' W 3582 m @ 06:15	# 849 (82%) +/- 959 m Wind 10.6 m/s to 91° Curr 0.07 m/s to 335° Heave 2.3 m FW	Several stable positions; most likely selected in agreement with northward vmADCP current. PIES D 0.83 m/s.

Mooring ID Station # running #	**Deploy-ment date/time [UTC]**	**Deployment position (GPS) Depth (DWS)**	**Final position (best estimate from Posidonia)**	**Posidonia Statistics Wind, vmADPC Ship heave, array/ice**	**Remarks (Posidonia) Remarks (Mooring)**
ANT15-1R PS77/38-1 21	11.12.2010 released @ 06:43	59° 2.32' S 0° 5.29' E 4645 m	59° 2.35' S 0° 5.28' E 4591 m	# 264 (38%) +/- 376 m Wind 13.7 m/s to 324° Curr 0.10 m/s to 150° Heave 0.4 m FI	Stable position fixes, some concent-ric echoes. Drift to NW with wind and ice at surface. PIES R -1.07 m/s.
AWI227-10Rf PS77/039-1 22	11.12.2010 released @ 09:41	59° 3.97' S 0° 4.45' E 4679 m	59° 4.09' S 0° 5.04' E 4678 m @ 10:25	# 128 (14%) +/- 1360 m Wind 13.3 m/s to 351° Curr 0.15 m/s to 147° Heave 0.3 m FI	Some concentric echoes, but most positions stable if at all contact (14% re-turn rate). Release failed. Mooring east of nominal position.
MARU1Rc PS77/040-1 23	11.12.2010 13:40	59° 9.42' S 0° 2.21' W 4742 m	59° 10.25' S 0° 0.39' E 4848 m	# 420 (68%) +/- 1822 m Wind 10.6 m/s to 31° Curr 0.10 m/s to 90° Heave 0.3 m FI	Some concentric echoes, but most positions stable (50% of the time). MARU, release cancelled due to ice.
AWI227-11D PS77/41-1 24	11.12.2010 17:54	59° 3.36' S 0° 6.19' E 4658 m	59° 3.25' S 0° 6.73' E 4202 m @ 18:22	# 99 (63%) +/- 561 m Wind 10.9 m/s to 48° Curr 0.13 m/s to 124° Heave 0.4 m FI	Consistent positions during descent; later position at bottom unli-kely. Estimate based on descent and vmADCP current. Anchor last D 2.50 m/s.
ANT15-2D PS77/042-2 25	11.12.2010 slipped @ 18:51	59° 2.37' S 0° 5.29' E 4647 m	59° 2.39' S 0° 5.52' E 4590 m @ 20:30	# 841 (97%) +/- 1384 m Wind 9.4 m/s to 59° Curr 0.12 m/s to 121° Heave 0.5 m FI	Most positions consistent PIES D 0.93 m/s.
MARU1R PS77/043-2 26	12.12.2010 released @ 02:08	59° 10.05' S 0° 0.17' E 4748 m	59° 10.25' S 0° 0.39' E 4830 m @ 02:08	# 222 (45%) +/- 271 m Wind 9.7 m/s to 85° Curr 0.07 m/s to 119° Heave 0.8 m FI	Most positions consistent. MARU R -1.62 m/s.

Mooring ID Station # running #	**Deploy-ment date/time [UTC]**	**Deployment position (GPS) Depth (DWS)**	**Final position (best estimate from Posidonia)**	**Posidonia Statistics Wind, vmADPC Ship heave, array/ice**	**Remarks (Posidonia) Remarks (Mooring)**
ANT17-1D PS77/053-1 27	14.12.2010 slipped @ 23:45	64° 0.70' S 0° 2.72' W 5201 m	no reception	# 0 (0%) +/- NaN m Wind 18.2 m/s to 206° Curr 0.05 m/s to 220° Heave 0.2 m FI	No reception. PIES D.
AWI229-8R PS77/053-4 28	15.12.2010 released @ 06:36	63° 58.18' S 0° 2.21' W 5209 m	no reception	# 0 (NaN%) +/- NaN m Wind 15.7 m/s to 161° Curr 0.05 m/s to 231° Heave 0.4 m FI	No reception. Mooring R. Partly under ice @07:12 to 11:54. .
AWI229-9D PS77/053-5 29	15.12.2010 slipped @ 16:29	63° 59.56' S 0° 2.65' W 5205 m	no reception	# 0 (NaN%) +/- NaN m Wind 14.6 m/s to 163° Curr 0.08 m/s to 228° Heave 0.4 m FI	No recpetion. Mooring D, anchor first.
MARU2Rc PS77/054-1 30	15.12.2010 17:15	64° 4.17' S 0° 4.72' W 5196 m	64° 5.03' S 0° 5.40' W 5188 m	# 121 (71%) +/- 1137 m Wind 12.3 m/s to 158° Curr 0.17 m/s to 176° Heave 0.7 m FI	Stable positions not before 17 min after first contact. MARU, release cancelled due to ice.
AWI230-6R PS77/058-1 31	16.12.2010 released @ 15:14	66° 1.49' S 0° 3.89' E 3615 m	66° 1.13' S 0° 4.97' E 3580 m @ 15:15	# 42 (51%) +/- 832 m Wind 9.1 m/s to 215° Curr 0.18 m/s to 168° Heave 0.4 m FW	Very few good positions; only three after release. Mooring R -3.17 m/s (but Posidonia depths unreliable)
AWI230-7D PS77/58-2 32	16.12.2010 slipped @ 19:35	66° 1.90' S 0° 3.25' E 3607 m	66° 2.02' S 0° 2.88' E 3400 m @ 19:56	# 89 (85%) +/- 829 m Wind 10.7 m/s to 224° Curr 0.05 m/s to 60° Heave 0.3 m FW	Positions only deeper 1800 m, last plausible position @ 19:56 before landing. Final pos. 0.2 nm SW of slip pos. Anchor last D 2.70 m/s.

Mooring ID Station # running #	Deploy-ment date/time [UTC]	Deployment position (GPS) Depth (DWS)	Final position (best estimate from Posidonia)	Posidonia Statistics Wind, vmADPC Ship heave, array/ice	Remarks (Posidonia) Remarks (Mooring)
AWI231-8R PS77/59-2 33	17.12.2010 released @ 06:21	66° 30.57' S 0° 2.87' W 4579 m	66° 30.79' S 0° 1.74' W 4480 m @ 06:20	# 302 (86%) +/- 1104 m Wind 10.9 m/s to 250° Curr 0.05 m/s to 123° Heave 0.3 m FW	Positions 0.2 nm to NW equally likely. Surfacing position 0.2 nm SW of nominal position. Mooring R -1.67 m/s.
AWI231-9D PS77/59-3 34	17.12.2010 slipped @ 11:22	66° 30.71' S 0° 1.54' W 4538 m	different positions; 4230 m @ 11:58	# 86 (54%) +/- 1244 m Wind 10.2 m/s to 263° Curr 0.08 m/s to 87° Heave 0.3 m FW	Different estimates +/- 0.5 nm, none agreeing with slip position. Anchor last, 1.95 m/s.
AWI232-9R PS77/66-2 35	19.12.2010 released @ 05:40	68° 59.95' S 0° 0.04' W 3414 m	68° 59.95' S 0° 0.11' W	# 6 (15%) +/- 90 m Wind 4.0 m/s to 230° Curr 0.05 m/s to 246° Heave 0.3 m FW	Only very few position estimates during ascend, 0.5 nm east of actual top float surfacing position. Mooring R -1.33 m/s.
AWI232-10D PS77/66-3 36	19.12.2010 slipped @ 09:50	69° 0.11' S 0° 0.11' W 3404 m	different positions, 3100 m	# 80 (61%) +/- 1106 m Wind 4.8 m/s to 228° Curr 0.02 m/s to 253° Heave 0.1 m FW	Scattered positions 0.5 nm NE of slip position, and circular 0.8 nm S, all of them unlikely. Anchor last D 2.07 m/s.
AWI244-1R PS77/68-1 37	23.12.2010 released @ 06:17	68° 59.83' S 6° 56.37' W 2942 m	no reception	# 0 (NaN%) +/- NaN m Wind 4.0 m/s to 46° Curr 0.08 m/s to 289° Heave 0.2 m FW	Mooring, at surface @06:26.
AWI244-2D PS77/68-2 38	23.12.2010 slipped @ 10:04	69° 0.30' S 6° 58.89' W 2950 m	69° 0.46' S 6° 59.42' W 2140 m @ 10:20	# 61 (81%) +/- 1127 m Wind 5.8 m/s to 76° Curr 0.08 m/s to 183° Heave 0.2 m FW	Some positions during descent until 10:20; at ground unlikely estimates 1 nm to NE. Mooring D 2.22 m/s.

Mooring ID Station # running #	**Deploy-ment date/time [UTC]**	**Deployment position (GPS) Depth (DWS)**	**Final position (best estimate from Posidonia)**	**Posidonia Statistics Wind, vmADPC Ship heave, array/ice**	**Remarks (Posidonia) Remarks (Mooring)**
AWI245-1R PS77/78-2 39	27.12.2010 released @ 06:08	69° 3.57' S 17° 26.35' W 4778 m	no reception	# 0 (0%) +/- NaN m Wind 7.0 m/s to 303° Curr 0.02 m/s to 259° Heave 0.3 m FI	Mooring at surface @06:15.
AWI245-2D PS77/78-3 40	27.12.2010 slipped @ 11:06	69° 3.52' S 17° 23.05' W 4778 m	inconsistent pos-itions 0.8 nm ESE	# 9 (1%) +/- 118 m Wind 7.8 m/s to 307° Curr 0.03 m/s to 229° Heave 0.1 m FI	Few and inconsistent position estimates; none during descent. Anchor first.
AWI209-5R PS77/84-1 41	29.12.2010 released @ 09:03	66° 36.73' S 27° 6.88' W 4876 m	inconsistent positions	# 13 (14%) +/- 853 m Wind 8.6 m/s to 349° Curr 0.03 m/s to 245° Heave 0.2 m FW	Few, inconsistent positions 0.8 nm to S and E.
AWI209-6D PS77/84-2 42	29.12.2010 slipped @ 14:06	66° 36.70' S 27° 7.31' W 4877 m	3250 m @ 14:34 during descent	# 21 (7%) +/- 351 m Wind 11.2 m/s to 335° Curr 0.02 m/s to 299° Heave 0.3 m FW	Few, inconsistent concen-trically scattered positions 0.8 nm to NE. Anchor last, 1.93 m/s.
AWI208-5R PS77/91-1 43	01.01.2011 released @ 06:04	65° 36.93' S 36° 24.47' W 4781 m 65° 37.34' S 36° 24.20' W @12:29 on deck	Scattered fixes Open array from 08:36 – 10:22 65° 36.84' S 36° 23.87' W 4050 m or 65° 36.87' S 36° 23.96' W	#1037 (75%) +/- 968 m Wind 6.2 m/s to 248° Curr 0.00 m/s to 80° Heave 0.6 m FI,then OI	Fixed array: Mooring po-sition at bottom unclear; later many concentrically scattered positions. Open array: two positions 0.05 nm apart (depending on Polarstern speed), no scatter. Mooring under ice floe (Posidonia depth @ 4000 m during this time).
AWI208-6D PS77/91-2 44	01.01.2011 slipped @ 17:44	65° 37.03' S 36° 25.24' W 4783 m	no reception	# 0 (NaN%) +/- NaN m Wind 5.6 m/s to 255° Curr 0.05 m/s to 251° Heave 0.3 m FI	Anchor first.

