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The Expedition of the Research Vessel "Polarstern" to the Antarctic in 2009 (ANT-XXV/4)

Edited by
Christine Provost
with contributions of the participants

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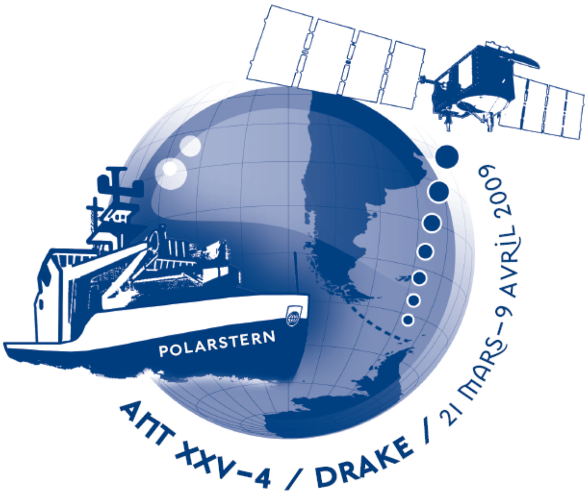

21 March - 9 April 2009

Punta Arenas – Punta Arenas
Drake Passage

Chief scientist
Christine Provost

Koordinator / Coordinator
Eberhard Fahrbach

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APPENDIX

1. ZUSAMMENFASSUNG UND FAHRTVERLAUF

Der Antarktische Zirkumpolarstrom (ACC), der größte Meeresstrom der Erde, ist ein wesentliches Element des Klimasystems. Dieser 2000 km breite Ring kalten Wassers umgibt den antarktischen Kontinent und wird von den Westwinden nach Osten getrieben. Der ACC ist in der Drake-Passage zu seiner geringsten Breite von 700 km zusammen gezwängt, weshalb dies ein günstiger Ort ist, ihn zu messen.

Den Transport und die Eigenschaften der Wassermassen zu überwachen ist notwendig, um den Zusammenhang zwischen Veränderungen des Klimas und denen dieses wichtigen Stroms zu verstehen. Dies ist allerdings ein schwieriges Unterfangen, denn die Strömung ist in engen Bändern mit hohen Geschwindigkeiten konzentriert und energiereiche Wirbel aller Größen sind zahlreich vorhanden.

Unser Messverfahren beruht darauf, dass sich ergänzende Aussagen von Satelliten und *in-situ*-Messungen ausgenutzt werden. Mit der Satelliten-Altimetrie wird die Höhe des Meeresspiegels entlang der Flugbahn des Satelliten Jason-1 alle 10 Tage mit einer horizontalen Auflösung von 7 km gemessen. Die *in-situ*-Messungen liefern Information über die Vertikalstruktur des Ozeans, die man mit dem Satelliten nicht erfassen kann.

Das hauptsächliche wissenschaftliche Ziel war es, die jahreszeitlichen und zwischenjährlichen Schwankungen des Gesamttransport des ACCs zu bestimmen sowie seine vertikale Aufteilung in den barotropen und baroklinen Anteil und seine horizontale Aufteilung in die Hauptfrontalzonen Subantarktische Front (SAF), Polarfront (PF) und Südliche ACC-Front (SACCF) zu erfassen. Mit diesem Ziel wurden bereits im Januar 2006 während der *Polarstern*-Reise ANT-XXIII/3 10 Strömungsmesserverankerungen entlang der Satellitenbahn #104 des Jason-1-Altimetrie-Satelliten ausgelegt. Während der Reise ANT-XXIV/3 wurden 8 Verankerungen aufgenommen (zwei wurden verloren) und bei den Positionen M1 bis M5 (Abb. 1.1a) wurden 5 neue Verankerungen ausgelegt. Dort wird der ACC durch den steilen und schmalen Rücken der Shackleton-Bruchzone kanalisiert.

Der Südliche Ozean spielt bei der globalen meridionalen Umwälzzirkulation eine wesentliche Rolle, da tiefe Wassermassen hier an die Oberfläche aufsteigen und durch Absinken des Oberflächenwassers Zwischen- und Bodenwasser erzeugt wird. Man nimmt an, dass das verhältnismäßig kleine Gebiet der Drake-Passage einen unverhältnismäßig großen Einfluss ausübt, da auf Grund der Geometrie, der rauen Topographie und des atmosphärischen Antriebs hier ein wesentliches Absinkgebiet von Zwischenwasser liegt. Ferner erfolgen erhebliche Veränderungen der tiefen Wassermassen, der Ausstrom von Wasser aus dem Weddellmeer und Vermischung.

Daher ist es ein weiteres wissenschaftliches Ziel, die Veränderlichkeit der Wassermassen und die Vermischung zu untersuchen. Dazu wurden während ANT-XXII/3 und ANT-XXIV/3 hydrographische Messungen über die gesamte Wassersäule entlang der Flugbahn #104 mit einer relativ hohen horizontalen Auflösung ausgeführt. Während ANT-XXIII/3 wurde der Schnitt in drei Wochen zweimal wiederholt, was eine bisher nicht vorliegende Information über kurzzeitige Veränderungen in der gesamten Wassersäule erbrachte.

Die Hauptaufgabe während des Fahrtabschnitts ANT-XXV/4 war die Aufnahme der 5 Strömungsmesserverankerungen, die 2008 ausgelegt worden waren, und die Ausführung eines ausgefeilten Netzes von CTD-Stationen entlang der Jason-Flugbahnen #104 und #28 mit der Messung von Spurenstoffen und der Mikrostrukturverteilung. Der südliche Teil der Flugbahn #28 führt genau entlang der Shackleton-Bruchzone, die bis zu 1.500 m unter die Meeresoberfläche aufragt (Abb. 1.1a). Die Shackleton-Bruchzone wirkt im Süden der Drake-Passage für das Tiefenwasser als Barriere. Ein Mikrostruktur-Profiler wurde an mehreren Stationen über dem Kamm des Rückens eingesetzt, um die Intensität der Vermischung zu messen. Die hydrographischen Stationen lieferten Profile der Horizontalgeschwindigkeit und von Temperatur, Salzgehalt, Sauerstoff, Nährstoffen, Chlorophyll-a, Alkalinität und Gesamt-CO_2, Helium/Tritium und Fluor-Chlor-Kohlen–wasserstoffen (FCKWs), um die Wassermassen umfassend beschreiben zu können (Eigenschaften, Herkunft, Ausbreitungspfade, Alter, Vermischung und Veränderung seit der WOCE A21 von 1990) sowie um den Partialdruck von CO_2 und den Beitrag dieses Meeresgebiets zur Quelle oder Senke von atmosphärischem CO_2 zu bestimmen.

Die Drake-Reise war auch eine Gelegenheit, um zu testen, ob das kinematische GPS geeignet ist, die Meeresspiegelhöhe und den Seegang über Entfernungen von Hunderten von Kilometern (etwa 800 km) mit wenigen Zentimetern Genauigkeit zu messen. Die GPS-Empfänger an Bord der *Polarstern* wurden genutzt, um die Meeresspiegelhöhe zu messen. Eine kleine Oberflächenboje, die mit einem GPS-Empfänger ausgerüstet war, wurde genutzt, um die Messungen des *Polarstern*-GPS in Bezug zur Meeresoberfläche zu kalibrieren. Die kleine Boje wurde bei jeder CTD-Station am Tage ausgebracht und blieb mit dem Schiff verbunden.

Fischereibiologen an Bord untersuchten Adaptionsstrategien, mit denen sich die Fische an Temperaturänderungen anpassen. Sie fingen die Fische für ihre Untersuchungen bei King George Island/Isla 25 25 de Mayo mit 4 Fischfallen, die 24 Stunden verankert blieben.

Fahrtverlauf

Wir begannen zwei Tage vor dem Auslaufen auf der *Polarstern* zu arbeiten, um unsere Geräte aufzustellen. Da die hydrographischen Stationen schon kurz nach dem Auslaufen im Eingang der Magellan-Straße beginnen sollten, mussten wir frühzeitig bereit sein. Dank der Effizienz der AWI-Logistik und der Besatzung, waren alle Geräte an Bord und standen bereit, so dass alle dankbar und glücklich ihre

Geräte und Labore vorbereiten konnten. *Polarstern* verließ Cabo Negro, ein Methan-Terminal nahe Punta Arenas, am Abend des 21. März 2009 um 18:00. An Bord waren 45 Besatzungsmitglieder und 45 Wissenschaftler aus 10 Nationen: Deutschland, Frankreich, Argentinien, China, Korea, Niederlande, Österreich, Spanien, Chile und Italien.

Dies war unsere dritte Reise mit der *Polarstern* in die Drake-Passage. Die erste (ANT-XXIII/3) fand im Januar/Februar 2006 statt. Während dieser Reise brachten wir 10 Strömungsmesserverankerungen entlang einer Flugbahn des Jason-Altimeter-Satelliten aus und führten ein Netz mit hydrographischen Stationen zur Messung zahlreicher Spurenstoffe aus. Die Strömungsmesserverankerungen wurden während ANT-XXIV/3 aufgenommen und 5 neue Verankerungen wurden in der nördlichen Hälfte der Drake-Passage, wo der ACC gebündelt ist, ausgebracht. Während ANT-XXV/4 wollten wir diese Verankerungen wieder aufnehmen und hydrographische Stationen entlang der Satellitenbahnen #104 und #28 ausführen, wobei entlang #104 schon 2006 und 2008 gemessen wurde und #28 entlang der Shackleton-Bruchzone führt (Abb. 1.1a).

Wir führten das Sicherheitstraining aus und begannen die Arbeit in der Mündung der Magellan-Straße mit 9 hydrographischen Stationen am 22. März.

Bald bestimmte das Wetter die Operationen des Schiffs und den Ablauf der Arbeiten. Die Wettervorhersage war sehr ungünstig mit einem Tief mit 925 hPa Kerndruck über der Drake-Passage. Wir versuchten hydrographische Stationen in der Le-Maire-Straße auszuführen, mussten aber bald aufgeben, da der Wind zu stark und die Wellen zu hoch wurden und die Gefahr bestand, die Geräte zu beschädigen. Die Vorhersage war mit 11 Beaufort sehr ungünstig und wir suchten hinter der Staateninsel Schutz, um auf besseres Wetter zu warten. Schließlich konnten wir drei hydrographische Stationen in der Le-Maire-Straße ausführen und dampften am 24. März in Richtung Drake-Passage.

- Entlang der Satellitenbahn #104 über die Drake-Passage

Wieder mussten wir zurück und hinter der Staateninsel vor Winden mit 11 Bft Schutz suchen. Schließlich gelang es uns, die nördlichste Verankerung M1 am 25. März aufzunehmen, wobei noch eine erhebliche Dünung vom vergangenen Sturm anstand. Am gleichen Tag versuchten wir M2 zu erreichen, aber der Wind nahm am Abend wieder zu. So fuhren wir wieder zurück und holten die hydrographischen Stationen nach, die wir auf dem Weg zu M2 übersprungen hatten. Am 26. März morgens gelang es uns, M2 bei schönem Wetter aufzunehmen. Wir nutzten das gute Wetter, um weitere hydrographische Stationen auszuführen und nahmen morgens am 27. März M3 auf. Anschließend fuhren weiter zu M4. Diese Verankerung wurde in der Abenddämmerung aufgenommen, als der Wind wieder zunahm und es in Strömen regnete. Am 28. März folgten weitere hydrographische Stationen und wir nahmen die letzte Verankerung M5 am ruhigen und nebeligen Morgen des 29. März auf.

Alle Verankerungen waren aufgenommen. Der Wind nahm wieder zu und erreichte am Nachmittag 8 Bft, so dass keine CTD gefahren werden konnte. Das ungünstige Wetter und der Seegang zwangen *Polarstern*, eine ganze Nacht vom 29. auf 30. März abzuwettern. Die zurückgelegte Fahrtroute mit Vor und Zurück und Drehen bezeugt die schwierigen Wetterbedingungen, die wir während des ersten Teils der Reise vorfanden, und unsere verzweifelten Anstrengungen, unseren Plan so weit wie möglich auszuführen (Abb. 1.1b).

Am 2. April veränderte sich das Wetter vollständig und ein Hochdrucksystem stabilisierte sich über der südlichen Drake-Passage. Über der gesamten Passage herrschten Ostwinde! Daher konnten wir nach der erfolgreichen Aufnahme der Verankerungen eine ausführliche Serie von CTD-Stationen in einem tiefen Canyon, der den West Scotia Ridge von Nord nach Süd in der Mitte der Drake-Passage durchzieht, ausführen. Das Ziel war, die Pfade des Tiefenwassers in dieser komplizierten Topographie zu erkennen und die Vermischung über dieser steilen Topographie zu dokumentieren. Auf Grund der hohen Wellen wurde das Einleiterkabel kurz über der Rosette beschädigt. Die Besatzung musste am 29. April 10 m vom Kabel abschneiden und eine neue Termination setzen.

Da das schlechte Wetter den Fortschritt der Arbeiten verzögerte, wurde zuerst beschlossen, den Stationsabstand zu vergrößern. Dann, als das schlechte Wetter anhielt, mussten einige Stationen ausfallen. Schließlich, als das schlechte Wetter gewonnen hatte, mussten wir den südlichen Teil der Satellitenbahn #104 aufgeben und umkehren, um in Richtung Jubany-Station zu dampfen.

Wir vergrößerten den Stationsabstand. Die letzte Station bevor wir nach Jubany umkehrten, erfolgte morgens am 1. April. Die Station lag an der westlichen Seite der Shackleton-Bruchzone mit einer Wassertiefe von über 5.000 m. Direkt nach diesem Tiefenrekord (die Wassertiefe beträgt in der Drake-Passage durchschnittlich 3.500 m) nahm der Wind wieder auf 10-11 Bft zu und die Wellen erreichten Höhen von 8 m. Das Schiff konnte die Fahrt nur mit 5 kn fortsetzen. Bei Sonnenuntergang erreichten wir King George Island/Isla 25 de Mayo und das Ausbringen der Fischfallen in der Admirality Bay musste auf den nächsten Morgen verschoben werden.

Während dieses ersten Teils der Reise (21. März – 1. April) gelang es uns, zwischen den Tiefdruckgebieten 5 Verankerungen aufzunehmen und 36 hydrographische Stationen auszuführen.

- Aufenthalt bei King Georg Island (2. April)

Die Fischfallen wurden am Morgen in der Admiralty Bay ausgebracht und die Helikopterflüge zur Versorgung begannen. Die beiden Helikopter der *Polarstern* flogen zwischen den Stationen, an denen sie Material aufnehmen sollten, und dem Schiff hin und her. King Geoge Island (Süd-Shetland-Inseln) ist ein kleine Insel (95 km x 25 km), die von der Antarktischen Halbinsel durch die Bransfield-Straße getrennt ist. Über 90% der Insel ist ständig mit Eis bedeckt. Auf der Insel befinden sich 9 Stationen von 8 Nationen: Chile (Frei und Escuero), Argentinien (Jubany), China (Great Wall), Südkorea (King Sejong), Polen (Arctowski), Brasilien (Ferraz), Peru (Machu Picchu) und Russland (Bellingshausen). Die Besatzung organisierte freundlicherweise während der Versorgungsflüge der Helikopter Fahrten mit dem Schlauchboot an Land. Wir hatten alle die Möglichkeit an Land zu gehen, wobei die Mehrheit zur Jubany-Station, die auch das deutsche Dallmann-Labor beherbergt, ging. Einige wurden vom koreanischen Schlauchboot abgeholt, um die King-Sejong-Station zu besichtigen.

Wir nahmen zwei Wissenschaftler auf, die zwei Monate auf Jubany verbracht hatten.

Die Bransfield-Straße ist eine tektonisch aktive Region. In ihr liegt eine sich ausdehnende Bruchzone mit untermeerischen Vulkanen. Einer dieser Vulkane ließ weiter südlich Deception Island entstehen. Gleich bei King George Island/Isla 25 de Mayo liegt der Vulkan Orca (auch Viedoff genannt). Während wir bis zum Morgen warteten, um die Fischfallen wieder aufzunehmen, führten wir eine CTD-Station genau über dem Vulkan und eine daneben aus, um zu untersuchen, ob der Vulkan aktiv ist oder nicht. Die vorläufige Analyse der Daten weist darauf hin, dass der Vulkan aktiv war. Die Fischfallen waren sehr erfolgreich: beinahe 1000 lebende Fische (Aalmuttern) wurden gefangen und unmittelbar in ein Aquarium mit der passenden Temperatur überführt. Wir führten in der Nähe der Fischfallen eine CTD-Station aus.

Anschließend fuhren wir zurück zum Kamm der Shackleton-Bruchzone.

- Zurück nach Norden entlang der Satellitenbahn #28 über die Shackleton-Bruchzone

Die Shackleton-Bruchzone ist ein 800 km langer gerade, schmaler (30 km breit) und ausgeprägter Rücken (mit Spitzen, die im südlichen Teil bis 1400 m unter die Meeresoberfläche aufragen). Der Rücken erstreckt sich über die Drake-Passage von Elephant Island bis Kap Hoorn (Abb. 1.1) Im südlichen Teil liegt er glücklicherweise genau entlang der Jason-1-Satellitenbahn #28.

Wir begannen eine intensive Folge von CTD-Stationen, um den Strom über dem Rücken zu messen. Mit dem *Polarstern*-Fächerlot folgten wir dem Rücken genau, um die Stationen auf den Kamm zu legen.

Unsere koreanischen Kollegen führten Mikrostruktur-Profilmessungen aus. Sie setzten ein profilierendes Gerät mit einer sehr hohen Messfrequenz (512 Hz) ein, das Feinstruktur und damit Vermischung in den oberen 500 m quantitativ erfasst. Es besteht die Hypothese, dass die Shackleton-Bruchzone kräftige Vermischung der Wassermassen hervorruft.

Die Arbeit ging reibungslos und effizient weiter. Jedoch das Ende der Reise nahte und wir mussten den Stationsabstand zwischen den letzten drei Stationen vergrößern.

Auf dem Rückweg wurden 18 hydrographische und 7 Mikrostruktur-Stationen entlang der Jason-Bahn #28 ausgeführt.

Insgesamt konnten wir während der Reise 57 hydrographische Stationen mit L-ADCP ausführen (siehe Stationsliste Annex A.4). Die Fahrtroute der Polarstern ist in Abb. 1.1 dargestellt.