Mooring ID Station # running #	**Deploy-ment date/time [UTC]**	**Deployment position (GPS) Depth (DWS)**	**Final position (best estimate from Posidonia)**	**Posidonia Statistics Wind, vmADPC Ship heave, array/ice**	**Remarks (Posidonia) Remarks (Mooring)**
AWI242-1R PS77/93-1 45	02.01.2011 released @ 07:34	65° 34.34' S* 37° 7.40' W* 4755 m @ 08:38	no reception	# 0 (NaN%) +/- NaN m Wind 4.3 m/s to 325° Curr 0.05 m/s to 49° Heave 0.5 m FI	Helicopter release. *Position @ 08:38 moo-ring on deck.
AWI217-3R PS77/101-1 46	04.01.2011 released @ 13:43	64° 23.70' S* 45° 52.00' W* 4466 m @ 14:27	no reception	# 0 (0%) +/- NaN m Wind 11.0 m/s to 163° Curr 0.04 m/s to 193° Heave 1.1 m FW	Helicopter release *Position @ 14:27 moo-ring on deck.
AWI217-4D PS77/101-2 47	04.01.2011 slipped @ 17:25	64° 23.88' S 45° 51.95' W 4466 m	64° 24.21' S 45° 51.59' W 4383 m @ 17:57	# 53 (38%) +/- 719 m Wind 6.1 m/s to 162° Curr 0.02 m/s to 18° Heave 1.1 m FW	Final position @ 17:57 0.25 nm SE of slip positi-on. Few scatter. Anchor last D 2.28 m/s.
AWI216-3R PS77/105-1 48	05.01.2011 released @ 14:13	63° 54.28' S 49° 3.32' W 3525 m	63° 53.94' S 49° 4.67' W 3480 m @ 14:15	# 181 (66%) +/- 206 m Wind 7.4 m/s to 343° Curr 0.05 m/s to 234° Heave 0.7 m OW	Consistent positions, little scatter. Mooring R -1.61 m/s.
AWI216-4D PS77/105-2 49	05.01.2011 slipped @ 15:57	63° 54.03' S 49° 4.72' W 3526 m	63° 54.06' S 49° 4.80' W 3482 m @ 16:23	# 83 (69%) +/- 453 m Wind 8.2 m/s to 357° Curr 0.08 m/s to 213° Heave 0.7 m OW	Consistent positions, few outliers. Mooring Anchor first D 2.23 m/s.
AWI207-7R PS77/109-2 50	06.01.2011 released @ 08:29	63° 42.97' S 50° 48.73' W 2561 m	63° 42.71' S 50° 50.56' W 2538 m @ 08:28	# 220 (89%) +/- 321 m Wind 8.3 m/s to 141° Curr 0.08 m/s to 323° Heave 1.6 m OW	Good positions, few outliers. Mooring R -1.54 m/s.

Mooring ID Station # running #	Deploy-ment date/time [UTC]	Deployment position (GPS) Depth (DWS)	Final position (best estimate from Posidonia)	Posidonia Statistics Wind, vmADPC Ship heave, array/ice	Remarks (Posidonia) Remarks (Mooring)
AWI207-8D PS77/109-3 51	06.01.2011 slipped @ 12:05	63° 43.07' S 50° 49.91' W 2552 m	63° 43.19' S 50° 49.55' W 2542 m @ 12:24	# 91 (78%) +/- 452 m Wind 10.0 m/s to 144° Curr 0.06 m/s to 260° Heave 1.3 m OW	vmADCP current 0.08 kn to NW. Good positions, few outliers. Mooring Anchor last D 2.23 m/s.
AWI206-6R PS77/111-1 52	06.01.2011 released @ 18:20	63° 29.09' S 52° 5.65' W 973 m	63° 28.76' S 52° 5.70' W 910 m @ 18:20	# 58 (43%) +/- 196 m Wind 5.9 m/s to 199° Curr 0.02 m/s to 327° Heave 1.8 m OW	Good positions, few out-liers. Mooring R -1.21 m/s.
AWI206-7D PS77/111-2 53	06.01.2011 slipped @ 20:37	63° 28.84' S 52° 5.77' W 970 m	63° 28.93' S 52° 5.87' W 896 m @ 20:53	# 34 (77%) +/- 26 m Wind 1.8 m/s to 199° Curr 0.11 m/s to 12° Heave 1.3 m OW	Good positions, none du-ring descent (Posidonia switched on later). Mooring D Anchor last.

Table 1: Summary of Posidonia reception characteristics during ANT-XXVII/2.
Explanations to abbreviations:

1st column: *Mooring ID + R (recovery), Rf (recovery failed), Rc (recovery cancelled), D (deployment), Df (deployment failed). Station # refers to station book Polarstern PS77/xxx-x. The last number is the "event number" (1 to 53).*

5th column: *Posidonia statistics: Example: # 34 (77%) +/- 26 m: # 34 (N_t, total number of transponder fixes) 77% (return rate, i.e. number of transponder fixes / ship fixes N_t / N_s, here 34/44). +/- 26 m: standard deviation of position fixes, as a measure for scatter.*

Wind and Current calculated from u- and v-average during mooring operation time. vmADCP current averaged between 100 m and 200 m depth, i.e. below Ekman depth.

Heave: maximum heave movement of the ship during mooring operation time. Posidonia array and seaice conditions: FW, FI, OW, OI: Fixed array (F)/ Open array (O), open water (W)/ seaice (I).

NaN values *refer to no data, zero return to no reception from transponder (but Posidonia working).*

Shaded fields *indicate operation of the open moon pool Posidonia array*

White fields *indicate use of the fixed Posidonia array*

A2: Maps, relative bearings, and Lat/Lon/Depth timeseries of selected Posidonia operations

Explanations to the figures on each page:

Title: Event number, mooring ID, and type of operation:

R	recovery
Rf	recovery failed
Rc	recovery cancelled
D	deployment
Df	deployment failed

Top left: Map of absolute Posidonia positions.

Dark blue circles:	Ship position.
Coloured dots:	Transponder position, colour = depth (same colour scaling in all figures).
Blue arrows:	vmADCP currents, 20 min averages over 100 to 200 m, i.e. below the Ekman layer. Length of the arrows corresponds to 1-hour displacement.
Red arrows:	Wind speed and direction from DShip, every 20 min. Length of arrows corresponds to 1-hour displacement * 0.01.
Black diamonds:	Maximum heave motion from DShip during 5-min interval every 20 min, relative scaling.
Text line:	vmADCP current 100-200 m, and wind, averages over entire Posidonia operation period. Maximum heave during entire period. N: total number of transponder fixes (NaN: Posidonia not operating, 0: Posidonia operating, but no fixes), dx and dy: standard deviation of absolute mooring position.

Top right: Relative bearings of Posidonia fixes, and expected bearing assuming nominal position and reported slant range. Pitch and roll not corrected.

Coordinates:	vertically below ship in centre, top=forward, right=starboard etc. The units are degrees (°). The figure shows relative bearings, not x-y coordinates as the relative display in the Abyss software does.
Coloured dots:	Bearings reported by Posidonia. Colour=depth.
Black/grey circles:	Expected bearings assuming nominal position and reported slant range.

“gd”: “good deep” fixes <250 m away from nominal position, depth >1000 m (bold dots, black lines and large black circles).

“pd”: “poor deep” fixes >250 m away from nominal position, depth > 1000 m (medium paler dots, grey lines, grey circles)

“s”: “shallow” fixes depth <1000 m (small pale dots, light grey lines and small grey circles)

Bottom left: Time series of reported Latitude, Longitude and Depth.

Colour refers to depth (same colour scaling for all plots).

Lat/Lon timeseries: The slanted black line indicates the horizontal displacement of the mooring if the current measured by vmADCP between 100 and 200 m would apply to the entire water column.

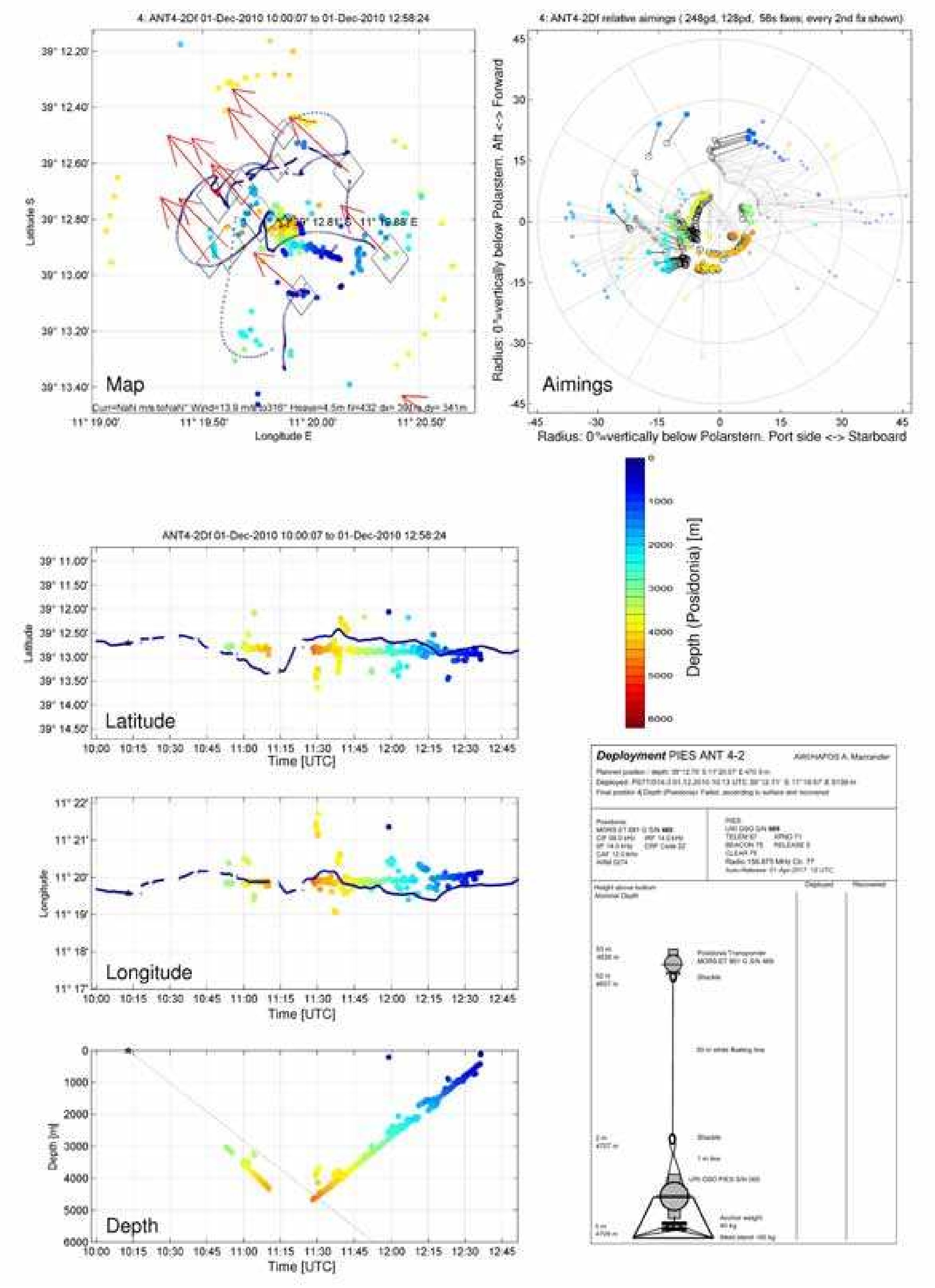
Depth timeseries: The slanted line indicates a vertical descent / ascent speed of

1 m/s. The actual speed can be somewhat smaller or larger, depending on the mooring configuration.

Bottom right: Drawing of deployed moorings.

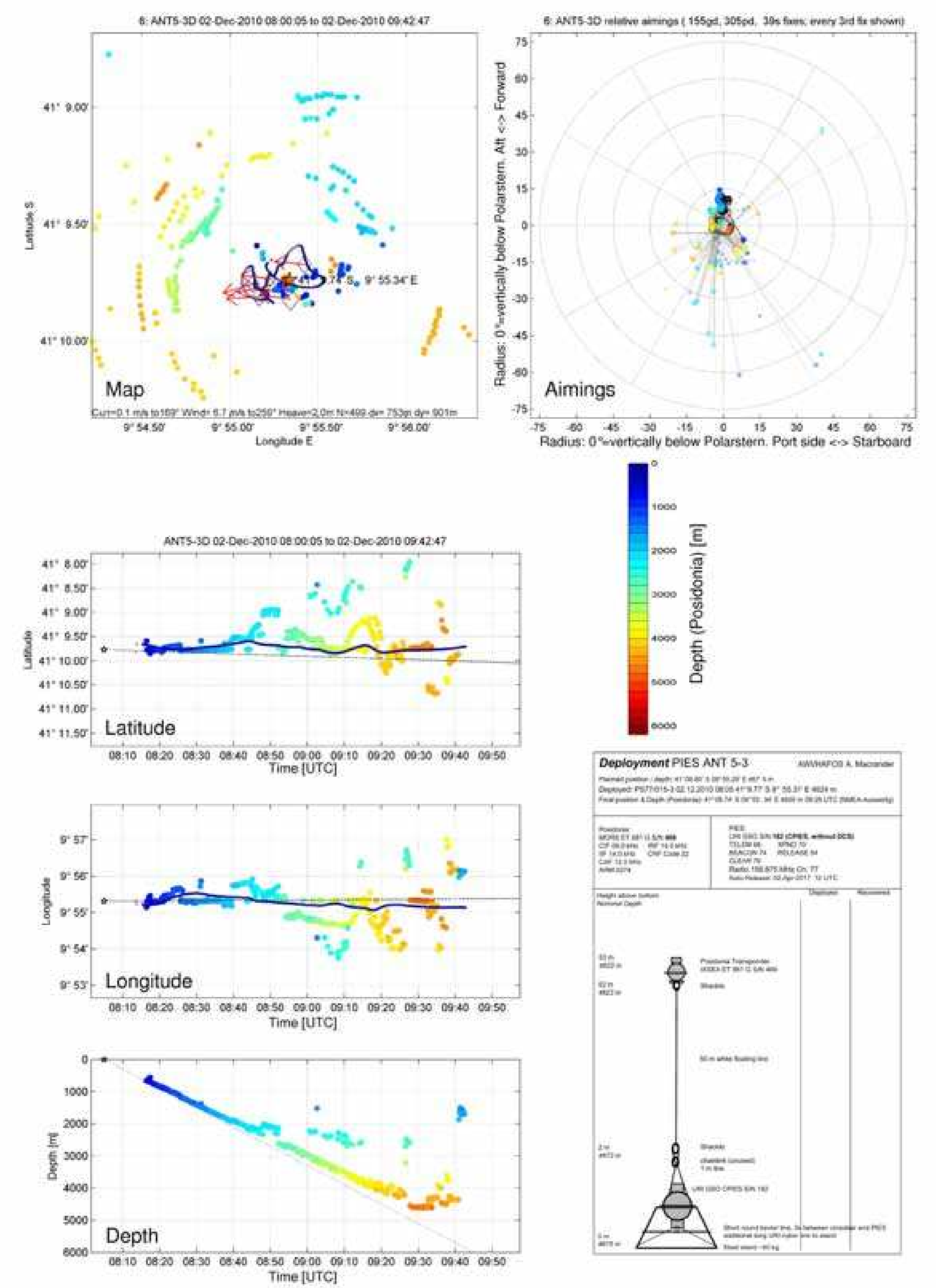
Note: Figures and Posidonia data for all 53 mooring operations are stored in the Observational Oceanography department of AWI along with other mooring information (deployment protocols, release codes etc.). Please contact Andreas Macrander or Gerd Rohardt. After recovery of the respective mooring, the data and figures will be included in the Pangaea database.

4 ANT4-2Df



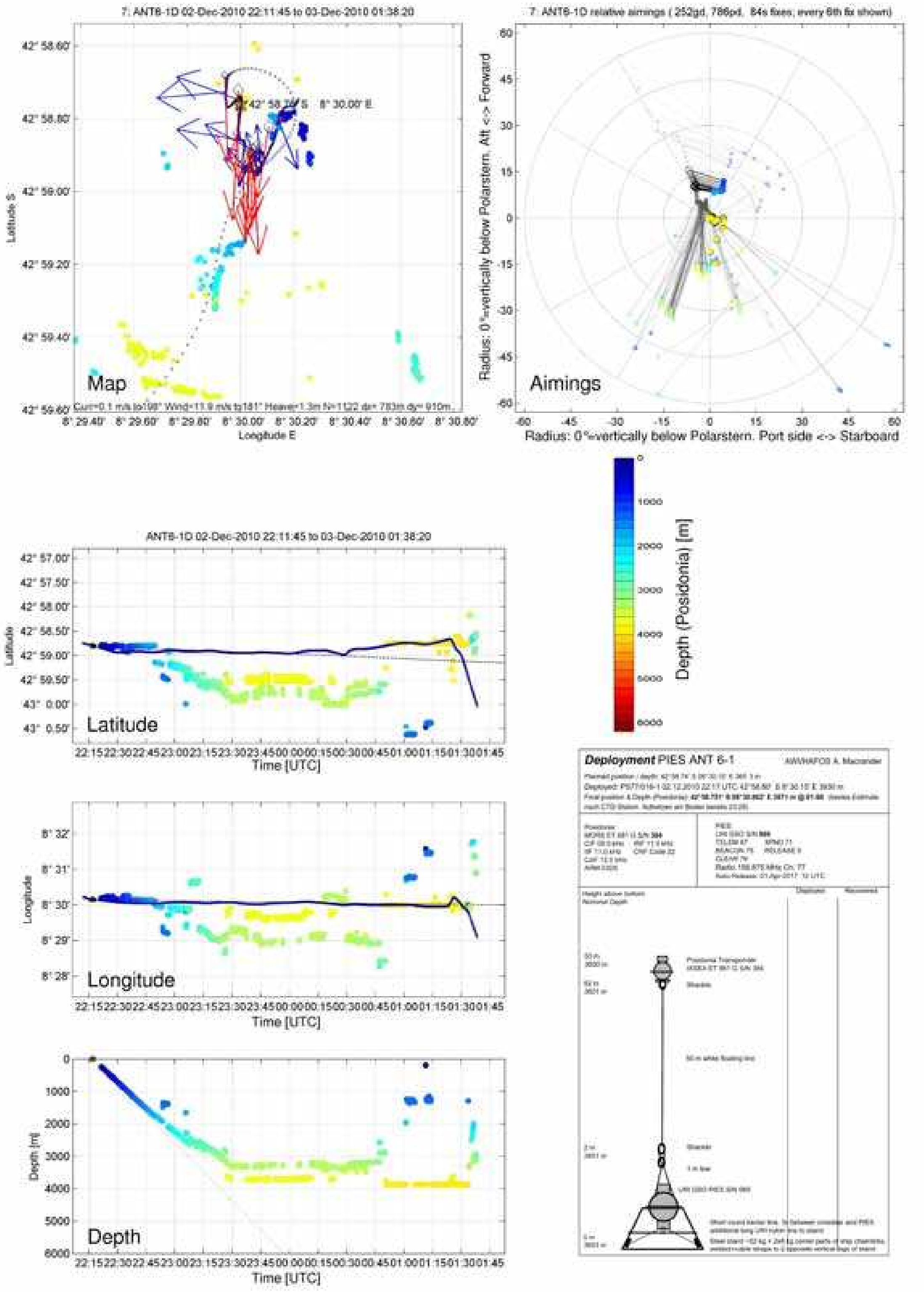
PIES deployment failed, as PIES release broke when the mooring hit the bottom.

6 ANT5-3D



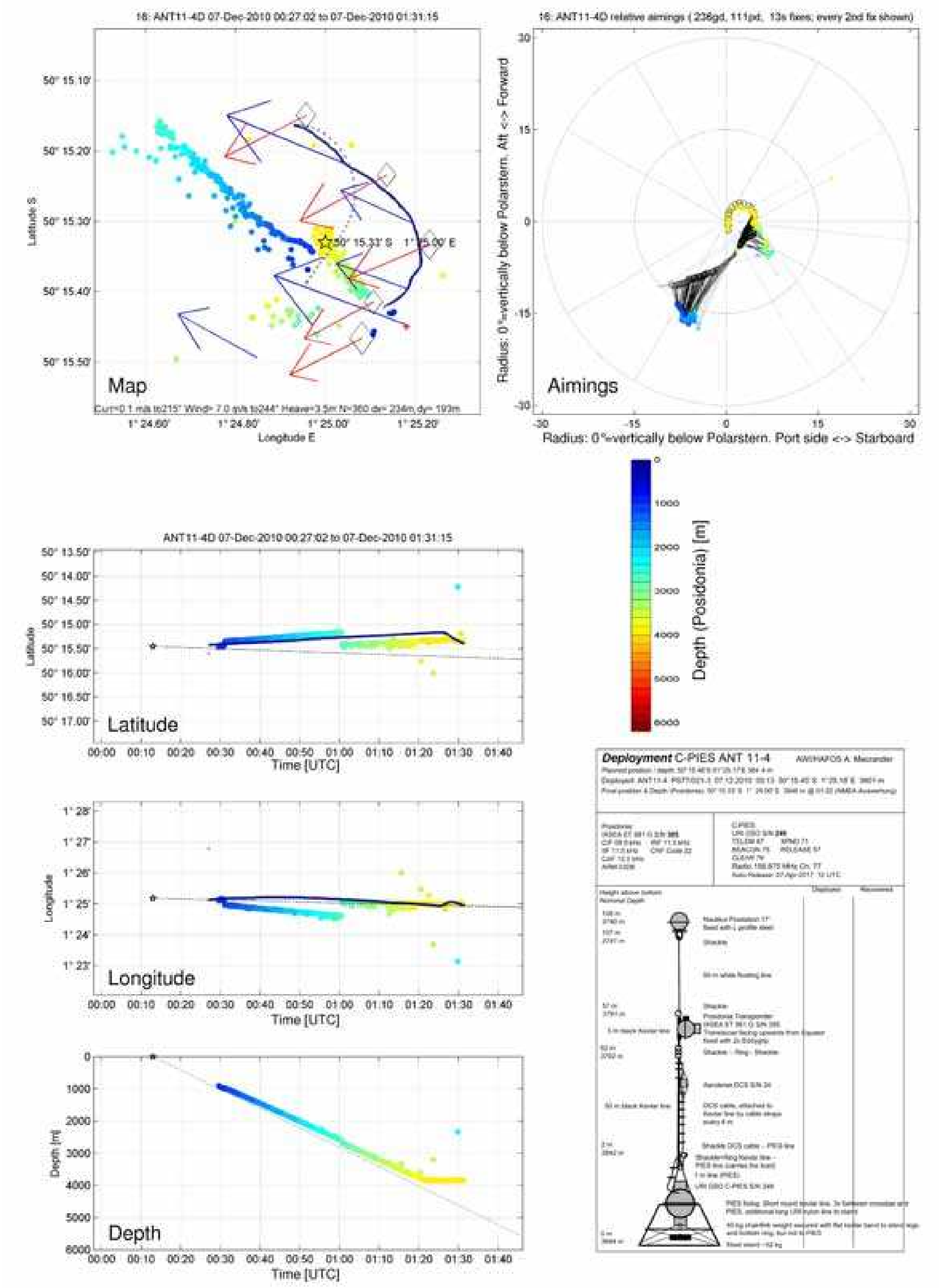
PIES deployment. Note concentric circles during turns of Polarstern.