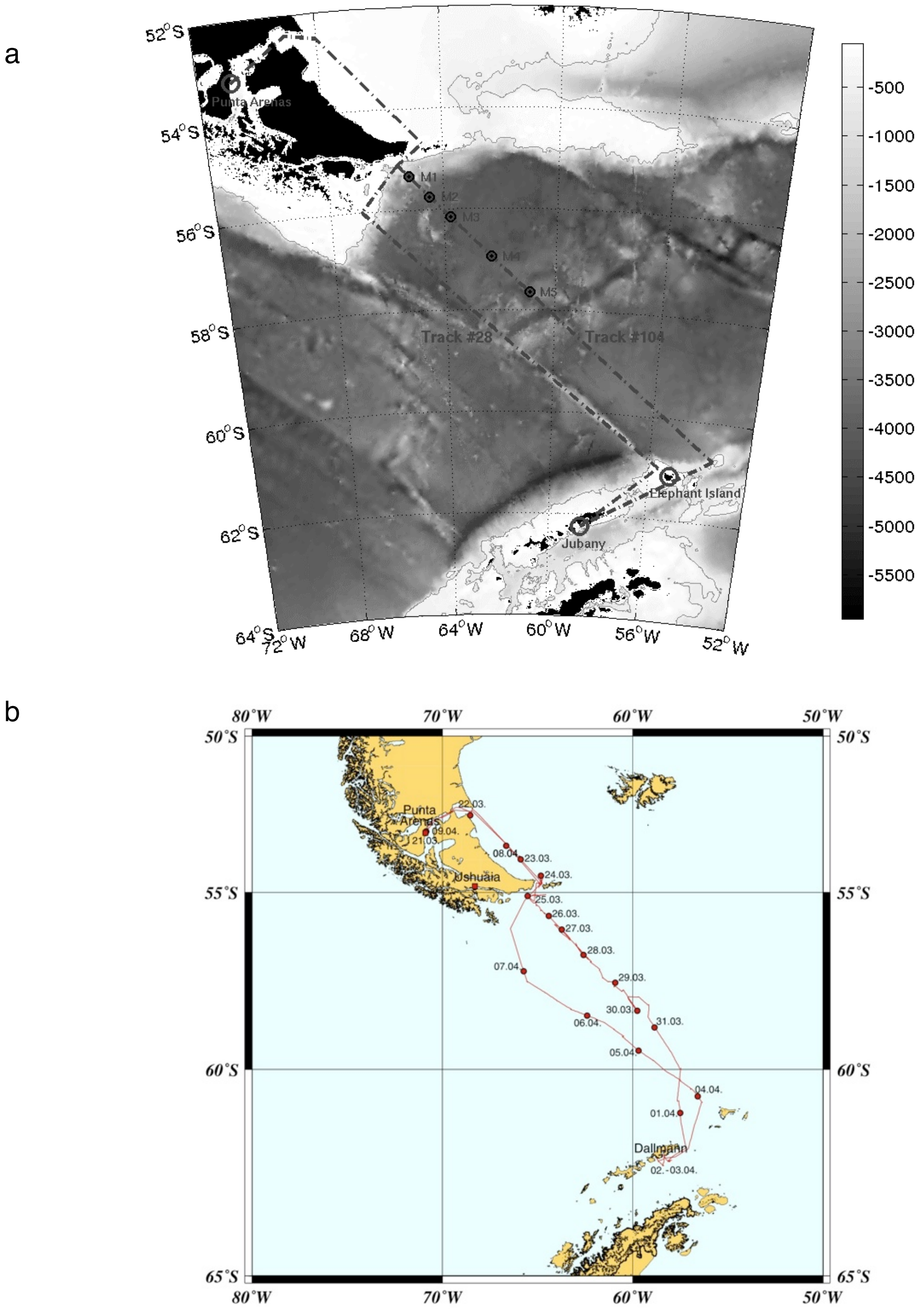

Abb. 1.1: Kurskarte der Polarstern Reise ANT-XXV/4, (a) geplante,r (b) wirklicher Verlauf.
Fig. 1.1: Planned (a) and performed (b) cruise track during the expedition ANT-XXV/4
a: background is bathymetry in meters. Circles indicate the location of the 5 moorings M1 to M5.
b: numbers indicate date (day.month)

SUMMARY AND ITINERARY

The Antarctic Circumpolar Current (ACC), the world largest current, is a key element of the global climate system. This 2000 km broad ring of cold water which encircles the antarctic continent is pushed eastward by the strong westerly wind belt. The ACC is constricted to its narrowest extent (700 km) in Drake Passage thus a convenient place for observations.

Monitoring the ACC transport and water mass characteristics is essential for understanding the coupling of this major current with climate change. It is not an easy matter since the current is concentrated in highly variable narrow bands of swift currents and energetic eddies of all sizes are numerous.

Our experimental set up is designed to use the complementarity between satellite and *in-situ* observations. Satellite altimetry measures the sea level of the ocean along tracks every 10 days with an horizontal resolution of 7 km. The *in-situ* measurements will provide information on the vertical structure of the ocean, information that cannot be obtained by satellite.

The main scientific objective is to determine the seasonal and interannual variability of the total ACC transport, its vertical partitioning between barotropic and baroclinic components, and its horizontal partitioning among the major fronts Subantarctic Front (SAF), Polar Front (PF), and Southern ACC Front (SACCF). In that aim, during ANT-XXIII/3, in January 2006, we had deployed an array of 10 currentmeter moorings along the ground track # 104 of Jason-1 altimetric satellite (Fig. 1.1a). During ANT-XXIV/3 8 of the currentmeter moorings were retrieved (two were lost) and five new moorings were deployed at the locations M1 through M5 (Fig. 1.1a) where the Antartic Circumpolar Current is canalized due to the steep and narrow ridge of the Shackleton Fracture Zone.

The Southern Ocean plays a crucial role in the meridional overturning circulation with the upwelling of the deep water masses, and the formation of bottom and intermediate water masses. The Drake Passage, a rather small region is thought to exert a disproportionately large influence as, because of its geometry, rough topography and its atmospheric forcing, it is a major site for subduction of intermediate waters, intense modification of the deep water masses, outflow of ventilated waters from the Weddell Sea and intense mixing. Therefore, another scientific objective is to examine water masses variability and mixing. Thus full-depth hydrological stations with tracers were performed along track 104 with a high horizontal resolution during ANT-XXIII/3 and ANT-XXIV/3. During ANT-XXIII/3 the section was repeated twice in three weeks providing unprecedented information short time variability througout the whole water column.

Therefore, the main tasks of the expedition were the recovery of the 5 currentmeter moorings deployed in 2008 and the realization of a refined array of hydrographic stations along Jason ground track #104 and along Jason ground track #28 with tracers and microstructure measurements. The southern part of track #28 rides exactly over the Shackleton Fracture Zone the crest of which is only 1,500 m below sea surface (Fig. 1.1a). The Shackleton Fracture Zone acts as a barrier for deep waters in the south of Drake Passage. A microstructure profiler was deployed at several stations over the crest to directly measure the mixing activity. The hydrographic stations provided profiles of horizontal velocity, temperature salinity, oxygen, nutrients, chlorophyll-a, alkalinity, total CO_2, Helium/tritium and Chlorofluorocarbons (CFC's) to properly examine the water masses (characteristics, origin, pathways, age, mixing, modifications since the WOCE A21 1990 cruise) and to compute partial pressure of CO_2 and to assess the contribution of this area to source/sink function CO_2 of the ocean.

The Drake cruise was also an opportunity to test the ability of kinematic GPS to measure sea level and sea state over a distance of a few hundred km (order 800 km) with a few centimeters accuracy. The GPS receivers on board *Polarstern* were used for doing the sea level survey. A small surface buoy equipped with a GPS was used to calibrate precisely the *Polarstern* GPS with respect to the sea surface. The small buoy was deployed (attached to the ship) at each CTD station during the day.

Biologists on board were studying thermal adaptation strategies of fish. During the cruise they aimed at collecting living fish to continue the work at AWI. Their fishing ground was King George Island/Isla 25 de Mayo. Four fish traps were deployed and stayed in place for over 24h.

Itinerary

We started to work on *Polarstern* two days before departure in order to install equipment. As hydrological stations were planned to begin soon after departure across the entrance of the Magellan Strait and we had to be ready in time. Thanks to the efficiency of AWI logistics department and the crew, all the equipment was on board and available, so everybody was grateful and happy and prepared the instruments and laboratories. *Polarstern* left Cabo Negro, a methane terminal just outside Punta Arenas, on 21 March at 18:00. On board were 45 crew members and 45 scientists from 10 nations: Germany, France, Argentina, China, Korea, Netherlands, Austria, Spain, Chile, Italy.

This was our third cruise in Drake Passage on board *Polarstern*. The first one (ANT-XXIII/3) took place in January/February 2006. During that cruise we deployed 10 current-meter moorings along a ground track of the Jason altimeter satellite and carried out a refined array of hydrographic stations with numerous chemical tracers. The current-meter moorings were recovered during ANT-XXIV/3 and 5 new moorings were redeployed in the northern half of Drake Passage where the ACC is concentrated. During ANT-XXV/4, we wanted to recover the 5 moorings and occupy hydrographic stations along two satellite ground tracks: track #104 as we did in 2006 and 2008, and track #28, which straddles the crest of the Shackleton Fracture Zone (Fig.1.1a).

We performed the security and fire drills and started work in the mouth of Magellan Strait, performing successfully 9 hydrographic stations on 22 March.

Weather soon took command on the ship operations and work development. The weather forecast was most unfavorable with a low of 925 hPa over Drake Passage. We attempted to perform hydrographic stations in Le Maire Strait and soon stopped as the wind and waves were too strong and would damage the equipment. The forecast being very unfavorable (11 Beaufort) we had to keep sheltered behind State Island hoping for better weather. We finally performed three hydrographic stations in Le Maire Strait and headed towards Drake Passage on the 24 March.

- Along Track #104 across Drake Passage

We went back to seek shelter behind State Island with 11 Beaufort winds again. Finally, we managed to recover mooring M1 the northernmost mooring on the March 25, in the presence of a fair amount of high swell leftover from the gale. We attempted to reach M2 on the same day, but the wind again picked up in the evening. Thus, we went back to perform the hydrographic stations we had passed in going directly to M2. We managed to recover M2 early on the 26 March with a nice weather. We took advantage of the calm weather to perform hydrographic stations, readily arrived at M3 early on the 27 March swiftly recovered the mooring and continued onto M4. M4 was recovered at dusk as the wind was picking up and rain pouring. We spend the 28 March performing hydrographic stations and recovered the last mooring M5 on the 29 March by a calm and foggy morning.

All the moorings were recovered. The wind picked up again in the afternoon with Beaufort 8, preventing deploying the CTD. The adverse weather and sea state forced *Polarstern* to spend a full night into a weathering position (29 to 30 March). The ship's trajectory with its back and forth progression and turning around testifies for the difficult weather conditions we encountered during this first part of the cruise and our obstinate efforts to carry out the work as planned initially (Fig. 1.1b).

Weather changed completely and early on 2 April, a high pressure system stabilized in the southern Drake Passage and easterly winds were even observed throughout the Passage! Thus after the successful retrieval of the 5 currentmeter moorings we could perform a detailed suite of CTD stations inside a deep canyon which crosses the West Scotia Ridge from north to south roughly in the middle of Drake Passage. The objective was to understand the deep waters pathways in this intricate bathymetry and document the mixing induced by the steep bathymetry. Because of the large waves, the CTD cable close to the rosette got damaged. The crew had to cut 10 m of cable and redo the cable termination on 29 March.

As the bad weather had slowed down work progress, it was first decided to increase the distance between stations, then, as bad weather continued, to skip a few stations and finally, bad weather winning, to abandon the southern part of track #104 and to head towards Jubany hoping for a change in the weather conditions.

We then increased the station spacing and the last CTD station before steering for Jubany, occupied early 1 April, was located on the western side of the Shackleton Fracture Zone and had a depth in excess of 5,000 m. Right after this record depth CTD (average water depth is about 3,500 m in the Drake Passage), the wind and waves picked up again to Beaufort 10-11 and waves up to 8 m. The ship then could only progress at a speed of 5 knots. We arrived by sunset near King George Island/Isla 25 de Mayo and fishtrap deployments in Admiralty Bay had to be postponed until the next morning.

During this first part of the cruise (21 March – 1 April) between depressions we managed to recover the 5 currentmeter moorings and carry out 36 hydrological stations.

- King George Island/Isla 25 de Mayo stop (2 April)

The fish traps were readily deployed in Admiralty Bay in the morning and helicopter flights for supply operations started. The two helicopters from *Polarstern* flew back and forth from the different bases where they had to pick up equipment. King George Island/Isla 25 de Mayo (South Shetland Islands) is a small island (95 km x 25 km) separated from the Antarctic Peninsula by the Bransfield Strait. Over 90% of the island is permanently glaciated. The island hosts 9 bases from 8 different countries: Chile (Frei and Escudero), Argentina (Jubany), China (Great Wall), South Korea (King Sejong), Poland (Arctowski), Brazil (Ferraz), Peru (Machu Picchu), Russia (Bellingshausen). The crew kindly organized rubber boat trips to the island while the helicopters were busy with logistics. We all got a chance to go to shore, the majority went to Jubany station which also hosts a German Laboratory (Dallman), and a few were picked up by a Korean rubber boat for a visit of the King Sejong Base.

We picked up 2 scientists who had stayed at Jubany for two months.

The Bransfield Strait is a geophysically active region. It hosts a fault that is expanding with submarine volcanoes. One of these volcanoes gave rise to Deception Island further south. Next to King George Island/Isla 25 de Mayo is volcano Orca (also called Viedoff). While waiting for the morning to recover the fish traps, we performed one CTD station above the volcano and one just at the side of the volcano to examine whether it is active or not. The preliminary analysis of the data suggests that the volcano was active. The fish traps were highly successful: close to a thousand live fish were captured and immediately put into an aquarium with an adequate temperature. The fish were mostly eelpod type. We performed one CTD station next to the fish traps.
We then headed towards the crest of the Shackleton Fracture Zone.

- Back north along track # 28 over the Shackleton Ridge

Shackleton Ridge is an 800-km-long mostly rectilinear, narrow (30 km wide) and pronounced ridge (with peaks rising to 1400 m from the sea surface in the southern part). The ridge extends across Drake Passage from Elephant Island towards Cape Horn (Fig. 1.1). Its southern part is fortuitously located exactly below Jason-1 ground track #28.

We started an intensive succession of CTD stations hoping to measure the flow crossing the ridge. We closely followed the bathymetry using *Polarstern's* multibeam sounder in order to place the CTD stations on the crest of the Ridge.

Our Korean colleagues started to perform microstructure profiling stations. They have a profiler with high frequency measurements (512 Hz), which quantifies fine structures and therefore mixing in the upper 500 m of the ocean. The hypothesis is that the Shackleton barrier induces strong mixing among water masses.

Work progressed smoothly and efficiently. However, the end of the cruise approaching, we had to increase the distance between the last three stations.

A total of 18 hydrological stations and 7 microstructure stations were carried out along Jason track #28 on the way back.

Therefore, a total of 57 hydrological stations with L-ADCP were performed during the cruise (see detailed list on page 72). The ship track is shown on Fig.1.1b.

2. WEATHER CONDITIONS

Thomas Bruns
Deutscher Wetterdienst

RV *Polarstern* left Punta Arenas on 21 March 2009 at 18:00 lt (22.00 UTC). The weather situation was first characterized by a low with a central pressure of 970 hPa entering the Drake Passage from the Pacific Ocean. Therefore, in the Magellan Strait westerly winds were increasing up to Bft 8 during the following night.

On 22 March a number of CTD-Stations were planned across the eastern entrance of the Magellan Strait. When the above mentioned low had disappeared, a new severe storm had formed west of the Drake Passage, whose central pressure was forecast to fall below 930 hPa in the night (Fig. 2.1). At the position of *Polarstern*, the increase of pressure gradient resulted in westerly winds Bft 7 to 9.

On 23 March, while *Polarstern* was cruising south off the coast of Tierra del Fuego, winds shifted to northwest, still at about Bft 8. In the evening we arrived in the Le Maire Strait between Tierra del Fuego and Isla de los Estados. For the next days it was planned to recover five moorings between 55.2°S and 57.6°S.

In the night to the 24 March the storm moved on a southerly track towards the Antarctic Peninsula (Fig. 2.2). On its northerly flank winds up to Bft 11 and significant wave heights up to 15 meters were expected (Fig. 2.3 and 2.4). It was therefore decided to wait in the shelter of the Le Maire Strait until the storm was over. In fact, the low crossed the Antarctic Peninsula and weakened quite rapidly. However, due to a following low that moved on a more northerly track, weather conditions were still not permitting the planned action.

On the 25 March weak high pressure influence led to a temporary improvement in the weather with westerly winds not exceeding Bft 5. So it was possible to recover the first two moorings on this and the following day. However, already in the afternoon of 26 March the wind increased again to gale force when the fourth but weakest low passed just south of Cape Horn.

Another change in the weather situation took place on 27 March when a large low pressure system developed over the southeast Pacific Ocean moving only very slowly eastward. This offered the chance to finally recover moorings M3 and M4.

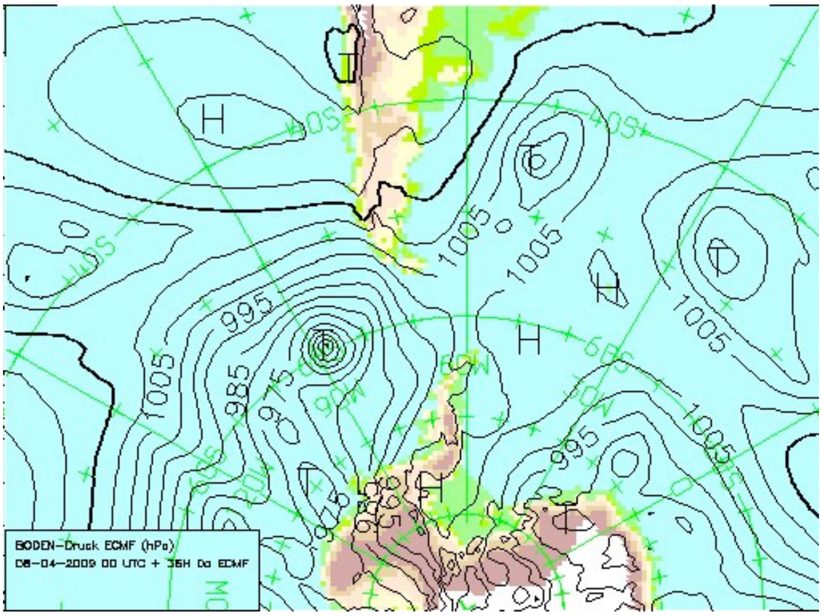

Fig. 2.1: 48-hour surface pressure forecast for 23 March 23 12 UTC

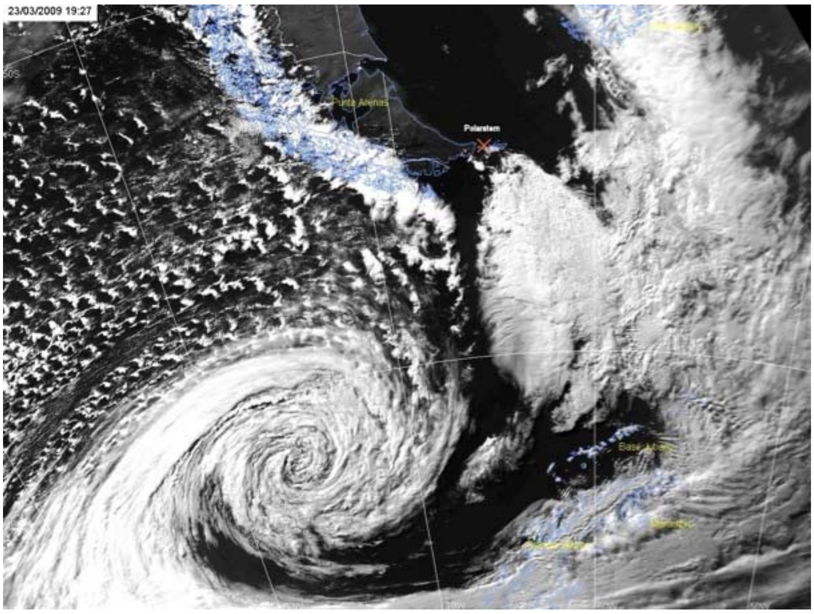

Fig. 2.2: Satellite image (visible channel) on 23 March 19:27 UTC

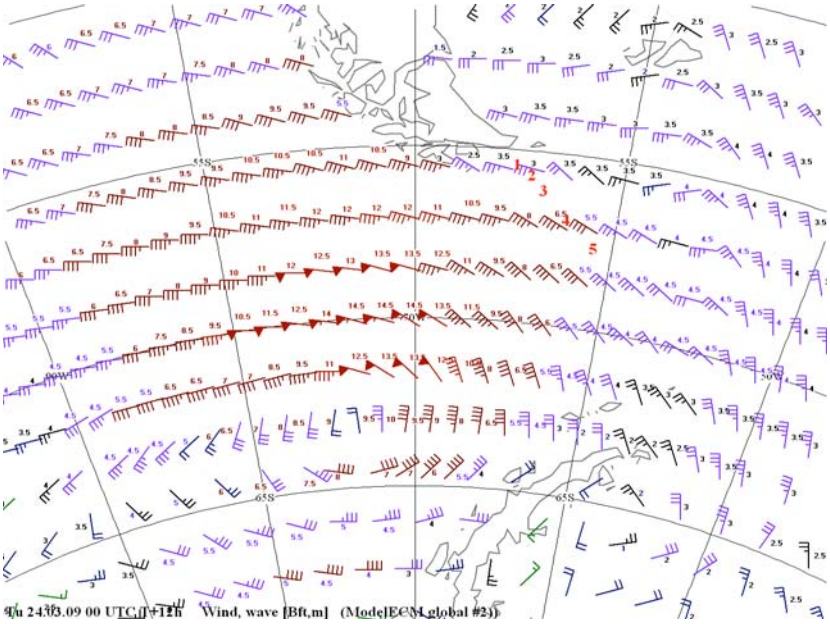

Fig. 2.3: 12hr-forecast of wind force and significant wave height for 24 March 00 UTC. Light red digits 1 to 5 indicate mooring positions.

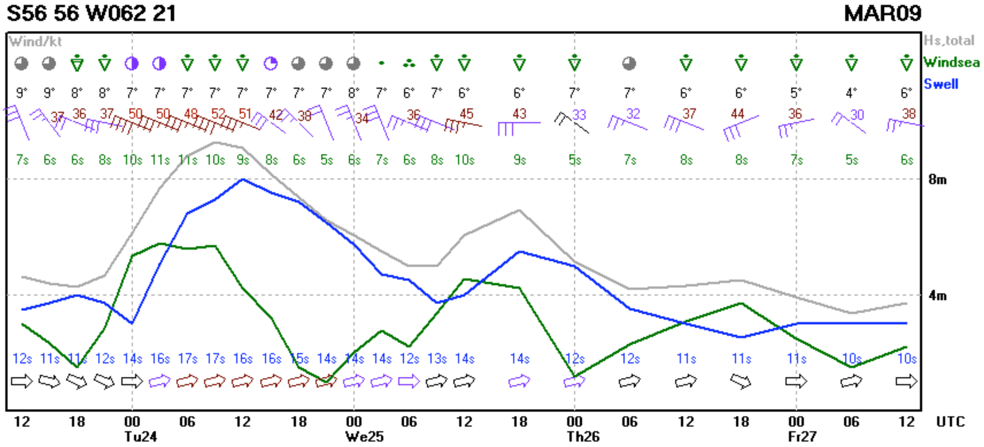

Fig. 2.4: Forecast time series of wind and significant wave height at mooring position M4, of 23 March 12 UTC.

The steering low was slow, but in the night to 28 March a secondary low moved across the Drake Passage and became stationary just at the ships position. After a short gale from northeast winds finally ceased in the centre of the low at 960 hPa. It was raining and visibility was poor when the last mooring M5 was brought on deck. On 29 March, when the remaining CTD-Stations on the way to King George Island/Isla 25 de Mayo were to be completed, the low moved eastward and in its rear *Polarstern* again was drawn into stormy weather. In the night to 30 March Bft 8 was reached for eight hours in a row, with significant wave heights up to 7 meters.

In the mean time, a new but not very noticeable low appeared over the Bellingshausen Sea. On the 31 March it moved northeastward along the Antarctic Peninsula. Shortly after the last CTD-Station was completed a severe storm came up from southeast in the morning of 1 April. After four hours at Bft 7, wind force reached Bft 10 at breakfast time und decreased very slowly to Bft 6 until dinner time.

When the storm was over, a large high over Argentina began to extend across the Drake Passage. The resulting isolated high over the northern Antarctic Peninsula blocked the propagation of low pressure systems into the Passage for four days. Therefore, as a compensation for the previous bad weather, *Polarstern's* stay near King George Island/Isla 25 de Mayo was characterized by light to moderate winds from variable directions. All Helicopter transport was completed on the 2 April under good weather conditions.

The return journey along track 28 of Jason-2 started on the 4 April with quite a number of CTD-stations ahead. The high persisted until the 5 April, before it began to weaken and moved eastward. Weather was good these days with moderate wind form northeast, 2 to 3 m swell form north and only occasional snow showers. On the 6 April a relatively weak low moved eastward just south of Cap Hoorn. On the 7 April, when *Polarstern* arrived at the northernmost CTD stations southwesterly winds of Bft 6 lasted for a few hours in the rear of the low and finally ceased in the afternoon.

The remaining cruise back to the Magellan Strait was characterized by strong to near gale westerly winds when the next severe storm was approaching from the South Pacific Ocean. In the morning of 9 April *Polarstern* arrived in Punta Arenas where this expedition ended.

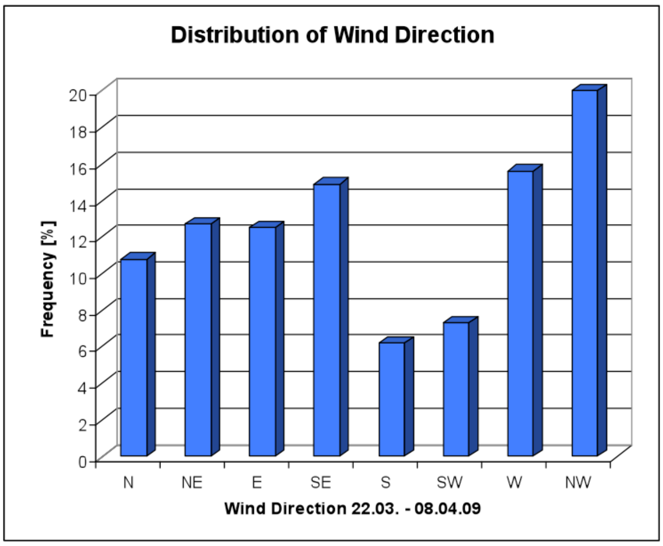

Fig. 2.5: Distribution of wind direction during ANT-XXV/4

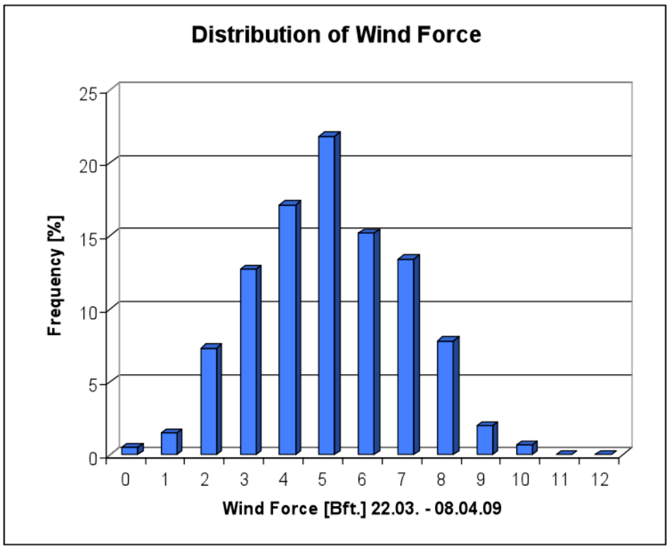

Fig. 2.6: Distribution of wind force during ANT-XXV/4

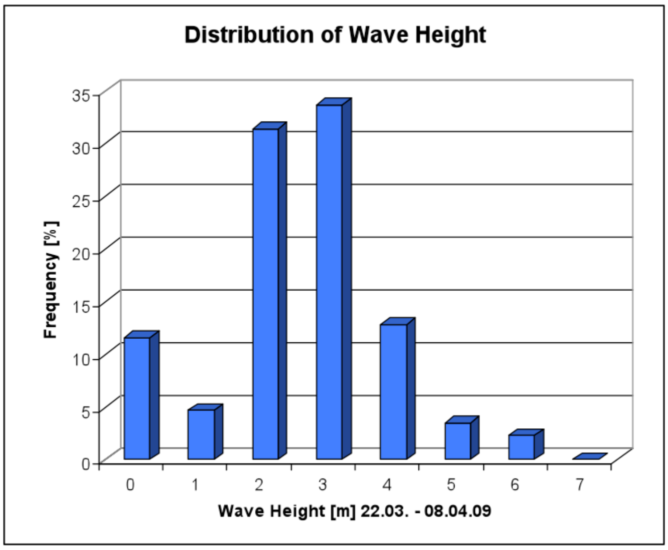

Fig. 2.7: Distribution of wave height during ANT-XXV/4

3. VARIABILITY OF THE ANTARCTIC CIRCUMPOLAR CURRENT AT DRAKE PASSAGE

Nicolas Barré[1)], Mickaël Beauverger[1)], Alejandro Bianchi[4)], Ghyslaine Boschat[1)], Marcella Charo[4)], Sang Su Hong[2)], Sang Chul Hwang[2)], Annie Kartavtseff[1)], Jae Hak Lee[2)], Carlos Mejia[1)], Luigi Nardi[1)], Ana Paula Osiroff[4)], Alberto Piola[4)], Guillaume Pouget[1)], Christine Provost[1)], Mehrad Rafizadeh[1)], Alice Renault[1)], Cristian Rodrigo[5)], Silvia Romero[4)], Martin Saraceno[6)], Nathalie Sennechael[1)], Joel Sudre[3)]

[1)]LOCEAN
[2)]KORDI
[3)]LEGOS
[4)]SHN
[5)]INACH
[6)]CIMA

Scientific background

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

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

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

Objectives

Monitoring the magnitude and variability of the ACC through Drake Passage

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

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

During ANT-XXIII/3 (January - February 2006) an array of 10 current meter moorings (M1 through M10) across Drake Passage was deployed below track 104 of altimetric satellite Jason-1 (Fig. 3.1).

During Expedition ANT-XXIV/3 (April 2008 ; E . Fahrbach and H. de Baar, 2010) 8 of the 10 moorings were retrieved (M2 and M8 were lost) and 5 new moorings were deployed at locations M1 through M5) to pursue the time series series in the northern Drake Passage (Fig. 3.1) where the flow is the strongest and where low frequency modes of variability in sea surface height have been identified (Barré et al., 2008).

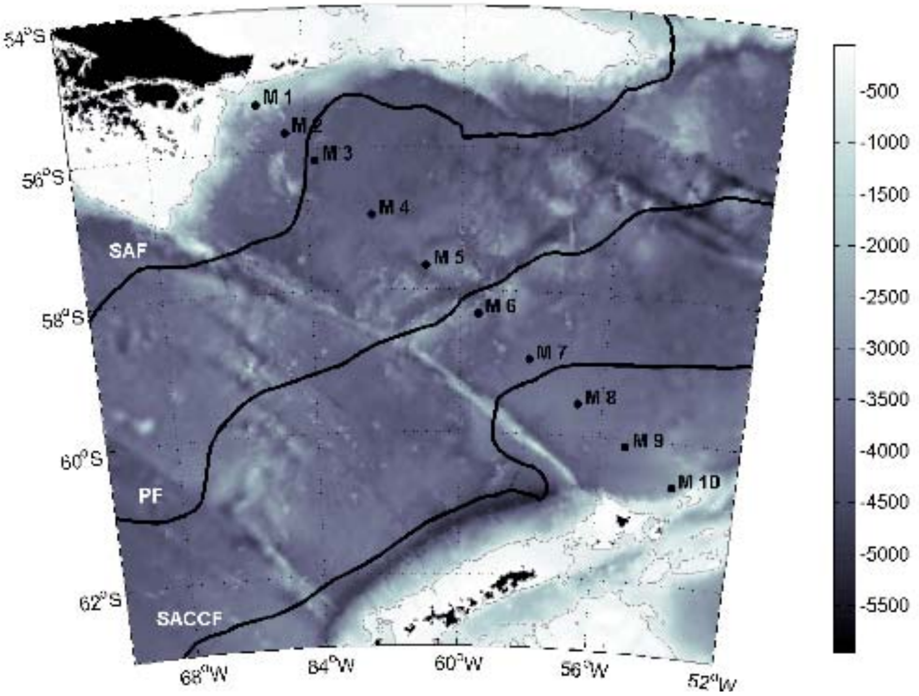

Fig. 3.1: Location of the moorings (M1 through M10). The climatological location of the major ACC fronts: SAF, PF and SACCF (Orsi et al., 1995) is indicated.

Thus, one of the objectives of ANT-XXV/3 was to retrieve the 5 moorings (M1 through M5) redeployed in 2008.

Validation of the altimetric signal

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

The upward-looking ADCPs on moorings M1 and M3 (Fig. 3.1) were planned to provide valuable data for validation.

Role of high frequencies and transients

The current meter data will permit to investigate the dynamic role that eddies play in the ACC. Although one of the major goals of DRAKE is to calibrate and verify satellite sea surface height with *in-situ* observations, the data also fill a lack of subsurface observations that are needed to address recent hypotheses about the dynamics of the ACC. Three questions will be addressed with these data: (1) what are the spatial modes and frequency distribution of variability of temperature, salinity, velocity, and eddy heat fluxes, (2) how do eddy heat fluxes relate to wind forcing, and (3) are there statistically significant changes in eddy properties since 1980? Thus in addition to a basic description of spatial and temporal structure of the velocity fields, mooring-derived eddy heat fluxes over the 3 years will also be analyzed in a similar manner. Wind forcing has increased in the past decade and mid-level waters have warmed slightly, yet the role of eddies in mediating this response below the surface is poorly understood. The eddy response to wind forcing is assumed to be linear but needs to be tested directly in Drake Passage. Determining the spatial distribution and forcing mechanisms of eddy fluxes and internal waves is critical to understanding the response of the Southern Ocean to long-term changes in wind-forcing.

Variations in the properties of water masses

The Drake Passage is the entry point for the water masses from the Pacific into the Atlantic Ocean. In Drake Passage water masses over the whole water column undergo substantial modifications as they mix with water from antarctic origin. Moreover, interannual and interdecadal variation in water mass properties have been examined at the intermediate (Naveira Garabato et al., 2009) and deep levels (Meredith et al., 2008).

A refined array of hydrographic stations with tracers and LADCP was performed twice in three weeks along track #104 during ANT-XXIII/3. The analysis showed large variations in properties of deep water masses in less than three weeks that were associated with mesoscale activities (Sudre et al., 2009). The section along track #104 was occupied again with hydrographic stations with tracers and LADCP during ANT-XXIV/3. The southern part of sections in the Ona Basin exhibited a lot of fine structures proof of an intense eddy induced isopycnal mixing which is not found upstream of the Shackleton Fracture Zone (Barré et al., 2008).

The cruise plan was to perform two hydrographic sections across Drake Passage: one along Jason track #104 as during ANTXX-III/3 and ANTXX-IV/3 and another one along Jason track #28. Jason track #28 is located about 55 nm to the west of track #104 and its southern part rides exactly over the to of the Shackleton Fracture Zone, the crest of which is only 1,500 m below sea surface (Fig. 3.2). These two tracks define a closed box.

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

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

Mixing

Observations in the southern ocean suggest that mixing is intense and widespread, even well above rough topography. These high mixing rates have retained much attention as they are key to the oceanic overturning circulation. Particularly high mixing rates have been estimated in the Drake Passage (Naveira Garabato et al., 2004, 2007). However mixing rates remain poorly constrained primarily because only few direct observations exist in the region. Therefore beyond getting indirect informations from the CTD, the LADCP and moorings, we also want to get direct microstructure measurements that can explicitly resolve small scale diapycnal mixing. High levels of diapycnal mixing are expected over the crest of the Shackleton Fracture Zone where microstructure measurements were planned.

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Work at sea

3.1 Moorings

Mickael Beauverger[1], Sang Chul Hwang[2], Chang Su Hong[2], Annie Kartavtseff[1], Jae Hak Lee[2], Christine Provost[1]

[1] LOCEAN
[2] KORDI

The 5 moorings deployed during ANT-XXIV/3 in April 2008 at locations M1 through M5 (Fig. 3.1.1) were readily recovered during the southbound transect, thanks to the POSIDONIA system on board *Polarstern* and the crew efficiency.

The data from the ADCPs, currentmeters and seacats were downloaded on board *Polarstern*. The data return is 100%.

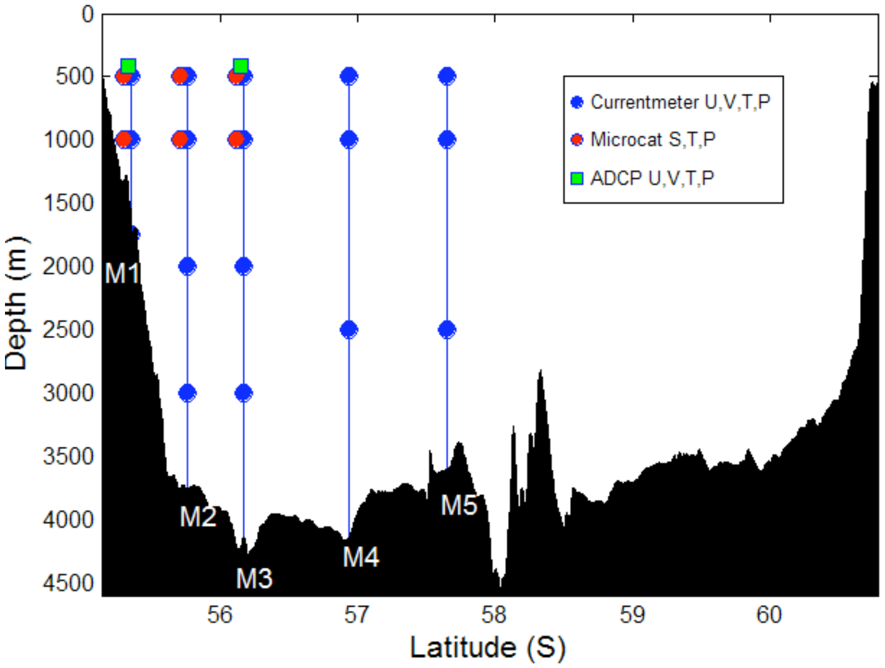

Fig. 3.1.1: Distribution of instruments on the 5 moorings M1, M2, M3, M4 and M5

The uncalibrated data from mooring M5 (Fig. 3.1.2) show the high degree of coherence on the vertical except for a few events.

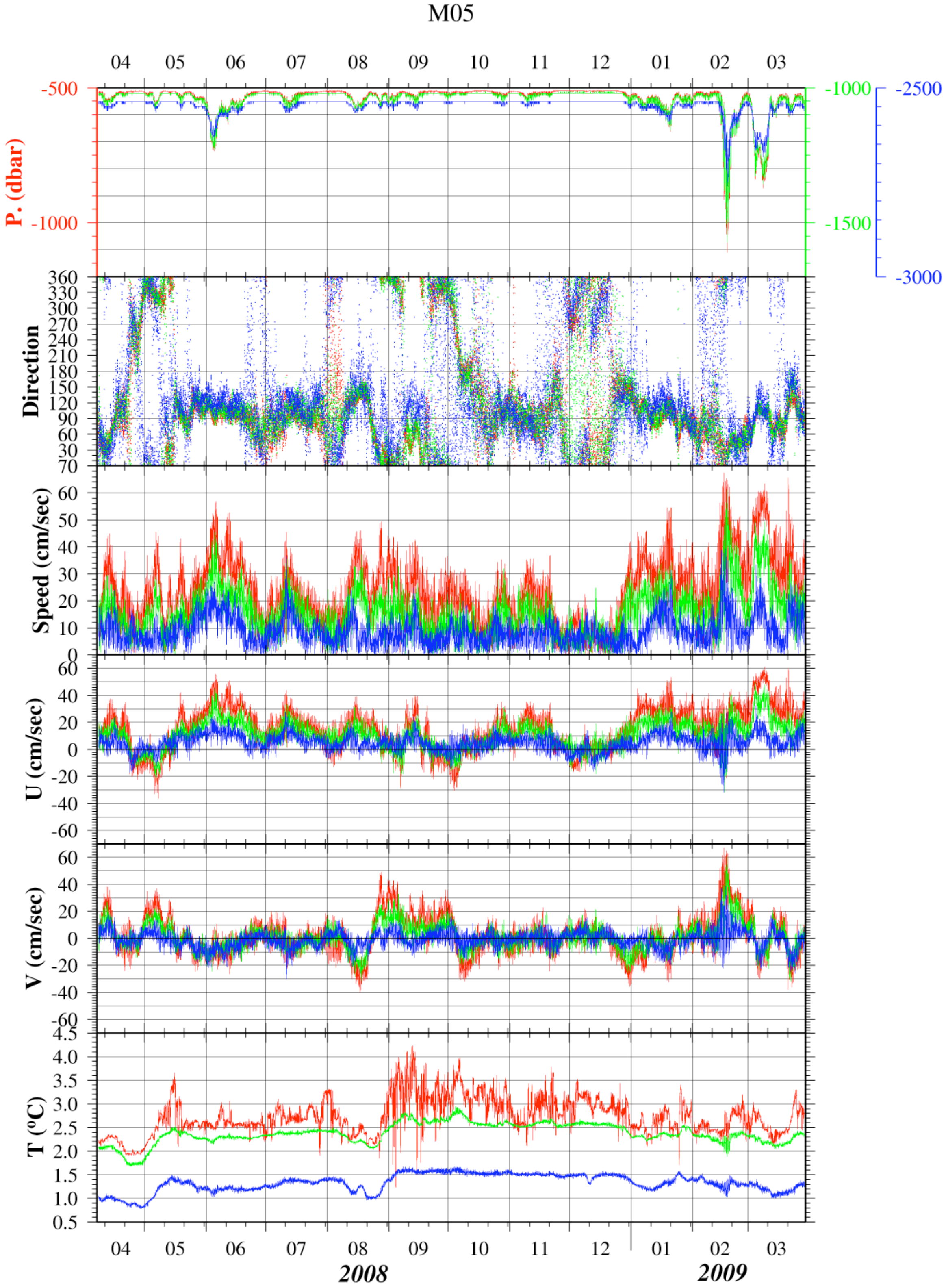

Fig. 3.1.2: Uncalibrated time series from mooring M5. Color code correspond to the 3 currentmeters placed at different depths: red about 550 db, green about 1000 db and blue about 2600 db.