7 ANT6-1D



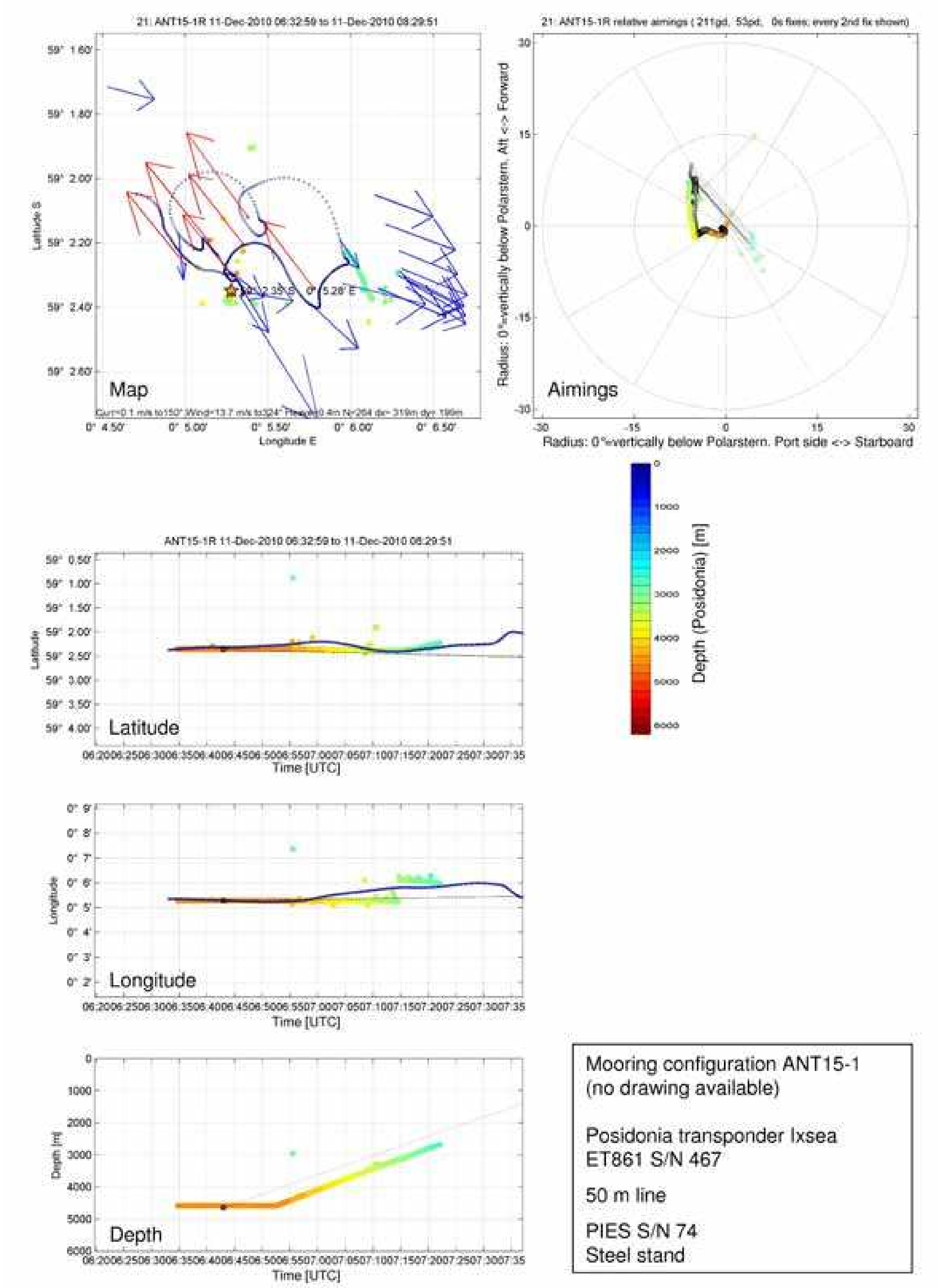
PIES Deployment. Note depth offsets associated with false fixes.

16 ANT11-4D



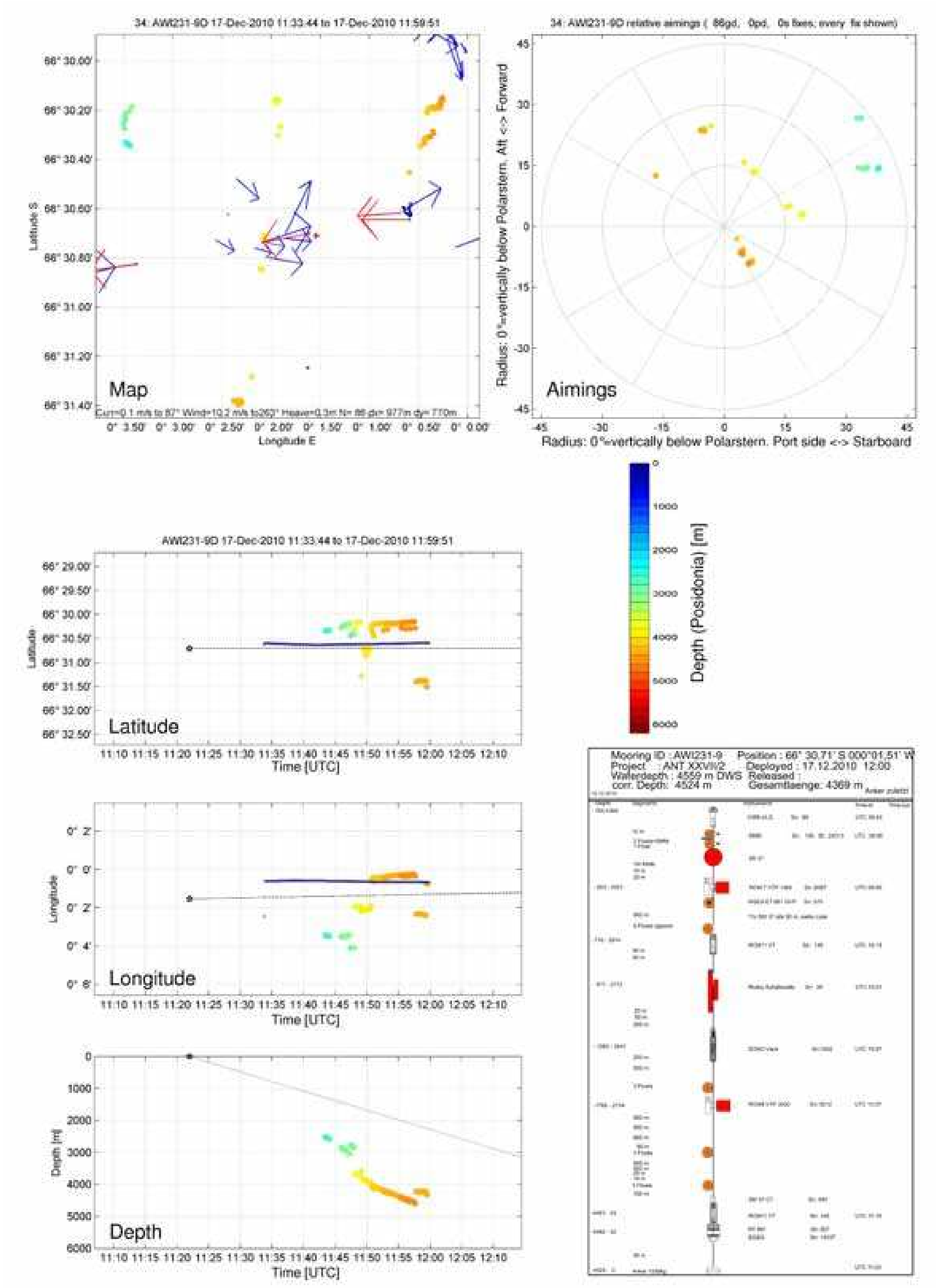
PIES Deployment. Note Depth and position offsets during mooring descent.