As a result of the three Drake cruises on *Polarstern*, here is a summary of the gathered mooring data:

M1: > 3 years (39 months) (ADCP)
M2: 1 year
M3: > 3 years (ADCP)
M4: > 3 years
M5: > 3 years
M6: > 2 years (27 months)
M7: > 2 years (27 months)
M8: nothing
M9: > 2 years (27 months)
M10: > 2 years + 1 year (KORDI)

Therefore over 3 years of data were obtained in the Yaghan Basin and more than 2 years in the Ona Basin with a data sampling rate of either 30 minutes or 1 hour.

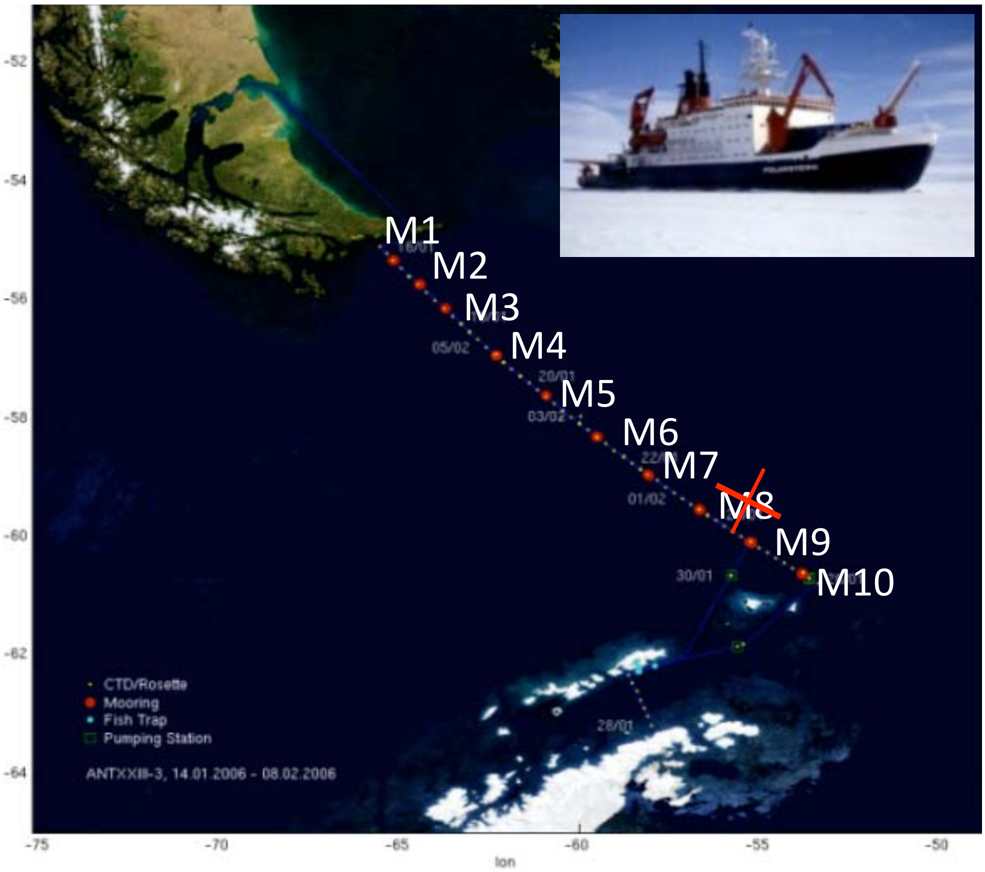

Fig. 3.1.3: Location of the currentmeter moorings along Jason track #104

Expected results

The data to be gathered will provide

- new information on the velocity field in the northern Drake Passage where the flow is the strongest. More than three years of data will then be available allowing precise quantification of time scales, vertical structure, transients, mean flow, seasonal and interannual variability (from current meters and full depth LADCP).
- A better understanding of the altimetric signal in the Drake Passage,
- a precise quantification of the mass and volume transport through DRAKE on the mean and variability, a precise distribution of the flow between the three fronts making up the ACC,
- a precise estimation of the exchanges between the PF and SAF in the Yaghan Basin (Northern DP),

3.2 Hydrographic station work with CTD-O_2 and water bottle sampling

Alberto Piola[1)], Joel Sudre[1)], Nathalie Sennéchael[1)], Silvia Romero[1)], Ana Paula Osiroff[1)], Carlos Mejia[1)], Mehrad Rafizadeh[1)], Alejandro Bianchi[1)], Nicolas Barré[1)], Guillaume Pouget[1)]

[1)] SHN
[2)] LOCEAN

Work at sea

Throughout the cruise we used a Sea-Bird Electronics (SBE) 911*plus* CTD fitted with a Digiquartz pressure (S/N 63488) sensor, and SBE conductivity (S/N 1075) and temperature (S/N 1327) sensors. Additional sensors fitted in the CTD were a SBE 043 dissolved oxygen (S/N 0214), a Chelsea Aqua 3 fluorometer (S/N 088-1002-056) and Chelsea/Seathech/Wetlab Cstar transmissometer (S/N CST-1190DR). The underwater unit was also fitted with a Benthos PSA-916 altimeter (S/N 1228), kindly made available by the *Polarstern*. Based on the altimeter readings most deep water casts were taken to within 15 - 20 m of the bottom. CTD casts in the Magellan (stations 213 - 221) and Le Maire Straits (stations 222 - 224), as well as within Admiralty Bay (stations 256 - 258) were taken to within 10 m of the bottom. The underwater unit was also fitted with two lowered Acoustic Doppler Profilers (LADCP) and the associated battery package. Weights were attached to the frame to provide more stability during deployment.

Water samples were collected for the analysis of helium, chlorofluoromethane (CFC), dissolved oxygen, alkalinity, nutrients, pigments, salinity, and phytoplankton at different levels. Procedures for each of these samples are reported separately. Samples were collected using a Sea-Bird Electronics SBE32 carrousel (S/N 329604-0025) with 24 bottle positions fitted with 22 Niskin bottles, each of 12-liter capacity. Two bottle slots (18 - 19) were not used to provide space for the upward looking LADCP. To prevent CFC contamination *Polarstern's* Niskin bottles fitted with stainless steel springs were used throughout the cruise.

Real time CTD data acquisition was carried out using the SBE Seasave software Win32 version 5.39c. NMEA GPS date, time and position data were recorded, but the NMEA message generated by the *Polarstern* navigation system was not in the format expected by Seasave. Consequently, the date had to be corrected.

A total of 57 hydrographic stations were carried out during ANT-XV/4.

The first 12 CTD casts were occupied in shallow waters at the eastern mouth of Straits of Magellan (stations 213 - 221, 22 March 2009) and at Le Maire Straits (stations. 222 - 224, 24 March 2009). These regions are important water mass inputs to the productive Patagonian shelf (see section 8).

Hydrographic stations down the continental slope of South America in northern Drake Passage (225 - 227) were occupied on 25 March 2009. The south bound crossing of Drake Passage along Jason track #104 was completed on 30 March 2009.

After departing Jubany, on 2 April 2009 we occupied two hydrographic stations in Bransfield Strait, one within the crater of the Orca seamount (256) and one outside (257), and one station close to the location of the fish traps in Admiralty Bay (258).

The northbound Drake Passage crossing closely followed the summit of Shackleton Fracture Zone and Jason track #28 and ended on 7 April 2010.

The location of the stations in Drake Passage are shown on Fig. 3.2.1.

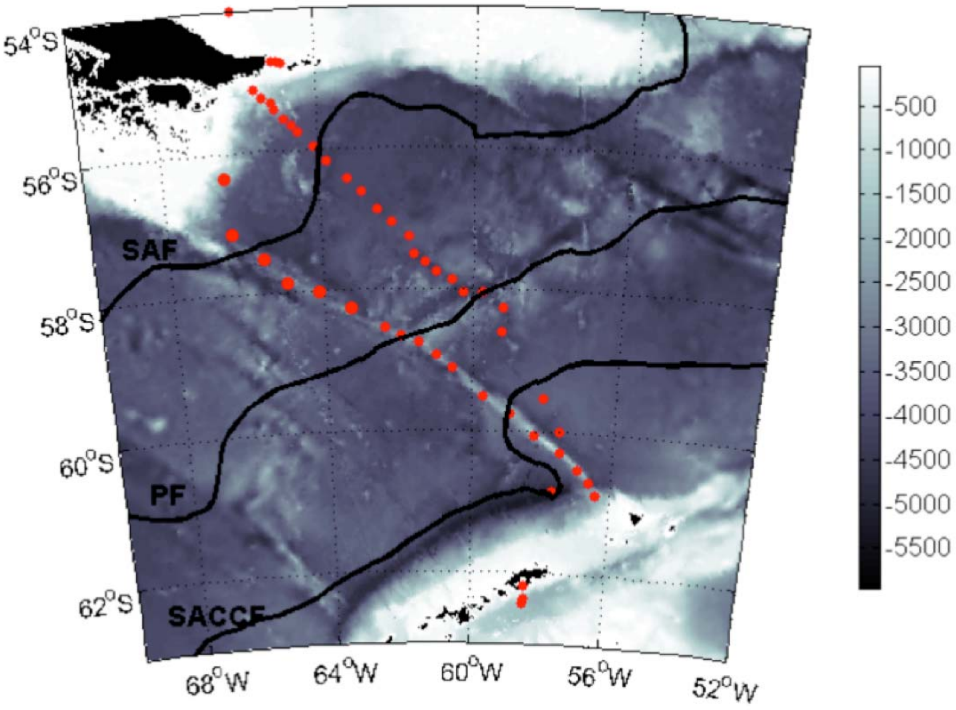

Fig. 3.2.1: Location of the hydrographic stations. Background is bathymetry in m.

Preliminary results

Preliminary potential temperature and salinity sections across Drake Passage are shown in Fig. 3.2.2.

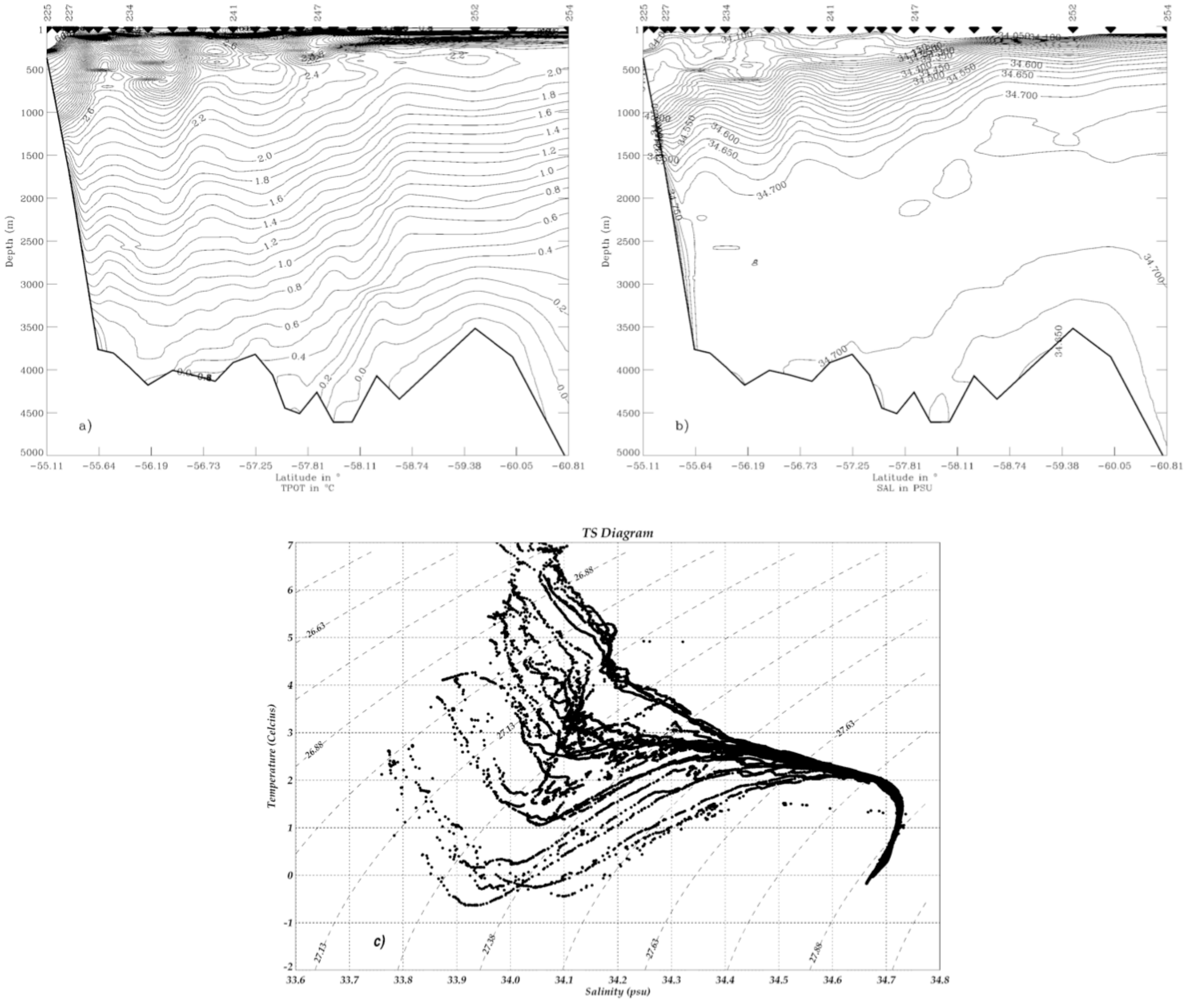

Fig. 3.2.2: a) Preliminary potential temperature, b) salinity sections and c) Theta – S diagram across Drake Passage for southward journey.

Instrument performance

Pressure, Temperature and Conductivity

The pressure sensor calibration was carried out 28 November 1994. The CTD pressure readings on deck before and after each cast were recorded and were typically less than 0.2 dbars. Temperature and conductivity sensors were calibrated 17 September 2008, prior to their shipment for the ANT-XXV/4 expedition. The CTD derived salinity data were contrasted against water sample salinities determined on board (reported separately). Throughout the cruise the conductivity sensor performed within specifications.

After completing the Magellan Straits survey a defective tubing connection between the T-C and the O_2 sensor was identified and fixed. As a result, the CTD oxygen from stations 213 - 221 will require a special calibration based on Winkler O_2 derived from bottles.

Oxygen

Using the most recent available calibration (14 April 2007) the SBE43 O_2 sensor presented a large negative bias (~ 60 -160 μmol/kg) against Winkler measurements, with larger errors for higher dissolved oxygen concentrations (Fig. 3.2.3). We contacted Sea-Bird via email to report the error and it was suggested that the behavior was probably associated with aging of the O_2 sensor. Following SBE recommendation, a preliminary adjustment was performed. The adjustment consists of determining a new *Soc* coefficient by multiplying the old coefficient by the rate of Winkler/SBE43 O_2 concentrations in ml/l (SBE Application Note 64-2, updated April 2008). Though the adjustment eliminated the initial gross bias of the SBE43, comparison of bottle derived O_2 data with WOCE data and ANT-XXII/3 data suggest that our Winkler values may also be off by several μ/kg. Therefore final oxygen data must await a post cruise calibration, preferably by the manufacturer.

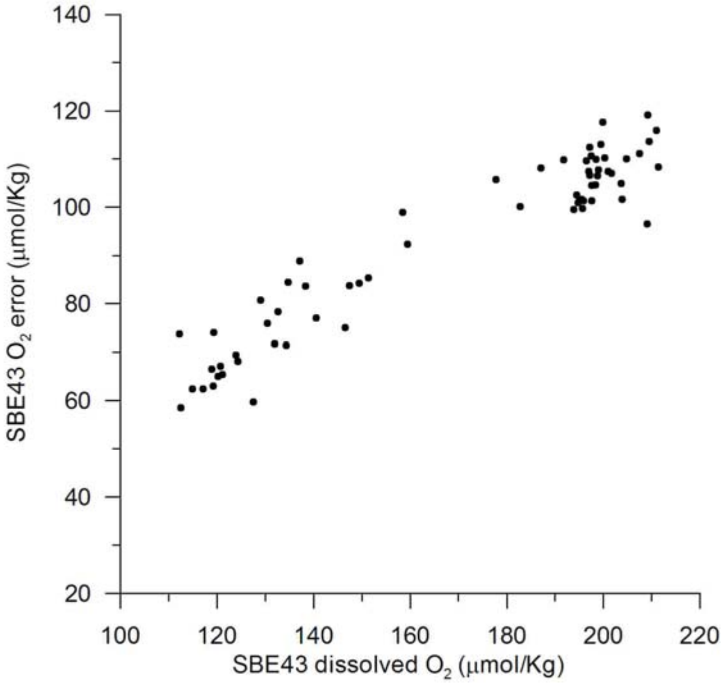

Fig. 3.2.3: initial SBE43 O_2 error as a function of SBE43 O_2 based on the calibration coefficients from 14 April 2007.

Sea cable

The sea cable was damaged twice during the cruise. First, an attempt to occupy the first station in Le Maire Strait (station 222) was cancelled because the heavy swell caused the underwater package to “float”, causing the wire to slack between the sheave and the winch during deployment. The end termination was remade, weigh was added to the CTD frame (~80 kg), and work continued only after weather conditions improved. The second event was also associated with heavy swell during station 247 (30). Analysis of the CTD descent rate and the sea cable tension revealed that several times during descent the underwater package sank at speeds slightly higher than 2 m/s. During these periods, lasting up to 6 - 8 seconds, the sea cable tension dropped to zero and then increased abruptly 6 - 8 KN. These observations indicate that the 2 m/s descent rate is close to the package free fall speed, during which the sea cable tension went to zero, and that the abrupt tension increase when the ship rolled in to board probably caused the sea cable damage near the CTD (~10 m).

3.3 Salinity samples

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Servicio de Hidrografia Naval, Buenos Aires, Argentina

In order to check the correct behavior of the CTD conductivity sensor, salinity samples were analyzed with an Autosal 8400B from GUILDLINE Instruments, on board the *Polarstern*. The instrument belongs to the AWI and is installed following the User’s Manual recommendations, at a lab with a strictly stabilized temperature (22.3 – 22.9°C). The SOFTSAL Software from Guideline Version 3, 1997 was used together with an Optoisolated Interface Box that connects the BCD port to the Autosal with a PC COM port. This software allows to fix critical standard deviations for single measurements and for three consecutive measurements of each sample.

Water samples for salinity measurements were taken from different levels. From stations 1 to 14, between 2 and 3 samples were collected at the deepest levels (Niskin bottles 1 to 3). From Stn. 15 to 18, discrete samples were increased to 8 or 9. From Stns. 19 to 39 samples were collected at the four deepest levels (Niskins 1 to 4) and from Stn. 40 on, salinity samples were increased again in order to make a more detailed analysis of the CTD conductivity sensor behavior, with pressure.

A total of 272 samples were measured and 11 IAPSO Standard bottles were used. The first 10 bottles correspond to batch P150 (22 May 2008), the last one corresponds to P146 (12 May 2005). All the samples were measured in 7 runs as follows:

3.3 Salinity samples

RUN #	Number of Samples Measured	Run Average of the Mean Std Dev of 3 consecutive
1	**21 (stns 2 to 9)**	**0.00070**
2	**43 (stns 10 to 18)**	**0.00084**
3	**49 (stns 19 to 30)**	**0.00064**
4	**28 (stns 31 to 37)**	**0.00060**
5	**50 (stns 38 to 45)**	**0.00059**
6	**60 (stns 46 to 53)**	**0.00058**
7	**30 (stns 2 to 9)**	**0.00058**

For all runs, critical standard deviations for single measurements were fixed at 0.0015 and for the three consecutive readings, the standard deviation was fixed at 0.0020 for the first and second run, but it was reduced to 0.0015 for the rest of the runs.

The first 12 stations correspond to two transects made at the Magellan and Le Maire Straits, with a maximum depth of 110 m. For a preliminary analysis based on (S_{ros} – S_{ctd}) differences the former stations were not included, and statistics were obtained only for the group of stations ranging from 13 to 57. The results obtained indicate a CTD performance within specifications. The total number of samples measured in this group was 227.

The minimum and maximum (S_{ros} – S_{ctd}) Deltas were -0.0092 and 0.0091, respectively. The mean value was 0.00014, and the standard deviation was 0.0025.

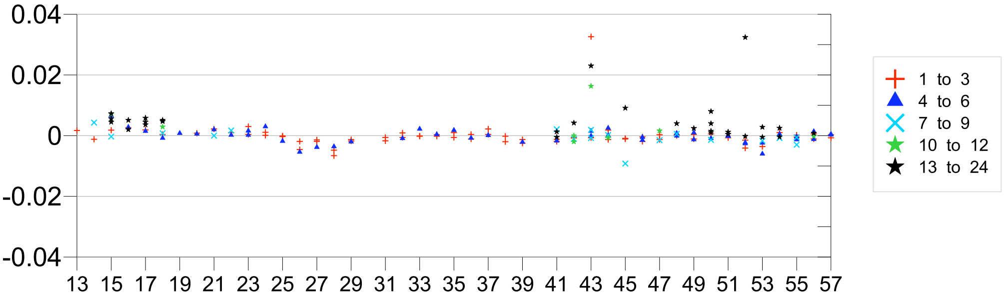

Fig. 3.3.1: (S_{ros} – S_{ctd}) Deltas vs. Stn. Number, for stations 13 to 57. Different classes show number of Niskin bottles (red: deepest ones, black: shallowest ones)

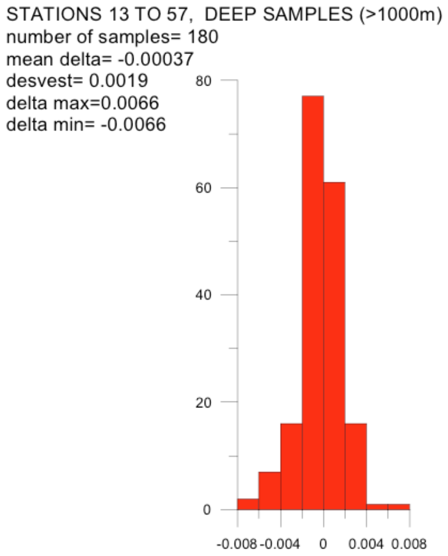

Fig. 3.3.2: Delta ($S_{ros} - S_{ctd}$) histogram for samples deeper than 1,000 m

3.4 Dissolved oxygen measurements

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[2)]LOCEAN, Universite Piere et
Marie Curie, Paris, France.
[3)]LEGOS, Toulouse, France

Water samples were collected for the analysis of dissolved oxygen at each CTD cast. Dissolved oxygen concentrations were determined according to the Winkler Method (Strickland and Parsons, 1972) using a potentiometer titrator (Mettler DL21). Thiosulphate used for the titration was standardized with a solution of Iodate Standard (0.01N) from Ocean Scientific Instruments Limited. Replicate samples were collected at the shallowest and deepest depths at each CTD cast. The whole water column was sampled at eleven different levels every other Niskin bottle starting at the bottom. A total of 617 samples were collected during ANT-XXV/4 cruise. These data will be used to ensure a proper calibration of the SBE43 dissolved oxygen sensor. A vertical transect of dissolved oxygen across the Drake Passage from South America to King George Island/Isla 25 de Mayo is shown on Fig. 3.1.9.

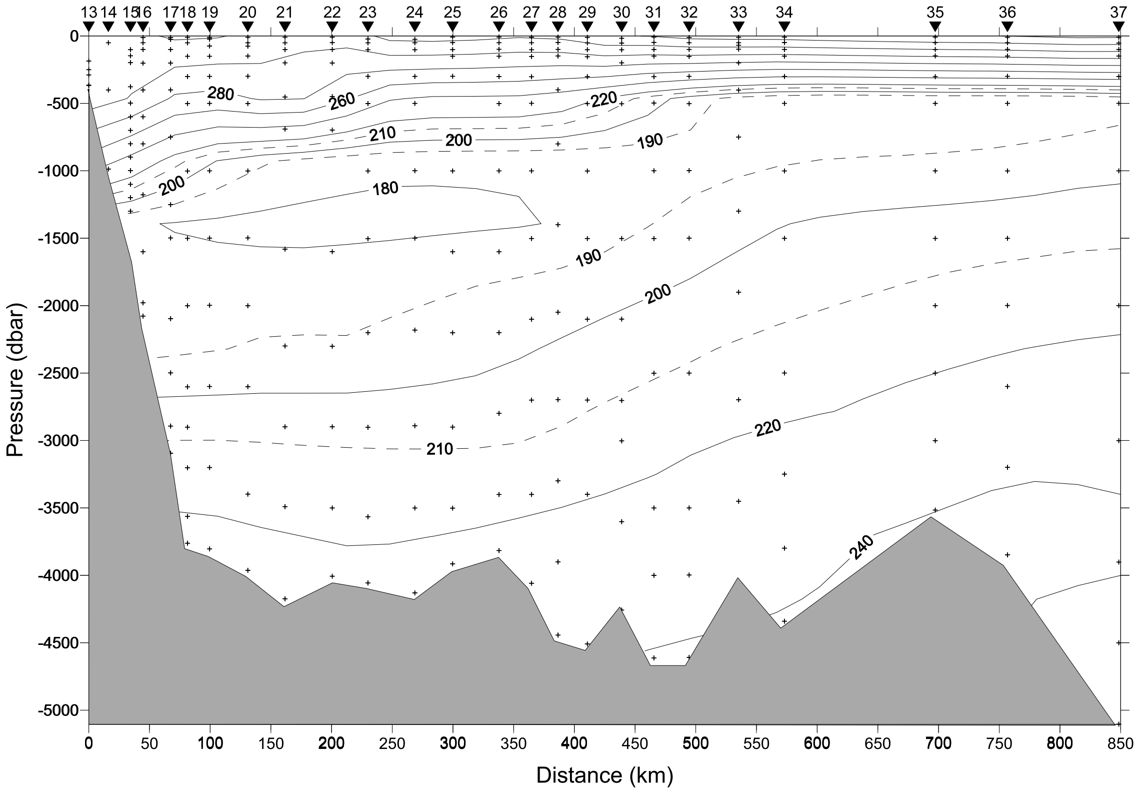

Fig. 3.4.1: Vertical distribution of dissolved oxygen along the southbound transect

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3.5 LADCP measurements

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Work on board

The measurements were carried out with two RDI Workhorse 300 kHz ADCPs attached to the CTD rosette. A Master/Slave configuration was used in which the Master ADCP was down-looking and the Slave ADCP was up-looking. An external battery case was connected to the two ADCPs with a star cable and supplied power to the 2 ADCPs.

The Master ADCP was instructed to send one ping per ensemble and one ensemble per second. Using a synchronization signal the two ADCP emitted their ping simultaneously. With 20 depths cells, each having a size of 8 meters, and a lowered speed of about 1 m/s, each ADCP were expected to perform one profile per second with a theoretical range of about 160 m. In fact, the range was about 120 m for the down-looking ADCP and 100 m for the up-looking ADCP. Between two consecutive stations, the data from the two ADCPs were downloaded from their internal memory card and the power supply was checked.

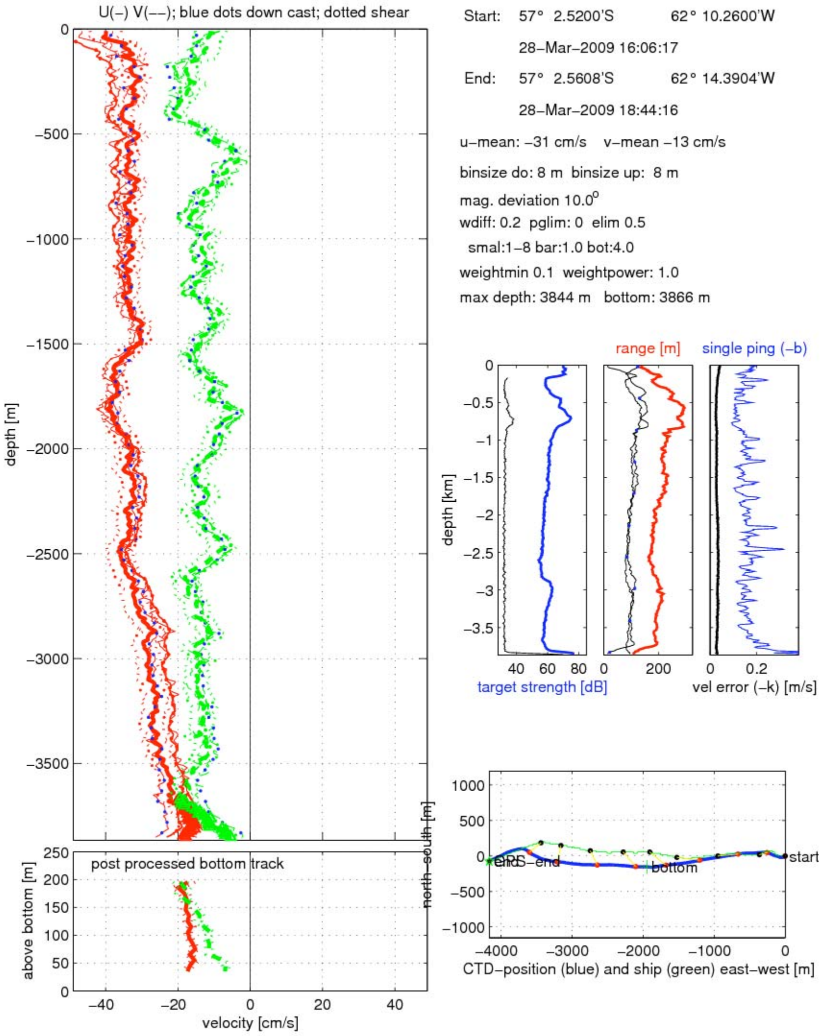

Fig. 3.5.1: LADCP processing with the IFM-GEOMAR/LDEO software: station 241

The two ADCP worked properly for the first five stations in the Drake Passage. At the sixth station however, one beam of the upward looking ADCP showed weakness and a compass difference was observed between the up- and downward looking ADCP. After several stations with the same problem, the upward ADCP was replaced by a spare one.

After the replacement, the deployment of the up-looking ADCP did not work for the first station but the problem was resolved for the following station by changing the software version of the ADCP. The four beams of the new one worked properly until the end of the cruise but the difference in the compass remained and was not constant from station to station. Therefore, this problem was maybe resulting from a default in the down-looking ADCP and it will be handled and corrected in the processing.

Preliminary results

The computation of the currents over the whole water column was then performed using the software from IFM-GEOMAR/LDEO developed by Martin Visbeck [1] and Gerd Krahmann, version 10.6 released in June 2008. This process, using a linear inverse method, allows the use of external data such as CTD measurements to correct from speed of sound and to know the depth, the ship navigation from the GPS sensors, the velocity of bottom-track data from the downward looking ADCP to constraint the inversion and the surface detection from the upward looking ADCP.

The software computed the two components of the horizontal current (Fig. 3.5.1), the error on the velocity amplitude and the rotation, tilt and trajectory of the rosette under the ship during the station.

The velocity amplitude error was quite small, around 3 to 4 cm/s, through the entire water column for all stations, with few exceptions. When the upward ADCP did not work or when the data between the two ADCP disagreed, then the error on the velocity amplitude is higher and around 5 to 10 cm/s.

Expected results

For the preliminary processing, the data coming from ship ADCP were not used. This will be in a second processing back home. The first 300 meters will be thus better constraint and the error on the velocity amplitude at the surface will be reduced.

The LADCP data will be used to give an estimation of the transport across the Drake Passage for the two sections that were performed and the results will be compared with the same data collected in 2006 and 2008. Mixing rate estimations using the vertical wavenumber spectral method for shear will also be computed.

References

[1] Deep velocity profiling using lowered acoustic doppler current profilers: Bottom Track and Inverse solutions, Martin Visbeck, JAOT 2002, Vol 19, pp.794-807

3.6 Dissolved nutrients concentrations

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Objectives

The distribution of dissolved nutrients (nitrates+nitrites, phosphates and silicates) will give us information on water masses and pathways, variability in water mass characteristics in the Drake Passage, cold water route of the thermohaline circulation.

Work at Sea

At each station, discrete bottle samples were collected at all levels for the analysis of dissolved nutrients concentrations: nitrates+nitrites, phosphates and silicates which were measured within a few hours after collection. Inorganic nutrients were determined with a Technicon Auto Analyzer II belonging to LEGOS. The determination of nitrate and nitrite is based on the method described by Armstrong et al. (1967), silicate was measured according to Grasshoff et al. (1983) and phosphate according to Gordon et al. (1993). Preparation of primary standard materials and reagents were done following the WOCE protocol (Gordon et al., 1993). Duplicates were collected at the deepest and shallowest levels at each CTD station. Ten replicates were collected three times to better assess the reproducibility of the measurements.

A total of 1450 samples was collected throughout the whole ANT-XXV/4 cruise.

Preliminary and expected results

Vertical sections along the outward journey from Punta Arenas to King George Island/Isla 25 de Mayo are presented below showing the crossing of the Subantarctic Front (SAF) and Polar Front (PF). Eddies were present north of the Polar Front. Fig. 3.6.1 features silicates in μmol/kg, Fig. 3.6.2 phosphates in μmol/kg and Fig. 3.6.3 nitrates in μmol/kg.

3.6 Dissolved nutrients concentrations

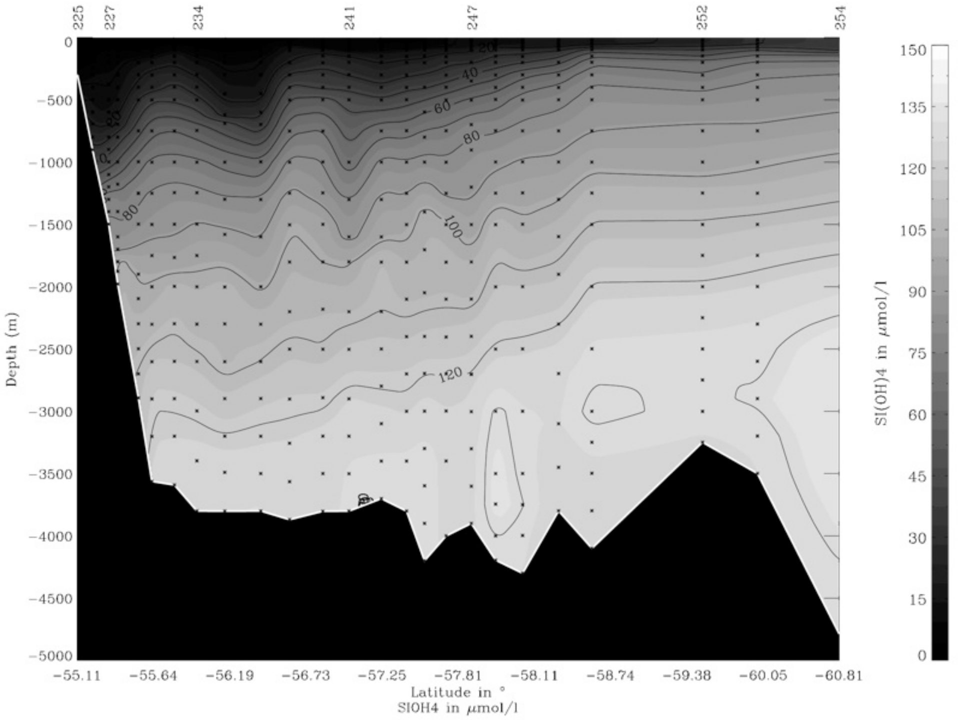

Fig. 3.6.1: Silicate concentration in µmol/kg

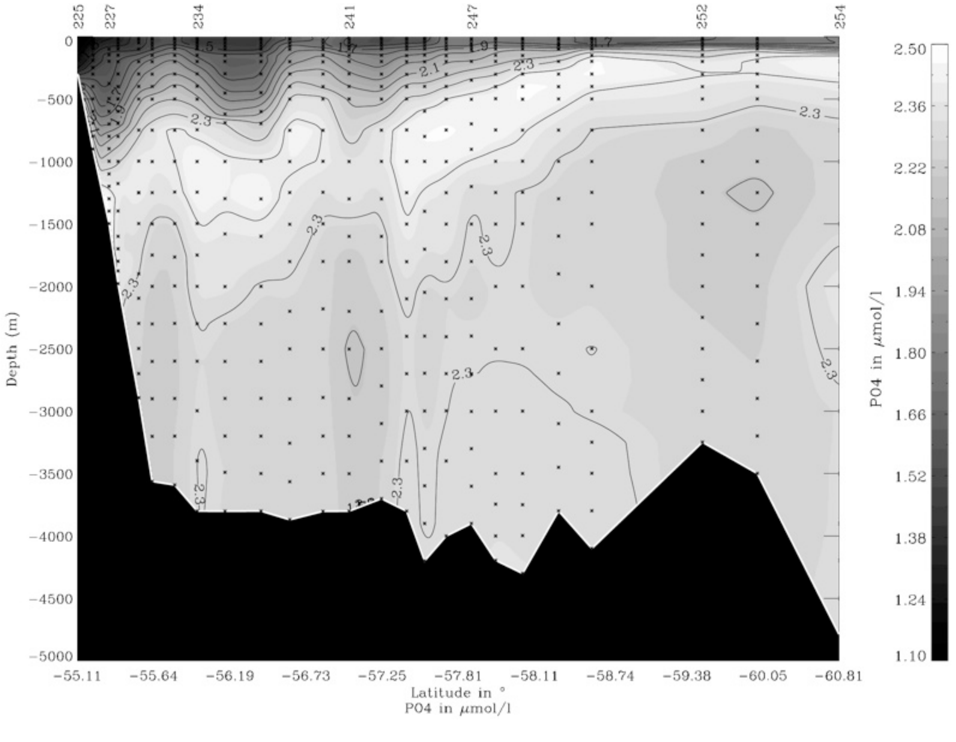

Fig. 3.6.2: Phosphate concentration in µmol/kg

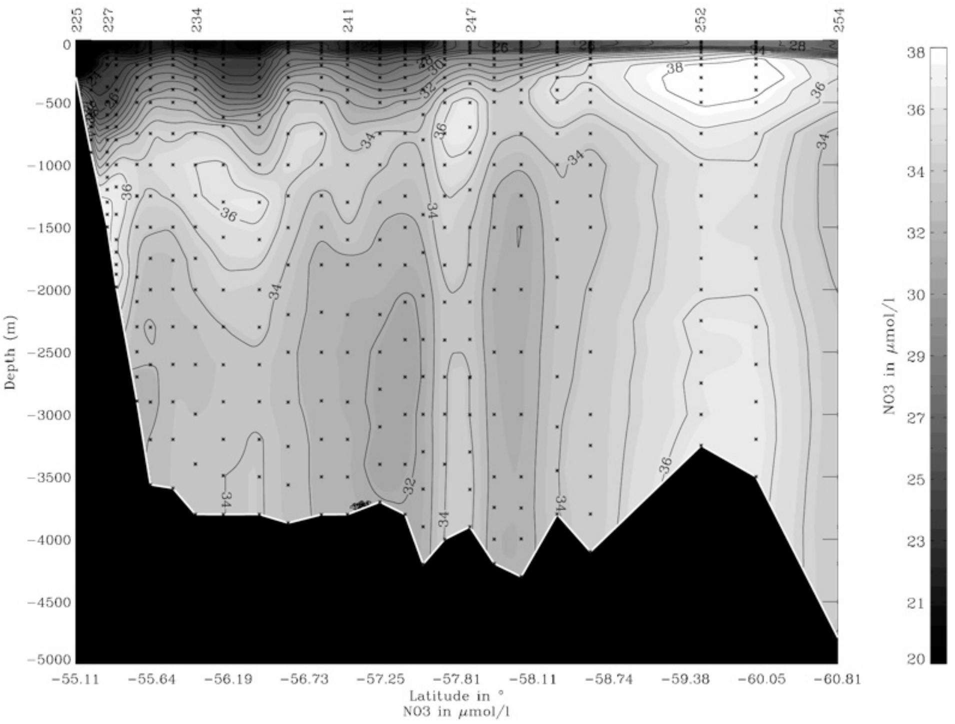

Fig. 3.6.3: Nitrate concentration in μmol/kg

The very detailed spacing across the West Scotia Ridge, together with the northward leg above the Shackleton Fracture Zone, will allow us to determine a precise flow pathway of the deep water masses (Lower Circumpolar Deep Waters, South Pacific Deep Waters and Weddell Sea Deep Waters) in Drake Passage.