21 ANT15-1R



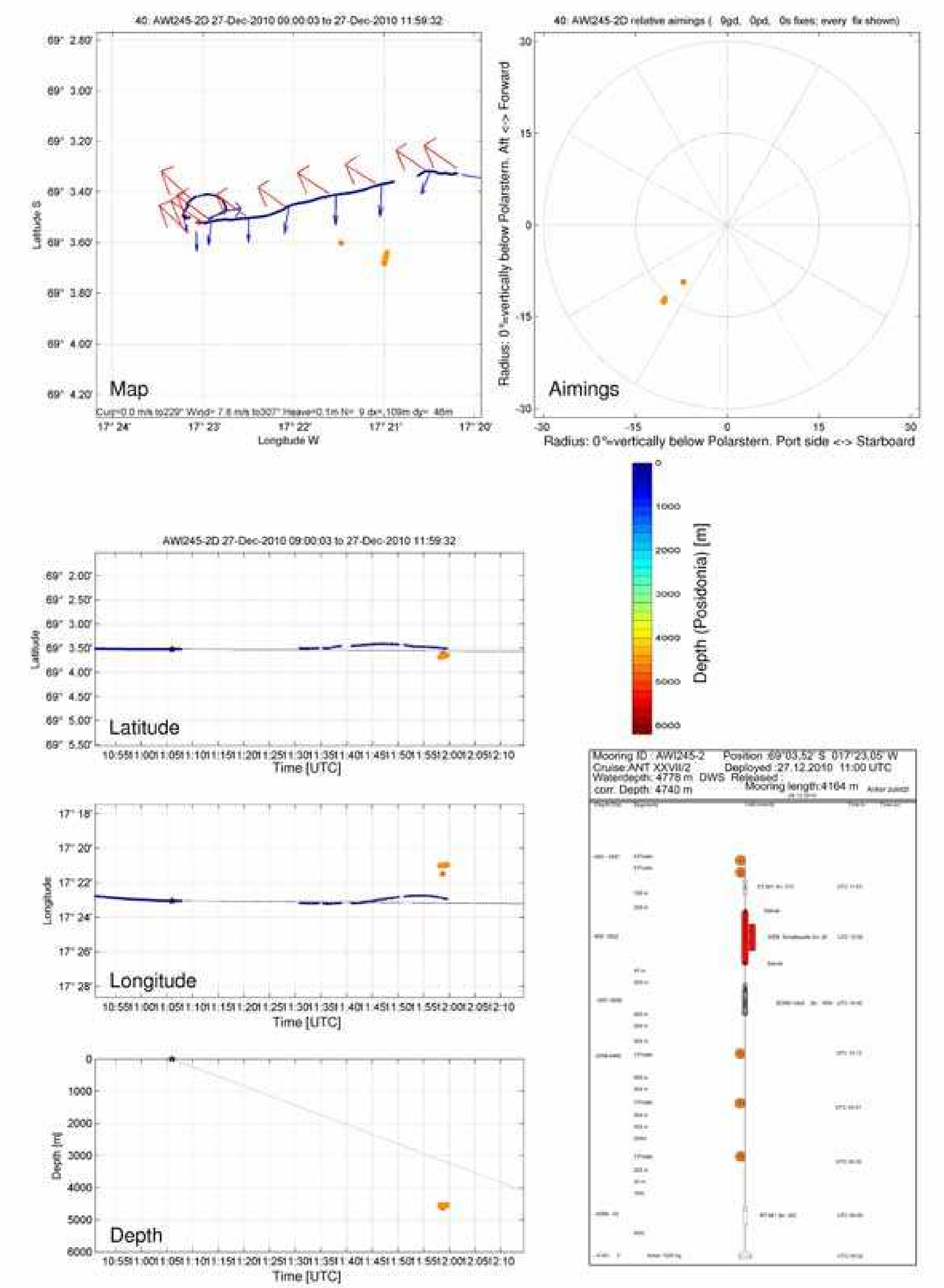
PIES Recovery. Note good fixes and ship turns.

34 AWI231-9D



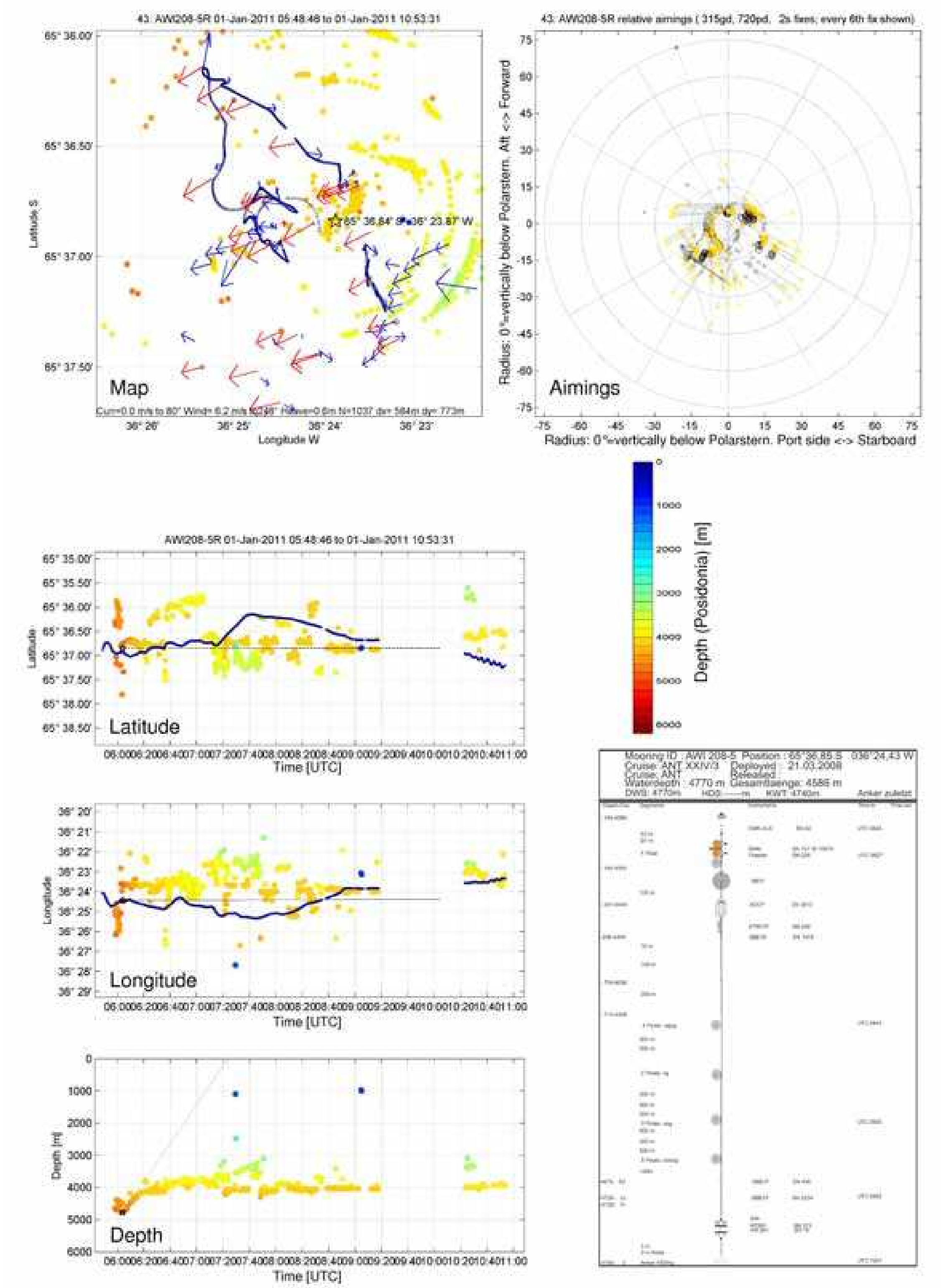
Mooring Deployment. Note relatively unclear fixes. No reliable final estimate obtained.

40 AWI245-2D



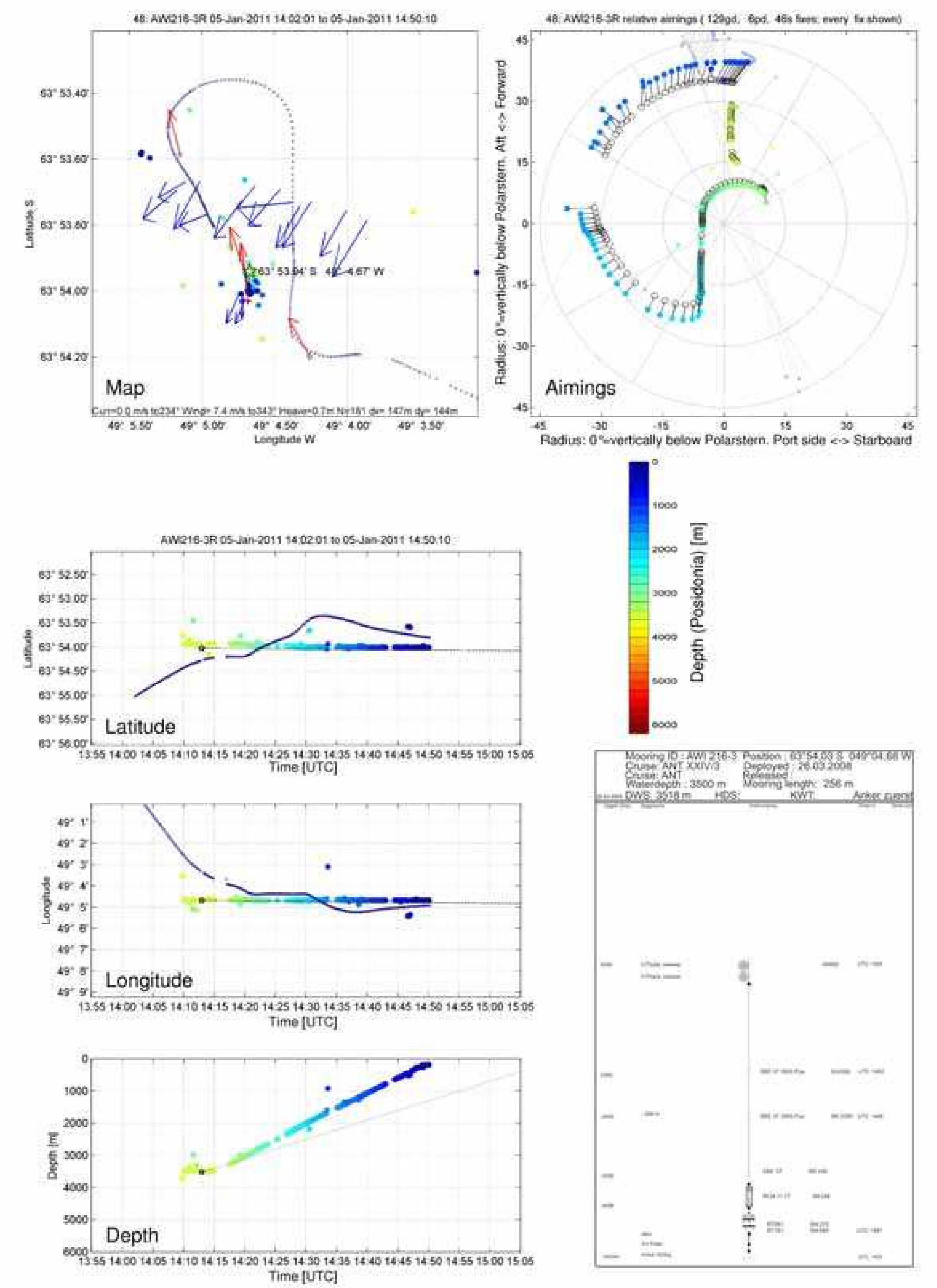
Mooring Deployment. Only 9 fixes were obtained, all at somewhat unlikely positions.

43 AWI208-5R



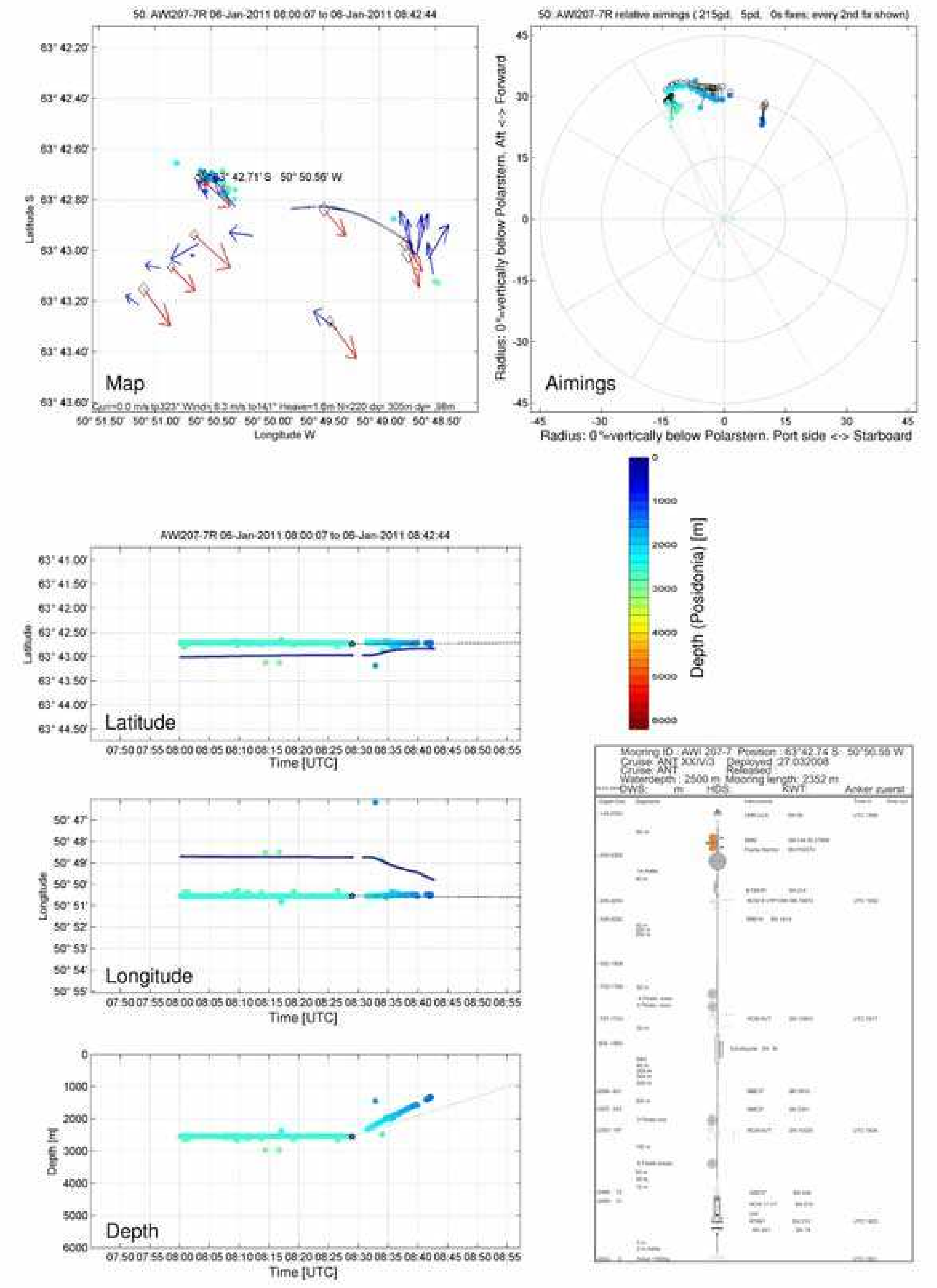
Mooring Recovery. Open Posidonia array used for extensive search when mooring was blocked below an ice floe.

48 AWI216-3R



Mooring Recovery. Open Posidonia array used.

50 AWI207-7R



Mooring Recovery. Open Posidonia array used.

A.6: PRESSURE INVERTED ECHO SOUNDERS (PIES) DURING ANT-XXVII/2 – TECHNICAL REPORT

Andreas Macrander, Olaf Boebel, Matthias Monsees, Stefanie Rettig, Olaf Strothmann, Jörg Walter (Marine Observing Systems, AWI)

During Polarstern ANT-XXVII/2, 6 Pressure Inverted Echo Sounders (PIES) were recovered, and 13 deployed on the GoodHope / Greenwich section across the Antarctic Circumpolar Current (ACC). The recovery of 3 PIES failed; 1 PIES surfaced immediately after its deployment, and was recovered.
In the cruise report, scientific objectives, work at sea, preliminary results, and some technical remarks on mooring failures are discussed. The following technical report summarizes relevant issues on mooring design, mechanical failures of the releasers, and implications for PIES recoveries and deployments on future cruises. Evaluation of the Posidonia acoustic underwater location system for both PIES and "standard" mooring operations are summarized in a separate appendix.

PIES mooring design
PIES measure the travel time of an acoustic signal from sea floor to surface and back. Travel time varies with water depth, and sound speed, which depends largely on temperature. Further, pressure is measured with a resolution equivalent to +/- 1 mm changes of Sea Surface Height. Additionally, some PIES (referred to as "C-PIES") are connected by a 50 m long cable to an acoustic Aanderaa Doppler Current Sensor 3820R (DCS) to measure local current speed. PIES developed and manufactured by the University of Rhode Island (URI, 2008) have been employed in hundreds of deployments in all oceans (Tracey et al., 2011).

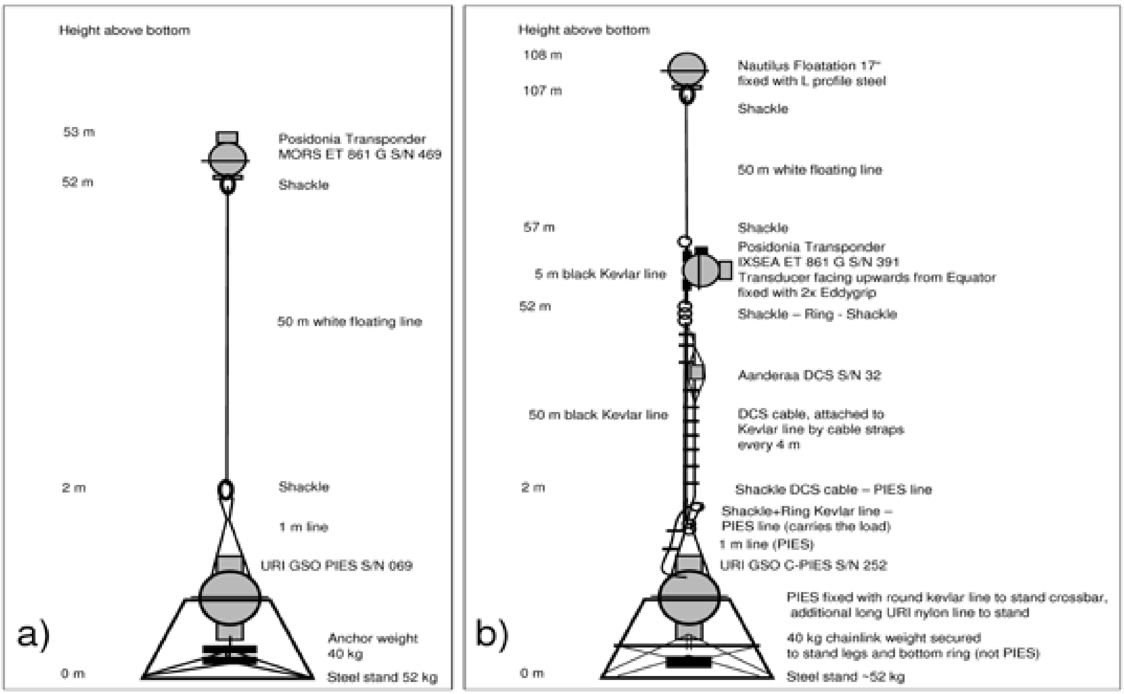


Fig. 1: PIES mooring designs. Drawings not to scale. a) Original design, here for "standard" PIES at ANT4-2 with a free-hanging 40 kg weight attached to PIES release (configuration "C"). b) Modified design, here for C-PIES at ANT13-3 with current meter. Weight attached to stand; PIES attached to crossbar welded into the stand (configuration "G").

The general mooring design used by AWI since 2002, and also during ANT-XXVII/2, is shown in Fig. 1a. The PIES is firmly seated by a freely hanging weight within a steel stand to ensure that the height of the instrument remains absolutely constant (c.f. pressure measurements) even under conditions of strong near-bottom currents.
On the steel stand itself, there may be attached two PopUp modules to the sides of the PIES, which receive daily averaged data from the PIES via an IrDA link. The PopUp modules release independently of the PIES, and transmit the data via an Iridium satellite link.
To the top, there may be attached different sets of equipment, depending on the actual mooring configuration. These may include an Ixsea ET 861 G transponder for underwater location by Polarstern's Posidonia system, Nautilus Vitrovex floatation, and Aanderaa DCS current meter. These components are connected with the PIES by Kevlar or floating lines, and/or the DCS cable. Weights, buoyancy, face area and drag coefficient are listed in Tab. 1.
Tab. 1 reveals that the 50 m long wires have the largest face area, whereas the contributions from instruments and floats are smaller. Hence the drag force due to abyssal currents will largely depend on the length and diameter of the lines used to connect the PIES with ET861 transponders and/or floats.

Table 1: PIES mooring components: Weight, buoyancy, face area, drag coefficient

	weight in air [kg]	buoyancy in water [kg]	net wt. in water [kg]	dimensi-ons	face area [m²]	c_w
Instruments / Floats						
PIES with 240 Ah battery pack	38	48	- 10	51 cmØ	0.26	0.95
Ixsea ET861G Transponder	31	48	- 17	51 cmØ	0.26	0.95
Nautilus 17" float	22	48	- 26	51 cmØ	0.26	0.95
Nautilus 13" 7000 dbar float	11.1	21.8	- 10.7	40 cmØ	0.16	0.95
Aanderaa DCS	≈ 3	≈ 1.2	≈ 1.8	11 cmH 12 cmØ	0.01	1.30
PopUp module	17	22	- 5	40 mØ	0.16	0.95
Lines / cables						
50 m DCS cable + 50 m Kevlar wire 9 mmØ	≈12.5	≈ 7.1	≈ 5.4	1.4 cmØ	0.70	1.30
50 m kevlar line 9 mmØ	4.4	3.2	1.2	0.9 cmØ	0.45	1.30
50 m floating line 20 mmØ	≈ 13.2	≈ 15.7	- 2.5	2.0 cmØ	1.00	1.30
50 m floating line 16 mmØ	≈ 8.5	≈ 10.0	- 1.5	1.6 cmØ	0.80	1.30
50 m Dyneema line 4 mmØ	0.5	0.6	- 0.1	0.4 cmØ	0.20	1.30
Stand / Anchor						
PIES stand (25mmØ steel)	32.4	4.6	27.8	300 cmL 2.5 cmØ	0.08	1.30
PIES stand (bottom ring 40mmØ)	52.6	7.5	45.1	300 cmL 2.5 cmØ	0.08	1.30
Original anchor weights (URI)	45	6.4	38.6	5 cmH 30 cmØ	0.02	1.30

Notes: Buoyancy of steel components assumes a steel density of 7850 kg m^{-3}. Dimensions: diameter Ø, height H, length L. Empirical drag coefficients c_w from Moordesign program (Dewey, 2009; gear database extended by G. Rohardt, O. Strothmann, M. Monsees, A. Macrander).