References

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Grasshoff, K., M. Ehrhardt, K. Kremling, 1983, Methods of seawater analysis, 2^{nd} ref. Ed. Verlag Chemie GmbH, Weinheim, 419 pp.

Gordon, L.I., Jennings, J.C.Jr., A.A. Ross, J.M. Krest, 1993, A suggested protocol for continuous flow automated analysis of seawater nutrients (Phosphate, Nitrate,Nitrite, Silic acid) in the WOCE Hydrographic Program and the Joint Global Ocean Flux Study, WOCE HPO.

3.7 Tracer Measurements: Helium Isotopes, Neon, and CFCs

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Objectives

The Drake Passage is an important entry for several water masses from the Pacific into the Atlantic Ocean as well as for trace substances like noble gases (e.g., helium and neon) and chlorofluorocarbons (CFCs). They are carried with the Antarctic Circumpolar Current (ACC) around the Antarctic Continent and, thus, can enter the South Atlantic and the Weddell Sea. On the opposite, recent observations indicate Weddell Sea Deep Water, formed in the western Weddell Sea, leaving the Weddell Sea through gaps in the South Scotia Ridge and entering the Drake Passage westwards.

Ocean surface water is mostly in equilibrium with atmospheric helium (mainly ^{4}He), the helium isotope ratio (^{3}He/^{4}He) and neon. Neon has no internal oceanic sources while primordial helium enters the ocean from spreading regions of the submarine ridge systems (mainly in the Pacific, mantle helium with a far higher ^{3}He/^{4}He ratio), from the earth crust (lower ^{3}He/^{4}He), and from glacial ice.

Southeast Pacific Deep Slope Water (SPDSW) carried by the ACC into the Atlantic was revealed on previous tracer sections across Drake Passage by its elevated ^{3}He/^{4}He ratio close to the continental slope of South America in depth of 1500 to 3500 m. This tracer signal originates from water which was in contact with the submarine ridge system in the deep Pacific. This water mass enters the South Atlantic through Drake Passage and is an important source of ^{3}He for the Atlantic Ocean and the Weddell Sea. Several repeated sections (1999, 2006, and 2008) indicate the high variability of the transport of this water mass. Here we use the unique opportunity to investigate the SPDSW transport on two almost parallel sections within very short time. This will enable us to determine the SPDSW transport and its variability.

The CFCs are anthropogenic trace gases that enter the ocean by gas exchange with the atmosphere. The evolution of these transient tracers in the ocean interior is determined by their temporal increase in the atmosphere since the middle of the last century and the formation, advection and mixing processes of intermediate, deep and bottom water. Hence, these transient tracers enable to determine transit times, i.e. the time elapsed since the water has left the surface mixed layer.

In the 2006 Drake Cruise we observed an enhanced CFC signal in the deep southern part of the Drake Passage, well confined below the 0°C potential temperature isotherm. This water has its origin most presumably in the western Weddell Sea. Here we repeat two previous sections (2006 and 2008) and take samples for the first time from the parallel section along the Shackleton Ridge, particularly in the deep gaps, to investigate the transit times, its variability, and the pathways of that water further westward.

Work at sea

On the two Drake Passage sections we took a total of 250 samples for helium isotopes and neon, distributed on 26 profiles down to the bottom (14 on the eastern section and 12 on the section along the Shackleton Ridge), mainly to capture the SPDSW core. Additionally we took one profile in the volcano near King George Island/Isla 25 de Mayo.

In total we took 580 samples for CFCs distributed on 40 deep profiles (23 on the eastern section and 17 on the section along the Shackleton Ridge) on the two Drake Passage sections to investigate the transit times and pathways of various deep water masses. Furthermore, we sampled on two profiles, one inside and one close to the volcano near King George Island/Isla 25 de Mayo in the Bransfield Strait.

The helium isotope and neon water samples are tapped in copper tubes, carefully preventing contamination with air during the filling. The tubes are squeezed at both ends to keep them gas tight during transportation and storage. They are shipped home immediately after the cruise. In our Bremen noble gas lab the gases will be extracted from the samples and then analysed with a sector field and quadrupole mass spectrometer. The measurements are expected for late 2009.

The CFC water samples are stored in glass ampoules without contact to the atmosphere during tapping. Immediately after sampling the ampoules are flame sealed after a CFC free headspace of pure nitrogen had been applied. Also the CFC samples are shipped home for analysis in our Bremen gas chromatography lab. The measurements are carried out by purging the water sample with nitrogen and trapping the gases on a cooling trap. Subsequently the amount of CFC-11 and CFC-12 is determined with a gas chromatograph and electron capture detector system (GC/ECD). The data will be available in late 2009.

Expected results

During this cruise we repeated the tracer section across Drake Passage from 2006 and 2008 and additionally one section further westwards along the Shackleton Ridge. These measurements are perfectly accompanied by the oxygen, nutrient, and CO_2 measurements, enabling an Optimum Multiparameter (OMP) analysis to calculate the fractions of SPDSW and deep water originating from the western Weddell Sea through Drake Passage. The transport will be calculated by combining the SPDSW fractions with the velocity field from geostrophic calculations and LADCP measurements or by combining the Weddell Sea Deep Water fractions with the CFC based transit times.

3.8 Microstructure measurements

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KORDI

Objectives

Estimation of ocean mixing rates in the Drake Passage is important to understand thermohaline circulation in part. The purpose of microstructure survey is to estimate turbulence parameters, such as the dissipation rate of turbulent kinetic energy and vertical eddy diffusivity, base on direct measurement of velocity shear.

Equipment and method

A microstructure profiler, TurboMAP 8 developed by Alec Elec. in Japan, is used for microstructure measurements (Fig. 3.8.1). It is designed for downward measurements and records data only during the descent. The maximum observation depth is 500 m and the profiler can be deployed at a speed ranging from 0 to 0.65 m/sec. Two shear probes measure the rate of velocity change in time with the sampling rate of 512 Hz. The profiler also measures other sea water properties such as temperature, conductivity and turbidity etc. The detailed specifications of sensors installed in TurboMAP are summarized in Table 3.8.1.

Fig. 3.8.1: TurboMAP microstructure profiler

Tab. 3.8.1: Specifications of the sensors installed on the microstructure profiler

Parameter	Sensor type	Range	Accuracy	Sampling rate(Hz)
du/dt	Shear probe	0 - 4 s^{-1}	5%	512
Temperature	FP07	-5 – 45°C	±0.01°C	512
Temperature	Thermistor	-5 – 45°C	±0.01°C	64
Conductivity	Inductive cell	0 - 7 S/m	±0.005 S/m	64
Pressure	Semi-conductor	0 - 500 dbar	±0.5% FS	64
Accelerometer-x		±1G	1%FS	256
Accelerometer-y		±1G	1%FS	256
Accelerometer-z		±1G	1%FS	64
Chlorophyll	Fluorescence	1 - 100 µg/L	0.5 µg/L	256
Turbidity	Back-scattering	1 - 100 ppm	1 ppm	256
dv/dt	Shear probe	0 - 4 s^{-1}	T%	512

Work at sea

It had been planned that the profiler deployed at nine selected sites. Measurement at one station was cancelled due to the bad weather condition and the last deployment was stopped due to the loss of the equipment.

Measurements were done one to three times at each station to get better data set. During the deployment of profiler, the operation of ship's engine may affect the data in the upper few tens of meters.

The deployment of profiler is summarized in Table 3.8.2.
At the last station (St. 275) the profiler was lost due to the wire being cut when the profiler reached the 338 m depth based on the recorded data.

Tab. 3.8.2 : Summary of microstructure measurements

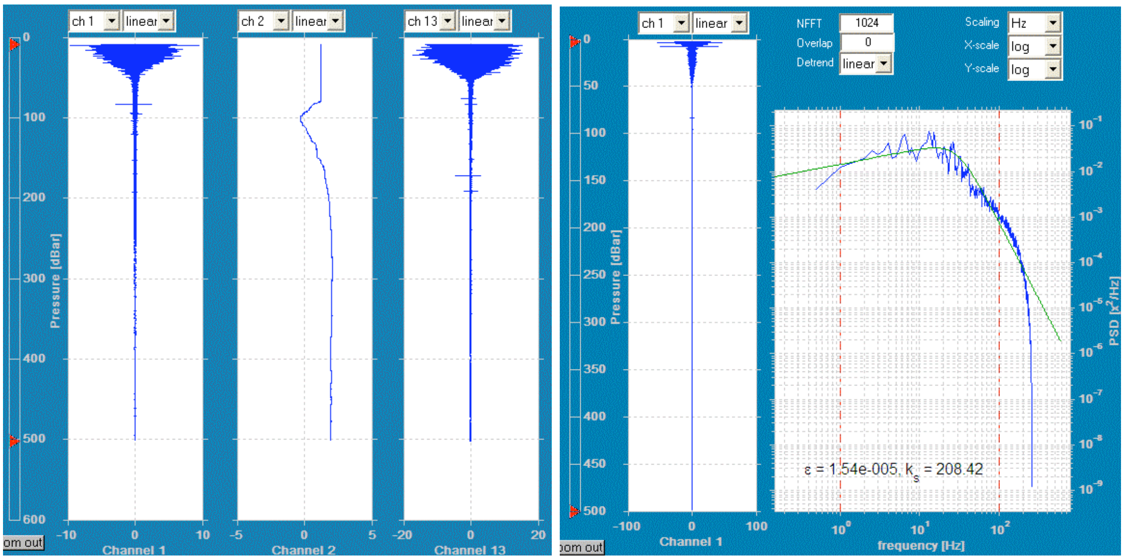
Station	Date	Time	Location		No. cast	Observation depth (m)	Remark
			Lat. (S)	Long. (W)			
259	2009/04/04	02:30	60° 51.8´	56° 23.5´	2	560/ 526/	
260	2009/04/04	07:34	60° 42.0´	56° 36.0´	1	526/	
261	2009/04/04	14:01	60° 31.0´	56° 57.5´	2	506/ 515/	
264	2009/04/05	03:07	59° 45.6´	58° 55.2´	2	505/ 507/	
266	2009/04/05	13:52	59° 07.2´	60° 33.0´	2	480/ 462/	
268	2009/04/05	22:50	58° 44.4´	61° 30.0´	3	278/ 487/ 522	1st cast failure
271	2009/04/06	13:08	58° 23.1´	63° 13.8´	2	504/ 475	
273	2009/04/06	23:00	57° 54.6´	64° 37.0´	-		cancelled due to strong wind
275	2009/04/07	14:08	56° 44.8´	69° 04.9´	1	338	Profiler lost (wire cut)

Expected results

- Estimation of the dissipation rate of turbulent kinetic energy and corresponding vertical diffusion coefficient in the surface layer
- Information on mixing over the Shackleton Fracture Zone.

Preliminary data

Fig. 3.8.2-a shows real time raw data shown on PC for selected channels (two shear data and temperature in this case) recorded at Station 260. The power spectrum of shear data was initially checked comparing with the Nasmyth universal spectrum as shown in Fig. 3.8.2-b.



NFFT 1024
Overlap 0
Detrend linear
Scaling Hz
X-scale log
Y-scale log

ε = 1.54e-005, k_s = 208.42

(a) (b)

Fig. 3.8.2. (a) The raw data displayed on PC at Station 260, (b) A shear data and the power spectrum of the displayed section of the shear profile. Green curve represents the Nasmyth universal spectrum which is scaled by the dissipation rate value shown.

4. PHYTOPLANKTON AND PIGMENTS DISTRIBUTION IN THE DRAKE PASSAGE

Luc Beaufort[1)], Véronique Garçon[2)]

[1)]CEREGE
[2)]LEGOS

Objectives

The coccolithophores are an important group of phytoplankton, and they are one the major calcite producers in the pelagic ocean. They are often believed to be best adapted to low latitudes, warm ocean, but the major blooms of coccolithophores are reported in mid and high latitudes. Very few studies concern the Southern Ocean. Winter et al. (1999) reported coccolithophores in the Weddell Sea in 1992. Eynaud et al (1999), Cubillos et al., (2007), Gravalosa et al., (2008) and Mohan et al. (2008) observed identified abundant *E. huxleyi* respectively from in the Southern Atlantic (up to 58°S), from the Western Pacific to 64°S, from the eastern Pacific across the Southern Antarctic Circumpolar Current Front (SACCF) to 66°N and from the Indian Sector of the Southern Ocean across the Polar Front. But previous investigations of the Western Pacific Sector in 1994/1995 (Findlay and Giraudeau, 2000) and 1983/1984 (Nishida, 1986) did not report populations of coccolithophores south of the Polar Front.

Coccolithophores have never been studied in the Drake Passage. The DRAKE cruises represent a special opportunity to provide observations on the presence of this group in this region and this represents the first goal of this investigation.

Another goal consists in comparing the calcite production with the siliceous one. In particular we will compare the diatoms abundance with the coccolithophores abundance, because they are often considered to be in competition. We want to test this in this area where both groups are living by comparing their relative abundance. The measurements of the pigments in the same sample will add another type of information, by permitting to quantify the amount of pigments produced by those different groups.

A third goal is to study the state of calcification of the coccolithophore cell, the coccosphere in relation to the carbonate chemistry of the water they lived in. We will use methods recently developed (Beaufort and Dollfus, Beaufort 2005) which permits to automatically estimate the mass of hundreds of single coccosphere in a water sample (Beaufort et al., 2008). This study is part of the EPOCA European programme on the acidification of the ocean.

Work at sea

Sampling strategy

Six samples were collected at 37 CTD stations (Table 4.1) in the shallowest Niskin bottles in most of the cases at 10, 25, 50, 75, 100 and 150 m. For the phytoplankton, 1 liter of sea water was filtered onto a membrane of nitrate cellulose of a 25 mm in diameter and with a nominal porosity of 0.47 μm. The membranes were dried immediately in an oven set at 40°C, and were let there during the entire cruise to be sure they stay dry. Several membranes were cut in two halves. One of the two has been mounted between slide and coverslip with Canadian balsam. These preparations were investigated with a polarizing microscope at a 500X magnification. Semiquantitive estimation of the coccolithophores, diatoms and silicoflagellate was done to check the sample quality. For the pigments, 2 liters of sea water were filtered onto glass microfibre filters (GFF) of 25 mm in diameter. The membrane were put into cryo tube vials and rapidly stored at -80°C.

Preliminary results on phytoplankton assemblages

The first semiquantitive results indicate that coccolithophore are very abundant up to the Polar Front. Values in the order of 600,000 coccosphere.l^{-1} are common. Then they decrease rapidly to almost disppear in the polar waters. However in the vicinity of King George Island/Isla 25 de Mayo they reappear in low quantities (around 5,000 /l). In particular *Emiliania huxleyi* was observed in a sample taken south of Jubany, with a temperature of 0.6°C and containing a very rich diatom flora. *Emiliania huxleyi* was the dominant coccolithophore species and the samples had a very low diversity. Some *Calcidiscus leptoporus* and *Helicosphaera carteri* were however seldom observed.

Diatoms are always present in those samples. They are not very abundant north of the Polar Front compare with the coccolithophore. South of the Polar Front they dominate and reach large number around 700,000 frustule.l^{-1}. The diversity is high and often dominated by the *Chaetoceros* species.

Silicoflagellates are always present in significant amounts.

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Tab. 4.1: List of samples

Date	Time UTC	Latitude S	Long. W	Station		Depth 1	Depth 2	Depth 3	Depth 4	Depth 5	Depth 6
mars 22, 2009	12:27	52°36.82	68°32.82	PS73-213	D1	19					
mars 22, 2009	16:57	52°28.807	68°28.038	PS73-218	D6	5.7	16.3	55			
mars 23, 2009	18:24	52°25.68	68°26.09	PS73-220	D8	5	19	39			
mars 25, 2009	12:12	55°6.65	65°30.40	PS73-225	D13	9	24	51	75	100	151
mars 25, 2009	20:31	55°23.059	65°2.071	PS73-228	D16	12	2	50	75	101	150
mars 26, 2009	10:58	55°44.781	64°26.541	PS73-232	D19	9	25	49	75	101	150
mars 26, 2009	22:27	55°56.922	64°6.651	PS73-234	D21	11	24	50	75	101	148
mars 27, 2009	09:46	56°21.719	63°18.022	PS73-236	D22	9	26	49	75	100	198
mars 28, 2009	06:04	56°36.79	62°55.24	PS73-239	D23	16	23	51	77	101	200
mars 28, 2009	18:43	57°2.561	62°14.390	PS73-241	D25	8	26	50	77	101	150
mars 28, 2009	23:55	57°16.9	61°45.48	PS73-242	D26	9	26	50	73	99	150
mars 29, 2009	08:47	57°36.36	61°15.73	PS73-244	D28	10	26	49	75	100	148
mars 29, 2009	18:47	57°44.219	60°55.201	PS73-246	D29	11	24	52	76	102	152
mars 29, 2009	23:25	57°50.851	60°29.421	PS73-247	D30	18	26	53	77	102	198
mars 30, 2009	18:26	58°2.730	60°12.140	PS73-248	D31	8	25	48	76	102	150
mars 30, 2009	23:37	58°2.100	59°42.601	PS73-249	D32	11	26	49	74	100	151
mars 31, 2009	10:03	58°36.016	59°11.605	PS73-251	D34	10	25	49	75	100	150
mars 31, 2009	18:32	59°32.130	57°59.800	PS73-252	D35	8	25	50	75	100	147
avril 1, 2009	00:16	59°59.142	57°28.815	PS73-253	D36	10	24	50	74	99	149
avril 1, 2009	08:59	60°48.896	57°35.561	PS73-254	D37	10	27	53	74	100	150
avril 3, 2009	11:15	62°25.328	58°24.385	PS73-257	D38	9	24	50	100	250	
avril 4, 2009	06:25	60°51.630	56°27.740	PS73-259	D41	10	25	60	75	100	150
avril 4, 2009	11:32	60°41.925	56°35.771	PS73-260	D42	10	25	49	75	100	151

Date	Time UTC	Latitude S	Long. W	Station		Depth 1	Depth 2	Depth 3	Depth 4	Depth 5	Depth 6
avril 4, 2009	20:07	60°31.040	56°56.940	PS73-261	D43	10	25	60	75	100	171
avril 4, 2009	22:43	60°16.930	57°29.630	PS73-262	D44	10	25	49	76	100	150
avril 5, 2009	03:01	60°02.863	58°15.238	PS73-263	D45	6	24	50	76	99	200
avril 5, 2009	06:59	59°45.950	58°55.06	PS73-264	D46	9	25	51	74	101	199
avril 5, 2009	12:26	59°29.9715	59°42.950	PS73-265	D47	11	25	54	100	200	301
avril 5, 2009	17:47	59°07.228	60°29.330	PS73-266	D48	10	20	49	75	98	199
avril 5, 2009	22:21	58°55.673	60°58.679	PS73-267	D49	10	24	50	75	99	200
avril 6, 2009	02:45	58°44.259	61°27.994	PS73-268	D50	10	25	50	76	100	151
avril 6, 2009	07:56	58°38.750	61°55.620	PS73-269	D51	9	25	50	74	150	200
avril 6, 2009	12:02	58°33.011	62°23.980	PS73-270	D52	9	23	49	74	100	150
avril 6, 2009	17:56	58°22.880	63°12.860	PS73-271	D53	10	25	51	75	100	150
avril 6, 2009	23:58	58°07.51	64°00.312	PS73-272	D54	10	24	48	74	100	150
avril 7, 2009	03:25	57°54.200	64°36.655	PS73-273	D55	11	26	50	74	102	148
avril 7, 2009	09:48	57°36.637	65°32.906	PS73-274	D56	10	25	50	74	100	150
avril 7, 2009				PS73-275	D57						

5. DISSOLVED CARBON DIOXYDE MEASUREMENTS

Carlos Balestrini[1], Renaud Bodichon[2], Véronique Garçon[3], Christian Brunet[4] (not on board)

[1]SHN
[2]IPSL
[3]LEGOS
[4]LOCEAN

Objectives

The objective is to assess the source/sink role of this region for CO_2 and the crucial role of the Polar Front as a bio-geo-chemical barrier. Thus monitoring the pCO_2 variations in surface waters and determining DIC content of the water column will be performed along both transects.