The different mooring configurations (here termed A to M) are listed in Tab. 2. The configurations A to E involve a heavy stand and free hanging weights, which have been deployed in the ACC array until 2008 (Böning et al., 2010; Klatt and Schulze, 2009), and at ANT3-3 and ANT4-2 in 2010 (this cruise report). F to G represent the modified designs used in 2010 after ANT4-2. H to M represent possible future configurations.

Table 2: PIES mooring configurations

	Instruments						***Wires***						***Stand***				Remarks
Configuration	PIES	ET861	17" float	13" float	DCS	PopUp	DCS cable [m]	DCS cable+wire*1[m]	9mm Kevlar [m]	20 mm float line [m]	16 mm float line [m]	4 mm Dyneema [m]	Stand [kg]	Weights [m]	Weight in water [kg] stand + weights	Buoyancy [kg] instruments + wires	
PIES deployments 2008 and ANT3-3 and ANT4-2																	
A	1	/	/	/	/	2	/	/	/	/	10	/	52	50	89.0	20.3	PIES only (e.g. ANT3-2Rf)
B	1	1	/	/	/	/	/	/	50	/	/	/	52	40	80.3	25.8	PIES+ET (2008 AWI standard)
C	1	1	/	/	/	/	/	/	/	50	/	/	52	40	80.3	29.5	PIES+ET (e.g. ANT4-2Df)
D	1	1	1	/	/	/	/	/	100	/	/	/	52	40	80.3	50.6	PIES+ET+17"float (ANT5-2)
E	1	1	1	/	1	/	/	50	50	/	/	/	52	40	80.3	44.6	C-PIES+ET (2008 AWI standard)
PIES deployments 2010 after ANT4-2																	
F	**1**	**1**	**/**	**/**	**/**	**/**	**/**	**/**	**/**	**50**	**/**	**/**	**62**	**/**	**54.1**	**29.5**	**PIES+ET (2010 AWI standard)**
G	**1**	**1**	**1**	**/**	**1**	**/**	**/**	**50**	**/**	**50**	**/**	**/**	**92**	**/**	**80.3**	**48.3**	**C-PIES+ET(2010 AWI standard)**
Possible future configurations																	
H	*1*	*1*	*/*	*/*	*/*	*/*	*/*	*/*	*/*	*/*	*/*	*50*	*62*	*/*	*54.1*	*27.1*	*PIES+ET+4mm line*
I	*1*	*1*	*1*	*/*	*1*	*/*	*/*	*50*	*/*	*20*	*/*	*/*	*92*	*/*	*80.3*	*46.8*	*C-PIES+ET+shorter line*
J	*1*	*1*	*1*	*/*	*1*	*/*	*/*	*50*	*/*	*/*	*/*	*20*	*92*	*/*	*80.3*	*45.8*	*C-PIES+ET+shorter 4mm line*
K	*1*	*1*	*/*	*1*	*1*	*/*	*/*	*50*	*/*	*/*	*/*	*20*	*77*	*/*	*67.2*	*31.5*	*as above, with 13"float*
L	*1*	*/*	*1*	*/*	*1*	*/*	*50*	*/*	*/*	*/*	*/*	*/*	*30*	*45*	*65.4*	*30.0*	*C-PIES (URI standard)*
M	*1*	*1*	*/*	*/*	*1*	*/*	*/*	*50*	*/*	*/*	*/*	*/*	*62*	*/*	*54.1*	*19.8*	*C-PIES+ET only*

*Notes: *1) DCS cable paralleled by 9 mm Kevlar wire. A-E: past configurations until ANT4-2. F-G: modified standard during ANT-XXVII/2. H-M: possible future configurations.*

Weight / buoyancy issues and descent / ascent speeds

The buoyancy and weight distribution greatly influence the descent and ascent speed of the mooring. Too much weight (and too fast descent speed) may overstress the release mechanism of the PIES, when the mooring lands on the sea floor. Little weight, or lots of equipment above the PIES may cause the PIES stand to tip over due to drag in strong currents.

Tables 3 and 4 document the actual configurations of all PIES serviced during ANT-XXVII/2, and the ascent / descent speed observed by Posidonia.

The vertical movement of the mooring assemblies depends almost linearly on net buoyancy (Fig. 2); descent speeds are comparatively slower due to the additional drag caused by the steel stand. The values agree well with those found during ANT-XXV/2 (Böning et al., 2010).

Descent speeds of > 1 m s^{-1} appear to be critical. The PIES at ANT4-2 which descended with 1.25 m s^{-1} lost its weight immediately upon hitting the sea floor, and returned to the surface. The anode wire was bent open, allowing the release bolt to leave its place. A further weak point appears to be the firm seat of the anode wire within the anode connector: At ANT3-2, the wire was pulled out of the seat by several mm just by the 40 kg weight on deck. It is very likely that this PIES also would have been lost, if it would have been deployed with this defective anode wire.

Beginning with ANT5-3, the in-water net weight was reduced to 25 kg (PIES; C-PIES: 32 kg) to reduce the descent speed to approx. 0.9 m s^{-1}. The PIES was attached to a new crossbar welded into the stand, which avoids any excess stress when the stand decelerates upon hitting the sea floor. We expect that the short Kevlar wire used to attach the PIES does not lengthen significantly over time; otherwise the pressure time series would be contaminated by the vertical displacement of the PIES.

Table 3: PIES recoveries during ANT-XXVII/2. Mooring weights and ascent speed.

Station Event #: Mooring ID	Date Release time Surface time	Mooring Configuration		Net buoy-ancy	Ascent speed	Remarks
PS77/013-2 1: ANT3-2Rf	30.11.2010 03:44 / never	PIES #192 +10m float line only	**A**	10.3 kg	0	no contact to PIES
PS77/014-2 3: ANT4-1Rf	01.12.2010 07:35 / never	PIES #071 +ET861 #462	**B**	25.8 kg	0	no contact to PIES and ET
PS77/014-3 4: ANT4-2Df	01.12.2010 11:20 / 12:45	PIES #069 +ET861 #469	**B**	25.8 kg	-1.04 m s^{-1}	
PS77/015-2 5: ANT5-2R	02.12.2010 05:53 / 07:13	PIES #062 +ET861 #470 +17” float	**D**	50.6 kg	-1.19 m s^{-1}	tipped over first 8 months
PS77/017-1 8: ANT7-3R	03.12.2010 14:06 / 15:30	C-PIES #184 +DCS #753 +ET861 #387 +17” float	**E**	44.6 kg	-1.28 m s^{-1}	
PS77/019-1 11: ANT9-2R	05.12.2010 08:02 / 09:40	PIES #113 +ET861 #388	**B**	25.8 kg	-0.91 m s^{-1}	
PS77/020-1 13: ANT10-1Rf	06.12.2010 01:31 / never	PIES #135 +ET861 #390 (+2 PopUps)	**B**	25.8 kg	0	no contact to PIES and ET
PS77/021-1 15: ANT11-3R	06.12.2010 19:05 / 20:33	PIES #189 +ET861 #386	**B**	25.8 kg	-0.77 m s^{-1}	
PS77/026-1 18: ANT13-2R	08.12.2010 09:11 / 10:08	PIES #125 +ET861 #471	**B**	25.8 kg	-0.93 m s^{-1}	
PS77/038-1 21: ANT15-1R	11.12.2010 06:43 / 08:06	C-PIES #074, no DCS, +ET861 #467	**B**	25.8 kg	-1.07 m s^{-1}	

Table 4: PIES deployments during ANT-XXVII/2. Mooring weights and descent speed.

Station Event #: Mooring ID	Date Deployment time	Mooring Configuration		Frame + anchor weight	Buoy-ancy PIES+ floats	Total net buoy-ancy	Descent speed	Remarks
PS77/013-3 2: ANT3-3D	30.11.2010 06:31	PIES #058 +ET861 #637	**C**	45.4 kg +34.9 kg	29.5 kg	-50.8 kg	1.18 m s^{-1}	
PS77/014-3 4: ANT4-2Df	01.12.2010 10:13	PIES #069 +ET861 #469	**C**	45.4 kg +34.9 kg	29.5 kg	-50.8 kg	1.25 m s^{-1}	releaser failed
PS77/015-3 6: ANT5-3D	02.12.2010 08:05	C-PIES #182, no DCS, +ET861 #469	**F**	54.1 kg	29.5 kg	-24.6 kg	0.91 m s^{-1}	
PS77/016-1 7: ANT6-1D	02.12.2010 22:17	PIES #069 +ET861 #384	**F**	54.1 kg	29.5 kg	-24.6 kg	0.86 m s^{-1}	
PS77/017-2 9: ANT7-4D	03.12.2010 18:37	C-PIES #181 +DCS #750 +ET861 #639 +17” float	**G**	80.3 kg	48.3 kg	-32.0 kg	1.03 m s^{-1}	
PS77/018-1 10: ANT8-1D	04.12.2010 14:55	C-PIES #183 +DCS #751 +ET861 #616 +17” float	**G**	80.3 kg	48.3 kg	-32.0 kg	0.95 m s^{-1}	
PS77/019-2 12: ANT9-3D	05.12.2010 10:20	C-PIES #251 +DCS #26 +ET861 #602 +17” float	**G**	80.3 kg	48.3 kg	-32.0 kg	NaN	no Posid. reception
PS77/020-2 14: ANT10-2D	06.12.2010 03:58	C-PIES #250 +DCS #31 +ET861 #617 +17” float	**G**	80.3 kg	48.3 kg	-32.0 kg	NaN	no Posid. reception
PS77/021-3 16: ANT11-4D	07.12.2010 00:13	C-PIES #249 +DCS #24 +ET861 #385 +17” float	**G**	80.3 kg	48.3 kg	-32.0 kg	0.93 m s^{-1}	
PS77/022-1 17: ANT12-1D	07.12.2010 10:52	PIES #062 +ET861 #612	**F**	54.1 kg	29.5 kg	-24.6 kg	0.90 m s^{-1}	
PS77/026-2 19: ANT13-3D	08.12.2010 11:23	C-PIES #252 +DCS #32 +ET861 #391 +17” float	**G**	80.3 kg	48.3 kg	-32.0 kg	0.94 m s^{-1}	
PS77/034-1 20: ANT14-1D	10.12.2010 04:15	PIES #191 +ET861 #638	**F**	54.1 kg	29.5 kg	-24.6 kg	0.83 m s^{-1}	
PS77/042-2 25: ANT15-2D	11.12.2010 18:51	PIES #189 +ET861 #614	**F**	54.1 kg	29.5 kg	-24.6 kg	0.93 m s^{-1}	
PS77/053-1 27: ANT17-1D	14.12.2010 23:45	PIES #125 +ET861 #601	**F**	54.1 kg	29.5 kg	-24.6 kg	NaN	no Posid. reception

Notes: All weights and buoyancy values in water (c.f. Tab. 1, for configurations Tab. 2).