Work at sea

To measure total alkalinity (TA) and total inorganic carbon (TCO_2) from sea-water samples, a specific integrated titration system developed at LOCEAN and transported from SHN, was embarked, installed and used during the cruise (Fig. 5.1). The operation principle of this equipment is based on a potentiomethric inflection point method called the “Gran Function Plot Method”, that determines the carbonate and bicarbonate endpoints by finding the greatest change in the measured pH per volume unit of hydrochloric acid, added during the titration of the sample. The system was calibrated every 24 hours with standards provided by Dr. Andrew G. Dickson, from Scripps Institution of Oceanography.

A total of 565 samples were taken during the cruise, corresponding to different levels from 56 of the 57 CTD/Rosette stations (station number 40 was not sampled). From this number, 238 samples were measured on-board, while the remaining (including duplicates of 24 of those processed during the cruise) were preserved and shipped to Paris, to be measured at LOCEAN. It was not possible to process a larger number of samples on-board because of an electronic hardware failure appeared during the second week.

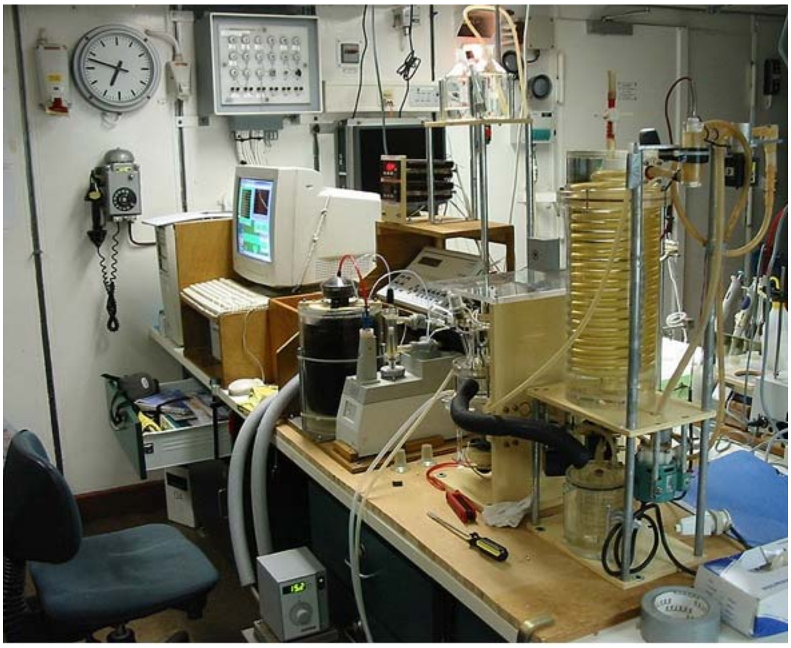

Fig. 5.1: Integrated TA and TCO_2 titration system on board Polarstern

Expected results

The CO_2 parameters will be compared with the distribution of phytoplanktonic groups. Data will enable us to compute an anticipated increase of anthropogenic carbon, particularly in the AAIW.

6. CONTINENTAL BACKGROUND IN OCEANIC AIR MASSES AND MARINE EMISSION OF VOLATILE ORGANIC COMPOUNDS

Aurélie Colomb, Rodolphe Paris, Rémi Losno (not on board)
LISA, University of Paris 12 and Paris 7, Créteil, France

Objectives

In the Drake Passage, continental air masses are mixed with pure oceanic air masses, and are evolving through the circumpolar atmospheric circulation. The most probable origin of continental air is Australia and Patagonia. The atmospheric dust content and deposition rate is quite unknown in Austral region. The long term evolution of continental air over the ocean is only poorly known, even if the oceanic surface is more than 80 % of the Southern Hemisphere. Recent field experiments have shown large differences between estimated and measured dust or deposition.

Dust particles can be carried up from the sources into the atmosphere for long range transport (Jickells et al., 2005). Then, dust is deposited into the ocean surface. Dust deposition can bring micro-nutrients to the marine biota as trace metals and metalloids. For instance, input of iron in the open ocean is dominated by atmospheric deposition of soluble iron from minerals aerosols (Fung et al., 2000; Sarthou et al., 2003).

During transport, some traces gases are oxidized depending on their lifetimes. It is therefore possible to calculate the photochemical age of the air masses, with some tracers of the long range transport and some tracers of sources origin.

The Southern Ocean is poorly characterized in term of organic compounds and trace gases. Numerous experiments have shown that marine biology, such as phytoplankton can emit volatile organic compounds (VOC) (Moore et al., 1994, Riemer et al, 2000, Colomb et al., 2006 but few shipborne measurements have been performed to determine potential source or sink of selected species. Especially in Austral region, recent campaigns (MANCHOT in Indian Austral Ocean in December 2004 (Colomb et al, 2009); OOMPH between Cape Town and Punta Arenas in January 2007) have shown the impact of oceanic emission on the local and global atmospheric chemistry (Singh et al, 2004).

Thus, the aims of the campaign were:

- to observe the relation between dust, trace gases and the photochemical age of the air mass

- to evaluate dust deposition and the water soluble fraction of aerosol over the remote Austral ocean region
- to analyze the atmospheric composition and determine the trace gases emission from marine sources, or from continental sources after a long-range transport.

Work at sea

During ANT-XXV/4 we took 165 air samples, 80 for the non oxidized compounds, 50 for the oxidized compounds and 25 for the aerosol distributed all along the track (Tables 6.1 and 6.2). Additionally we took 4 rain samples to estimate the wet deposition. All the samples were taken at the front of the crow deck.

- Aerosols were sampled on two different filters :
  - On Polycarbonate filter for water soluble fraction (to measure chlorure, nitrate, sulfate, formate, acetate and oxalate ions).
  - On Zefluor filter for elemental composition **(***Fe, Al, Cu, K, Ca, Mg***)**

- Non-oxygenated Volatile organic compounds (VOC) were sampled on solid adsorbents (Tenax TA 60-80 Mesh)
  - Oceanic tracers: DMS, CH_3Br, $CHBr_3$, CH_3I,…
  - Continental tracers: benzene, toluene, trichloroethylene,….
  - Short-lived compounds: isoprene, terpenes,..

- Oxygenated VOC were sampled on 2,4 DNPH-Silica cartridges:
  - Formaldéhyde, acetaldehyde, acetone,…
  - Glyoxal

We were also measuring continuously particles size and distribution (every minute) and ozone concentration (every 5 minutes).

Below are the figures of the air samples location (Fig.6.1) and the ozone distribution (fFig 6.2, 6.3).

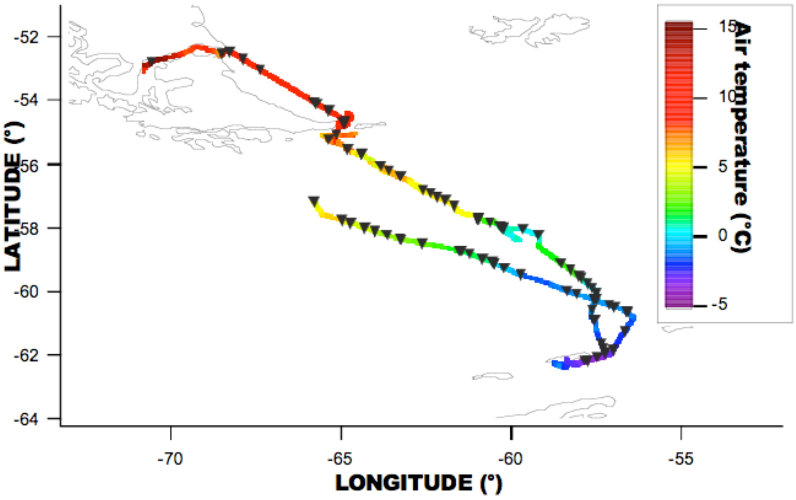

Fig. 6.1: Location of the VOC samples during the ANT-XXV/4 cruise

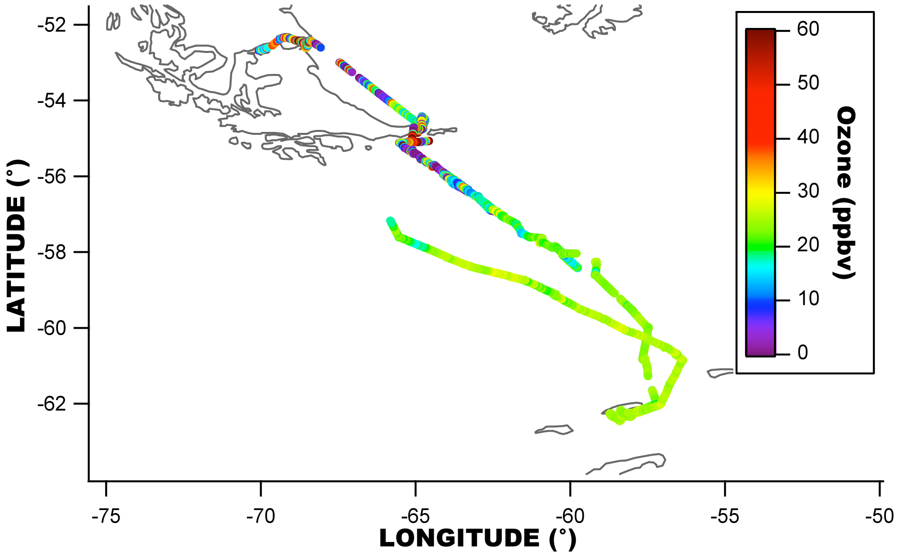

Fig. 6.2: Ozone distribution (ppbv) along the track of the ANT-XXV/4 cruise

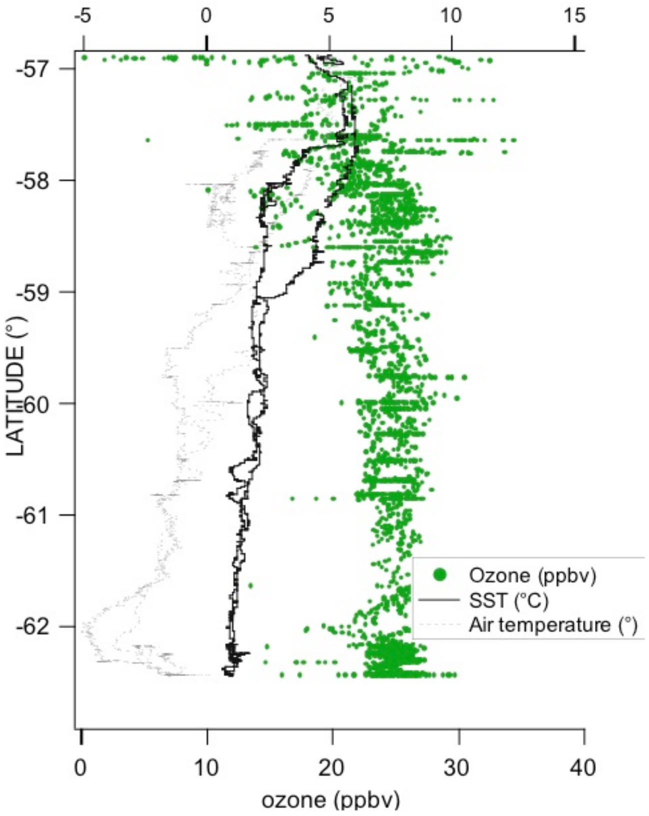

Fig. 6.3: Latitudinal gradient of air temperature, sea surface temperature and ozone (ppbv) from -57°S to -62.3 °S

Tab. 6.1: Non-oxygenated volatile organic compounds samples

Volatile Organic Compounds Samples									
VOCs	**Begin**	**End**	**LAT (°)**	**LON (°)**		**Begin**	**End**	**LAT (°)**	**LON (°)**
1	21/03/09 23:20	22/03/09 00:43	-52.8	-70.57	41	01/04/09 00:58	01/04/09 02:17	-60.05	-57.50
2	22/03/09 15:04	22/03/09 16:46	-52.54	-68.5	42	01/04/09 02:17	01/04/09 03:04	-60.28	-57.55
3	22/03/09 20:05	22/03/09 21:09	-52.49	-68.27	43	01/04/09 04:04	01/04/09 05:17	-60.61	-57.62
4	22/03/09 22:53	23/03/09 00:09	-52.72	-67.88	44	01/04/09 09:58	01/04/09 11:06	-60.93	-57.56
5	23/03/09 02:10	23/03/09 03:49	-53.04	-67.38	45	01/04/09 11:06	01/04/09 11:06	-60.93	-57.56
6	23/03/09 12:33	23/03/09 13:33	-54.06	-65.8	46	01/04/09 18:11	01/04/09 20:08	-61.66	-57.35
7	23/03/09 13:00	23/03/09 13:30	-54.11	-65.72	47	01/04/09 20:08	01/04/09 21:16	-61.81	-57.29
8	23/03/09 14:30	23/03/09 15:30	-54.33	-65.35	48	01/04/09 21:37	01/04/09 22:48	-61.96	-57.23
9	23/03/09 16:56	23/03/09 18:14	-54.68	-64.86	49	01/04/09 22:59	02/04/09 00:14	-62.08	-57.46
10	24/03/09 16:40	24/03/09 17:55	-54.73	-64.93	50	02/04/09 00:29	02/04/09 02:34	-62.19	-57.84
11	24/03/09 20:29	24/03/09 21:30	-55.1	-65.14	51	03/04/09 20:27	03/04/09 21:44	-62.22	-57.75
12	25/03/09 14:45	25/03/09 15:47	-55.24	-65.36	52	03/04/09 23:07	04/04/09 00:43	-61.86	-57.00
13	26/03/09 01:36	26/03/09 02:54	-55.54	-64.81	53	04/04/09 02:15	04/04/09 03:57	-61.30	-56.66
14	26/03/09 13:01	26/03/09 14:01	-55.7	-64.39	54	04/04/09 12:42	04/04/09 13:42	-60.69	-56.58
15	26/03/09 15:48	26/03/09 16:40	-55.71	-64.39	55	04/04/09 15:00	04/04/09 16:00	-60.67	-56.60
16	26/03/09 18:16	26/03/09 19:20	-56.06	-63.83	56	04/04/09 17:01	04/04/09 18:09	-60.52	-56.96
17	27/03/09 15:12	27/03/09 16:44	-56.21	-63.59	57	04/04/09 19:49	04/04/09 21:12	-60.44	-57.11
18	27/03/09 16:44	27/03/09 18:36	-56.41	-63.25	58	04/04/09 21:16	04/04/09 22:02	-60.28	-57.50
19	27/03/09 16:44	27/03/09 17:04	-56.41	-63.25	59	05/04/09 00:40	05/04/09 03:36	-60.10	-58.08
20	27/03/09 16:44	27/03/09 17:04	-56.41	-63.25	60	05/04/09 03:41	05/04/09 05:29	-60.00	-58.36
21	28/03/09 13:28	28/03/09 14:48	-56.84	-62.58	61	05/04/09 12:36	05/04/09 13:44	-59.49	-59.72
22	28/03/09 14:48	28/03/09 15:38	-56.94	-62.36	62	05/04/09 14:28	05/04/09 15:32	-59.28	-60.20
23	28/03/09 19:11	28/03/09 20:20	-57.07	-62.18	63	05/04/09 15:39	05/04/09 17:14	-59.14	-60.50
24	28/03/09 20:20	28/03/09 21:16	-57.17	-61.93	64	05/04/09 17:22	05/04/09 18:23	-59.12	-60.50
25	29/03/09 00:32	29/03/09 01:36	-57.35	-61.68	65	05/04/09 19:14	05/04/09 20:13	-59.09	-60.55
26	29/03/09 15:02	29/03/09 15:42	-57.76	-60.99	66	05/04/09 20:18	05/04/09 21:33	-58.99	-60.84
27	29/03/09 15:42	29/03/09 17:02	-57.75	-60.97	67	05/04/09 23:20	06/04/09 00:33	-58.84	-61.22
28	29/03/09 17:02	29/03/09 18:09	-57.74	-60.95	68	06/04/09 00:40	06/04/09 02:50	-58.74	-61.50
29	29/03/09 20:02	29/03/09 21:12	-57.87	-60.62	69	06/04/09 02:50	06/04/09 04:07	-58.74	-61.47
30	30/03/09 01:43	30/03/09 03:22	-57.98	-60.32	70	06/04/09 04:24	06/04/09 05:07	-58.73	-61.52
31	30/03/09 15:31	30/03/09 16:53	-58.04	-60.25	71	06/04/09 12:54	06/04/09 13:48	-58.51	-62.62
32	30/03/09 16:58	30/03/09 18:44	-58.04	-60.23	72	06/04/09 14:47	06/04/09 15:49	-58.39	-63.23
33	31/03/09 00:04	31/03/09 01:19	-58.06	-59.65	73	06/04/09 18:21	06/04/09 19:23	-58.36	-63.28
34	31/03/09 02:28	31/03/09 04:14	-58.26	-59.20	74	06/04/09 19:32	06/04/09 20:50	-58.25	-63.65
35	31/03/09 13:28	31/03/09 14:38	-59.12	-58.54	75	06/04/09 21:05	06/04/09 21:55	-58.13	-64.00
36	31/03/09 14:46	31/03/09 15:47	-59.33	-58.26	76	06/04/09 22:45	07/04/09 00:10	-58.13	-64.01
37	31/03/09 17:14	31/03/09 18:11	-59.53	-58.01	77	07/04/09 00:17	07/04/09 01:35	-58.02	-64.31
38	31/03/09 19:03	31/03/09 19:59	-59.60	-57.93	78	07/04/09 04:00	07/04/09 04:58	-57.88	-64.71
39	31/03/09 19:59	31/03/09 20:47	-59.77	-57.75	79	07/04/09 05:01	07/04/09 06:31	-57.79	-64.97
40	31/03/09 20:47	31/03/09 21:57	-59.90	-57.61	80	07/04/09 12:40	07/04/09 13:42	-57.20	-65.80