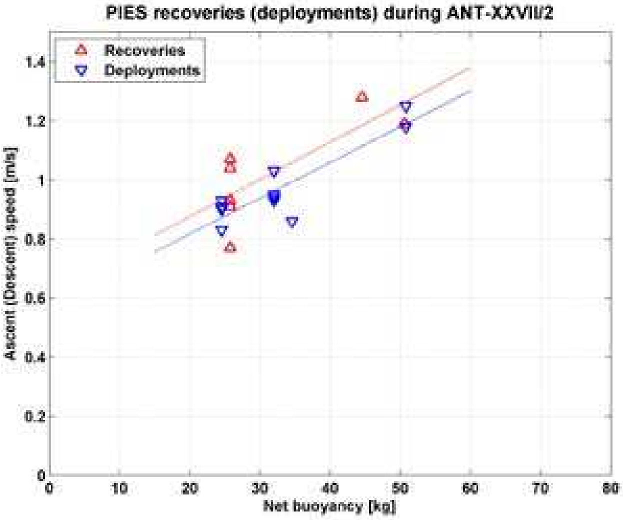
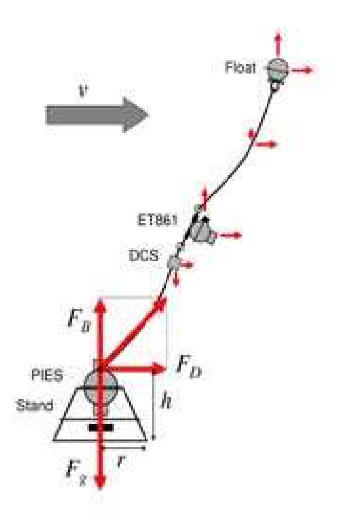


Fig. 2: Observed ascent and descent speed during PIES recoveries (red ▽ and deployments (blue ▽) as a function of net buoyancy. Note that for better comparison, both recoveries and deployments have been plotted with the absolute values of speed and net buoyancy.

Drag and tipping issues

Abyssal currents imply a drag force on mooring components. While the upper part of the PIES mooring (e.g. wires, ET861 transponders and 17" floats) may lean to the side as in any conventional mooring, the tilting moment due to buoyancy and drag which acts on the stand may tip the PIES stand over to the side.
So far, drag was not considered critical, as only few PIES have been lost in the past. However, during ANT-XXVII/2, weight was reduced to lower the mechanical stress acting on the release. Further, 50 m long and 20 mm thick floating lines have were introduced for connection of the top float. While this improves recovery handling, it also increases drag. That tipping is actually possible is also suggested by the pressure time series from the first 8 months of the ANT5-3 deployment; later the PIES appears to have been uprighted by a favourable current (c.f. this cruise report).
Here, drag and critical velocities which may cause the PIES stand to tip over are assessed.
To estimate the critical current velocity which causes the PIES to tip over, the uprighting moment $M_g = F_g\, r$ (weight), and the tilting moments $M_B = F_B\, r$ (buoyancy) and $M_D = F_D\, h$ (drag) need to be in balance (Fig. 3).



v current velocity

r = 0.61 m lower ring radius
(lever arm for F_g and F_B)

h = 0.93 m stand height + ½ PIES height
(lever arm for F_D)

h_I = 0.68 m stand height
(lever arm for F_D from PIES, not shown)

Fig. 3: Sketch of forces and moments acting on a PIES mooring.

The drag force F_D can be estimated roughly by

$$F_D = \frac{1}{2} \rho A c_w v^2 \qquad (1)$$

with ρ density of seawater, A face area of the mooring components (Tab. 1), drag coefficient c_w = 0.95 ... 1.30 (Tab. 1), and current velocity v.
To compare the different mooring configurations, drag force, and moment have been calculated using Eq. 1, and the Matlab® program Moordesign (Dewey, 2009), which has proven as a reliable tool to estimate drag also on larger AWI moorings (G. Rohardt, pers. comm.). In the turbulent bottom boundary layer, current velocity increases with height above the sea floor. For a geostrophic current velocity of 0.50 m s^{-1}, a realistic near-bottom profile based on ADCP measurements (Macrander, 2004) is given in Tab. 5. Note that 50 m above the ground, where the DCS current meter of a C-PIES is located, the current speed attains about 90% of the geostrophic current of the open water.

Tab. 5: Current profile used for drag simulations

Height above bottom [m]	v [m s^{-1}]
120	0.50
80	0.50
50	0.45
10	0.25
5	0.22
1	0.18
0	0.18

This sheared current profile was used to estimate drag forces F_D, and tilting moments M_D acting on the different PIES moorings (Tab. 6). Secondly, the critical geostrophic velocity which causes the PIES stand to tip over (i.e. $M_D > M_g + M_B$), was estimated. Finally, the critical velocity, assuming a (rather unrealistic) uniform current profile was calculated.

Table 6: PIES mooring configurations, and critical current velocities

Config	vertical forces			horizontal forces			M_{total} =	v_{max}	v_{max}	Remarks
	Stand weight [kg]	Instr. Buoy. [kg]	M_g+M_B [Nm]	F_D PIES [N]	F_D wires, ET [N]	M_D PIES+ wires etc. [Nm]	M_g+M_B -M_D [Nm]	sheared profile below 80 m [m s^{-1}]	uni-form profile [m s^{-1}]	
PIES deployments 2008 and ANT3-3 and ANT4-2										
A	89.0	20.3	411	11	5	7+5	**399**	2.92	1.24	PIES only (e.g. ANT3-2Rf)
B	80.3	25.8	326	6	51	4+47	**275**	1.26	0.85	PIES+ET (2008 AWI standard)
C	80.3	29.5	304	6	83	4+77	**223**	0.97	0.69	PIES+ET (e.g. ANT4-2Df)
D	80.3	50.6	178	6	140	4+130	**44**	0.58	0.47	PIES+ET+17”fl. (ANT5-2, tipped)
E	80.3	44.6	214	6	153	4+142	**68**	0.61	0.49	C-PIES+ET (2008 AWI standard)
PIES deployments 2010 after ANT4-2										
F	**54.1**	**29.5**	**147**	**6**	**83**	**4+77**	**66**	**0.67**	**0.48**	**PIES+ET (2010 AWI standard)**
G	**80.3**	**48.3**	**191**	**6**	**207**	**4+193**	**-6**	**0.49**	**0.42**	**C-PIES+ET(2010 AWI standard)**
Possible future configurations										
H	*54.1*	*27.1*	*162*	*6*	*36*	*4+33*	***125***	*1.05*	*0.69*	*PIES+ET+4mm line*
I	*80.3*	*46.8*	*200*	*6*	*145*	*4+135*	***61***	*0.60*	*0.47*	*C-PIES+ET+shorter line*
J	*80.3*	*45.8*	*206*	*6*	*106*	*4+99*	***103***	*0.71*	*0.52*	*C-PIES+ET+shorter 4mm line*
K	*67.2*	*31.5*	*214*	*6*	*91*	*4+85*	***125***	*0.78*	*0.57*	*as above, with 13”float*
L	*65.4*	*30.0*	*212*	*6*	*54*	*4+50*	***158***	*0.99*	*0.67*	*C-PIES (URI standard)*
M	*54.1*	*19.8*	*205*	*6*	*60*	*4+56*	***145***	*0.92*	*0.65*	*C-PIES+ET only*

Notes: All forces and moments calculated using the sheared current profile with 0.50 m s^{-1} above the bottom boundary layer (Tab. 5), except the critical current velocities v_{max}.

The critical current velocities range between 2.92 m s^{-1} for a single PIES (configuration A), and 0.49 m s^{-1} for a C-PIES with ET861, connected with a 17” float by a 50 m long 20 mm floating line (configuration G).

While the average abyssal current velocity in the ACC is well below these values, they may be exceeded locally. The only C-PIES current meter data from the ACC array available so far come from ANT11-2 near the Polar Front. Here, maximum daily *averages* of 0.25 m s^{-1} have been observed 50 m above the bottom (i.e. 0.28 m s^{-1} geostrophic current, assuming the sheared profile from Tab. 5). The maximum current speeds (not retrieved, as the C-PIES was lost during its recovery; c.f. Böning et al., 2010) may have been higher. So the observed tipping of ANT5-2 (configuration “D”), with a critical velocity of 0.58 m s^{-1} may well be explained by drag.

Implications for future deployments

Buoyancy vs. weight

Whether the modified design chosen during ANT-XXVII/2 (PIES attached to crossbar, instead of hanging weight) is uncritical to the pressure timeseries needs to be assessed after the first recoveries of these PIES. Otherwise, a return to hanging weights as recommended by URI should be considered. In order to stay within the load range accepted by URI, the overall net weight in water should remain below 35 kg. This ensures descent speeds <1 ms^{-1}. In this case, a freely hanging weight of 40 kg should not overstress the PIES release, provided that all PIES releases pass stress-testing before deployment. The hanging weight could be supported by corrosion links which dissolve a few days after the deployment. This solution would solve the overstressing problem, and ensure that the PIES is seated firmly in the stand even after years, whereas lines may lengthen over time. An additional safety line to the bottom ring of the stand prevents the loss of the instrument in case of weld failure at the weight.

Drag and tipping
Tipping of the stand depends on the drag. In fact, a large part of the drag is caused by the face area of the lines connecting the PIES with the ET861 transponder and floats. During ANT-XXVII/2, floating lines have been used instead of the Kevlar lines used in previous deployments. The highly visible white floating lines greatly improve the recovery procedure. For future deployments, however, thinner and shorter lines should be considered to reduce the drag. The 50 m length between PIES and first float should not be reduced, as a closer distance may affect the acoustic pathway. However, for C-PIES moorings, the second float may be attached only 20 m above the ET861, using a thinner 4 mm Dyneema line (configurations J and K). The mooring simulation revealed further that even the ET861 alone may have sufficient buoyancy to keep the current meter upright (configuration M). This setup has a critical current velocity of 0.92 m s^{-1}, and comes rather close to the values of the original URI design (L).

Posidonia monitoring
In all deployments, the descent of the mooring should be monitored with the ship's Posidonia device, until it has been verified that the PIES remains on the sea floor. This procedure ensures that the PIES does not ascend unnoticed after to a possible release failure.

PopUps
The design of the PopUp modules requires a revision, as so far, only two PopUps retrieved actual data from PIES. In case of ANT10-1, the PopUp records end on 30-12-2009, several months before the PopUp released according to its pre-programmed schedule. It is unclear if this points to a loss of the PIES on 30-12-2009, alignment problems of the IrDA connection, or malfunction of the PIES or PopUp. Neither PIES nor ET861 could be located during ANT-XXVII/2. As it appears unlikely that both instruments failed concurrently, a loss of the PIES on 30-12-2009, possibly due to a corroded weld on its anchor weight, may be a likely scenario. The PopUps that are scheduled for deployment during ANT-XXVIII/2 have a completely new designed mainboard which should avoid malfunctions which were observed in previous PopUps.

Pinger Charger Alert 2011
In July 2011, University of Rhode Island became aware of a hardware problem (Watts and Sousa, 2011), which may affect some newer PIES; at AWI these are the new C-PIES S/N 249, 250, 251 and 252. In these instruments, the PIES might not transmit sampling pings in deep deployments, as the pinger charger may not reach the required voltage. However, as all these C-PIES passed on-board tests even at maximum output level of 197 dB re1µPa@1m prior to their deployment, it is likely, that they will work correctly also in the ocean (E. Sousa, pers. comm.). An advanced recovery to solve the Pinger Charger issue appears not urgent, as the pinger charger alert has no negative effects on power consumption, temperature / pressure / current sampling, acoustic pings during recovery, and the function of the releaser and relocation module.

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