Tab. 6.2: Oxygenated volatile organic compounds samples

Oxygenated Volatile Organic Compounds Samples									
OVOCs	**Begin**	**End**	**LAT (°)**	**LON (°)**		**Begin**	**End**	**LAT (°)**	**LON (°)**
1	21/03/09 23:20	22/03/09 03:41	-52.8	-70.57	26	31/03/09 00:16	31/03/09 04:15	-58.07	-59.61
2	22/03/09 03:41	22/03/09 11:21	-52.43	-69.45	27	31/03/09 04:20	31/03/09 13:28	-58.26	-59.16
3	22/03/09 15:04	22/03/09 20:05	-52.54	-68.5	28	31/03/09 13:28	31/03/09 17:05	-59.12	-58.54
4	22/03/09 20:05	23/03/09 03:49	-52.49	-68.27	29	31/03/09 17:14	31/03/09 20:47	-59.53	-58.01
5	23/03/09 03:49	23/03/09 12:25	-53.22	-67.11	30	31/03/09 20:47	01/04/09 00:46	-59.90	-57.61
6	23/03/09 12:33	23/03/09 17:26	-54.06	-65.8	31	01/04/09 00:58	01/04/09 05:20	-60.05	-57.50
7	23/03/09 17:26	23/03/09 20:38	-54.74	-64.89	32	01/04/09 05:20	01/04/09 09:55	-60.83	-57.67
8	24/03/09 16:40	24/03/09 20:37	-54.73	-64.93	33	01/04/09 09:55	01/04/09 12:30	-60.93	-57.56
9	24/03/09 20:37	25/03/09 02:40	-55.12	-65.14	34	01/04/09 12:30	01/04/09 12:30	-61.16	-57.50
10	25/03/09 02:40	25/03/09 12:49	-55.09	-64.8	35	01/04/09 18:23	01/04/09 22:48	-61.67	-57.34
11	25/03/09 12:49	26/03/09 01:31	-55.15	-65.45	36	01/04/09 22:59	02/04/09 02:34	-62.08	-57.46
12	26/03/09 01:31	26/03/09 13:01	-55.54	-64.81	37	03/04/09 20:27	04/04/09 02:13	-62.22	-57.75
13	26/03/09 13:02	26/03/09 18:02	-55.7	-64.39	38	04/04/09 02:13	04/04/09 11:25	-61.30	-56.66
14	26/03/09 18:16	26/03/09 20:57	-56.06	-63.83	39	04/04/09 12:42	04/04/09 16:58	-60.69	-56.58
15	26/03/09 20:57	27/03/09 13:21	-55.95	-64.11	40	04/04/09 17:01	05/04/09 00:32	-60.52	-56.96
16	27/03/09 15:12	27/03/09 21:17	-56.21	-63.59	41	05/04/09 00:32	05/04/09 03:36	-60.10	-58.08
17	28/03/09 13:28	28/03/09 19:11	-56.84	-62.58	42	05/04/09 03:41	05/04/09 12:32	-60.00	-58.36
18	28/03/09 19:11	29/03/09 00:13	-57.07	-62.18	43	05/04/09 12:36	05/04/09 17:14	-59.49	-59.72
19	29/03/09 00:32	29/03/09 04:51	-57.35	-61.68	44	05/04/09 17:22	05/04/09 23:15	-59.12	-60.50
20	29/03/09 04:51	29/03/09 13:46	-57.52	-61.52	45	05/04/09 23:20	06/04/09 04:07	-58.84	-61.22
21	29/03/09 13:47	29/03/09 17:02	-57.64	-60.90	46	06/04/09 04:24	06/04/09 12:50	-58.73	-61.52
22	29/03/09 17:03	29/03/09 21:12	-57.74	-60.95	47	06/04/09 12:54	06/04/09 18:21	-58.51	-62.62
23	29/03/09 21:23	30/03/09 01:43	-57.87	-60.55	48	06/04/09 18:21	06/04/09 22:45	-58.36	-63.28
24	30/03/09 01:43	30/03/09 13:08	-57.98	-60.32	49	06/04/09 22:45	07/04/09 04:58	-58.13	-64.01
25	30/03/09 15:31	30/03/09 20:09	-58.04	-60.25	50	07/04/09 05:01	07/04/09 13:31	-57.79	-64.97

Expected results

The gas samples are stored in the fridge and will be shipped home to be analyzed in LISA lab. Water soluble fraction of aerosol and rain samples will be analyzed with ionic chromatography, elemental composition determined with a ICP-AES, VOCs with gas-chromatography-mass spectrometer (GC-MS) and OVOCs with a high pressure liquid chromatography (HPLC).

Thanks to these data, we will improve our knowledge on air chemistry over the Drake Passage, especially:

-Dust content in air, dust flux to the ocean, solubility of trace metals and metalloids, biochemical impact on atmospheric deposition
-Chemistry of aged continental air masses,
-Marine emission and impact on local and global atmospheric chemistry
-Interaction between continental and oceanic VOC, impact on the chemistry

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7. INPUT OF SE PACIFIC WATERS TO THE PATAGONIAN CONTINENTAL SHELF: THE STRAITS SURVEY

Alberto Piola, Alejandro Bianchi, Ana Paula Osiroff, Marcela Charo, Silvia Romero
SHN

Objectives

The continental shelf off southeastern South America is the largest marine ecosystem in the southern hemisphere. South of around 40ºS the region presents intense chlorophyll blooms (Podestá, 1997; Longhurst, 1998; Saraceno et al., 2005; Romero et al., 2006; Signorini et al., 2006) and is important for the life cycle of a variety of species throughout the water column and in the benthic domains (Bertolotti et al., 1996, Sanchez and Ciechomski, 1995; Rodhouse et al., 2001; Acha et al., 2004; Bogazzi et al., 2005).

The shelf is occupied by diluted Subantarctic waters with salinity (S) lower than 33.9 (Guerrero and Piola, 1997, Fig. 7.1).

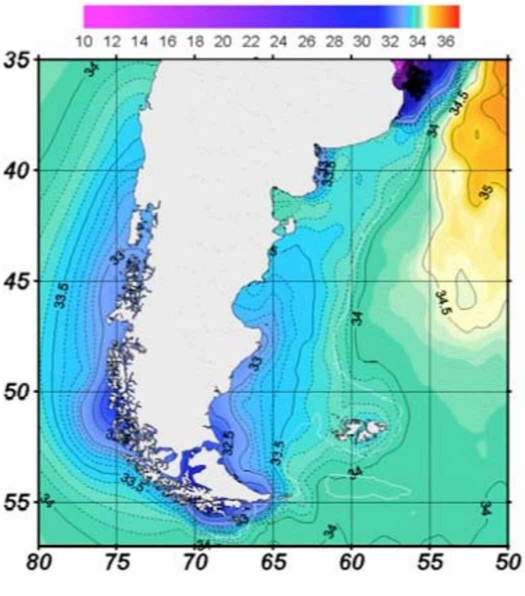

Fig. 7.1: Climatological surface salinity around southern South America

Given that continental runoff from Patagonia (Vörösmarty et al., 1996) and evaporation-precipitation imbalance (Hoflich, 1984; Schmitt and Wijffels, 1993) are small, additional freshwater sources is required to explain the low salinity that dominates the shelf. The most likely source for low salinity waters is the southeastern South Pacific, where high precipitation and continental discharge create a large pool of low salinity waters (Fig. 7.1).

Work at sea

Two sources of low salinity waters into the western South Atlantic continental shelf were explored during ANT-XXV/4: the Magellan and the Le Maire Straits (Fig. 7.2). The surveys consisted on high resolution, full-depth hydrographic sections occupied across these straits. The data were collected with LOCEAN´s CTD and Rosette system, and included LOCEAN´s L-ADCP, but given that the regions are relatively shallow, the quality of the L-ADCP data is uncertain.

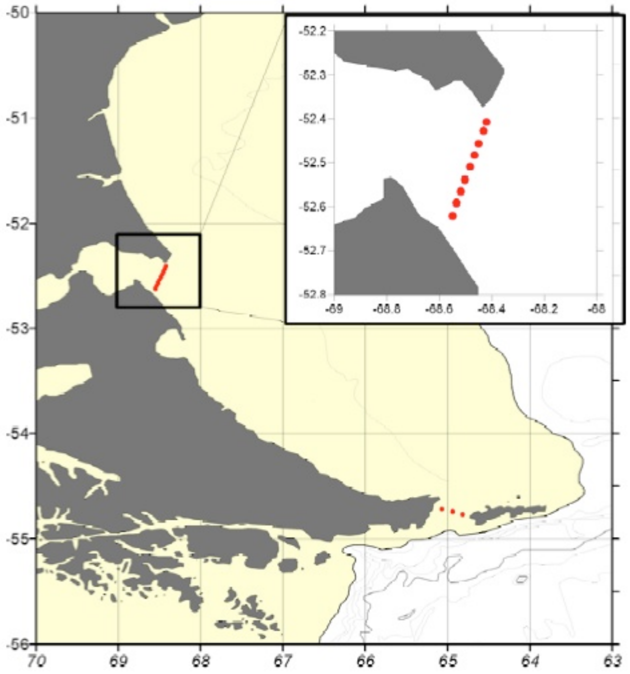

Fig. 7.2: location of the CTD stations collected across the Magellan (detail in inset) and Le Maire Straits during ANT-XXV/4.

Throughout the cruise we used a Sea-Bird Electronics (SBE) 911*plus* CTD fitted with a Digiquartz pressure (S/N 63488) sensor, and SBE conductivity (S/N 1075) and temperature (S/N 1327) sensors. Additional sensors fitted in the CTD were a SBE 043 dissolved oxygen (S/N 0214), a Chelsea Aqua 3 fluorometer (S/N 088-1002-056) and Chelsea/Seathech/Wetlab Cstar transmissometer (S/N CST-1190DR). The underwater unit was also fitted with a Benthos PSA-916 altimeter (S/N 1228), kindly made available by the *Polarstern*. Water samples were collected for the analysis of dissolved oxygen, nutrients, and salinity at selected levels. Procedures for each of these samples are reported separately. Samples were collected using a Sea-Bird Electronics SBE32 carrousel (S/N 329604-0025) with 24 bottle positions fitted with 22 Niskin bottles, each of 12-liter capacity. Two bottle slots (18 - 19) were not used to provide space for the upward looking L-ADCP.

The Magellan Straits connects the Atlantic and Pacific Oceans north of Tierra del Fuego. The eastern (Atlantic) mouth is approximately 32 km wide and is deepest near the central region, where the bottom depth exceeds 70m. The section across the Magellan Strait was occupied on 22 March 2009 starting at the southern end of the strait. The section consisted of nine CTD casts (stations 1 to 9 i.e. 213 to 221). The section presents warmest (> 9.9°C) and lowest salinities (< 31.2) waters in the upper 15 m of the water column in its northern end (stn 9 i.e. 221). Coldest (< 9.5°C) and saltiest (> 32.5) waters occupied the near bottom region of the central and southern strait (Fig. 7.3).

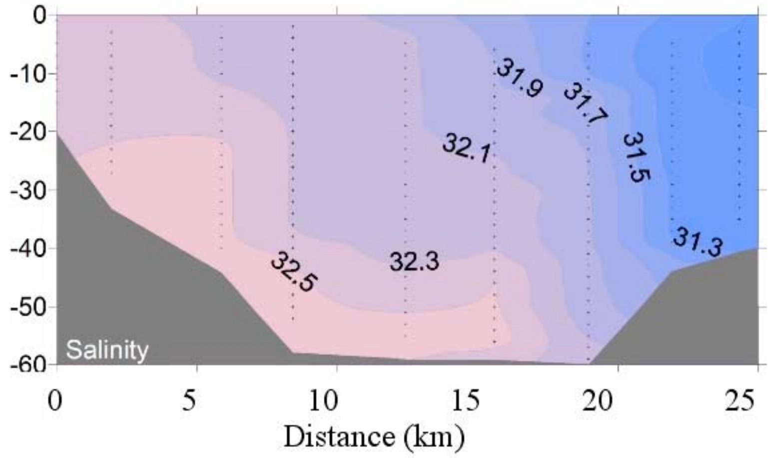

Fig. 7.3: Salinity section across the Magellan Strait occupied during ANT-XXV/4

The Le Maire Strait is the westernmost entrance of Pacific water into the Patagonia continental shelf, the passage is about 25 km wide and 115 m deep. The Le Maire survey consisted of three CTD casts (stns. 10 - 11 i.e. 222 - 223). These data show the warmest (> 9°C) and less saline (< 32.6) waters in the western side. There is little temperature change across the Strait, but salinity increases eastward to ~ 33.2 near the bottom of stn. 10 (i.e. 222).

The water mass characteristics of the Straits survey are summarized in Fig. 7.4, which presents a T-S diagram of stations 1 to 12 (i.e. 213 to 223). Fig. 7.2 clearly shows the extreme conditions of the Magellan Strait water in terms of salinity. As suggested by Guerrero and Piola (1997) these waters are the freshest inflow into the Patagonia continental shelf. Interestingly, however, the water characteristics in the southern (saltiest) Magellan suggest mixtures with inflow from the south: station 2 (214) has T-S characteristics nearly identical to Lemaire Strait waters (Fig. 7.3).

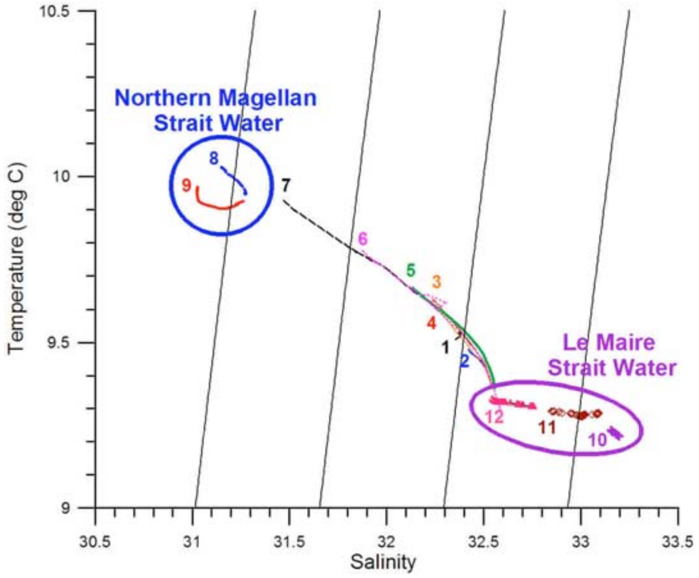

Fig. 7.4: T-S diagram of stations 1-12 (i.e. 213 - 224), occupied in the Magellan and Le Maire Straits during ANT-XXV/4.

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8. VALIDATING JASON-1 AND JASON-2 TANDEM ALTIMETRY THROUGH HIGH FREQUENCY GPS POSITIONING AND MARINE GRAVIMETRY

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CNES

Objectives

Our geodetic approach aims at the amelioration of the spatial resolution through combination of high frequency GPS positioning and marine gravimetry observations aboard *Polarstern*. Our sampling rate is continuous thus covering all spatial and temporal resolutions.

Our approach consists in using continuous high frequency (1 Hz) GPS sea-level observations from a buoy and *Polarstern* along Jason ground tracks 104 and 28. The GPS *Sea Surface Height* (SSH) and *Significant Wave Height* (SWH) during the cruise will be used to validate and correct the altimetric data as *Sea-State Bias* (SSB) is one of the major sources of altimetric errors.

Our challenge is to precisely determine the position of the floating targets (buoy and ship) by GPS from one side (using as well an altimeter device to get the information of the floating line) and to collect a series of marine gravity observations using the relative gravimeter aboard the *Polarstern* from the other.

The four main objectives foreseen are:

1. to validate with respect to altimetry data such a kinematic high frequency GPS technique for measuring sea state and the sea surface height (SSH) in absolute and relative positioning mode over baselines of a few hundred km;
2. to give recommendations based on this innovative technique for future offshore Cal/Val activities with observations on the ground tracks of the altimeter satellites (GFO, Envisat, Jason-2, Altika);
3. to combine GPS derived sea level data with altimetric and gravimetric observations to compute a gravity anomaly profile and an improved marine geoid along JASON 1 and 2 ground tracks and determine the mean sea surface profile of the geostrophic current, its high frequency variability (few days) and associated velocity field (surface transport);
4. to give recommendations for improving the demonstrated GPS technique in order to use it again during dedicated or opportunity cruises especially in coastal areas to do the connection with offshore altimetry data.

Work at sea

The work was concentrated in three parts. The first concerns the acquisition of data sets from 4 GPS receivers aboard *Polarstern* well tied to the ship's center of equilibrium and a new design buoy for the ship's floating line definition and SWH determination. The second part concerns the realization of an absolute determination of the floating line of the ship through an appropriate altimeter device installed on the port side. The third part concerns the use of *Polarstern's* gravimeter for the production of a detailed marine geoid that will better represent the shorter wavelength (< 20 – 40 km) features of the gravity field.

Marine Gravimetry

The objective is to determine precise and accurate geophysical corrections in this region of rough seas, examine particularly JASON-2 capabilities along the DP and estimate the ACC's short wavelength features (< 15 – 30 km) and especially its high frequency temporal variability.

Since the onboard KSS31 sea gravimeter only provide measurements of relative gravity (affected by bias and possibly drift), it is essential to calibrated it before and after the campaign. Thus, we performed gravimetry measurements with a Scintrex CG5 gravimeter on two referenced absolute gravimetry points, two in Punta Arenas (before and after the cruise) and one in Jubany. The relative gravimeter instrument has been provided from IRD in Santiago.

The GPs working plan

The collection of the new GPS SSH data set was performed in the following steps:

1. GPS aboard: We installed 4 complementary GPS receivers (from CNES and INSU) aboard *Polarstern*: 3 on the free deck, in front (Fig. 8.2), on port and starboard, and one on top of the mast. After their ties definition they were set on for all the duration of the journey along the DP passage.

2. GPS Ties: Inside the port aboard *Polarstern* we defined the exact positions of the 4 GPS antenna phase centers with respect to well known point of the R/V; They were then tied to the ship reference point (MINS1). The observations were accomplished through the use of an optical instrument (theodolite) provided by CNES

3. GPS buoy: We used a new design wave-rider buoy which was tethered up to 50 m from the boat (independent from the antenna's cable length) by a kevlar rope (Fig. 8.2). At all we accomplished 10 GPS buoy calibrations during the cruise. 2 were performed during JASON-2 passes, one on track 104, one on track 28.

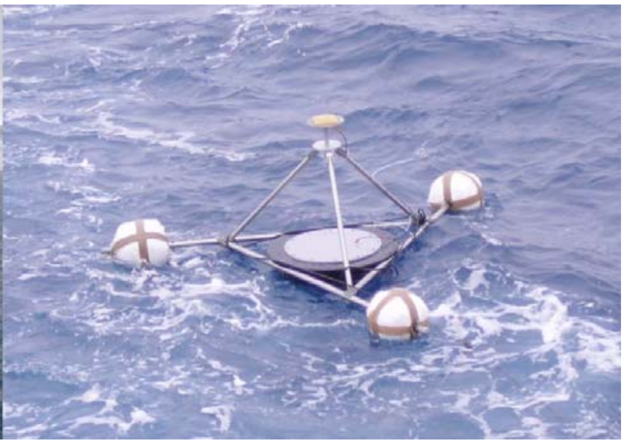

Fig. 8.1: View of the bow GPS antenna Fig. 8.2: View of wave-rider GPS buoy

The altimeter working plan

A dedicated radar altimetric device of type Optiwave 7300C (Krohne) was installed at an approximate height of 17m on the crow deck on the port side of the ship (Fig. 8.3). It has been tied to the GPS antennas. This altimeter allows to transform the GPS on board position time series from the 4 GPS antennas to the instantaneous sea surface with a precision of 3mm. Altimeter measurements were sampled between 1 and 6 s.

Fig. 8.3: View of the Optiwave radar altimeter

Expected results

JASON-1 and JASON-2 altimetry will be evaluated with respect to the i*n-situ* GPS observations and altimeter biases estimated. We will evaluate the geophysical corrections in this region of rough seas. That will lead to an improved mean sea estimate and altimetry data treatment as well in the DP. From the improved marine gravity geoid combined with GOCE data and gravity anomaly observations, we will quantify the ACC transport.

We will also evaluate composite maps from merged altimetric data sets and operational models (MERCATOR) with respect to our observations.

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

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Alfred-Wegener-Institut, Bremerhaven

Objectives

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

Temperature has a large impact on all biological processes and is therefore especially important in marine ecosystems. Animal organisms, due to their inherently high levels of organisational complexity, specialize on environmental temperature much more than unicellular bacteria and algae (Pörtner, 2002). Accordingly, thermal tolerance windows differ between ectothermal animal species depending on latitude or seasonal temperature acclimatisation and are therefore related to geographical distribution. Tradeoffs and constraints in thermal adaptation become visible when ectotherms specialized on various temperature regimes and their tissues are compared. The hypothesis of oxygen limited thermal tolerance provides a conceptual framework for the investigation of how ectotherms compensate for changing ambient temperatures (Pörtner, 2001, 2002). Accordingly, thermal limitation becomes effective firstly at high hierarchical levels of organisation, the intact organism, and then at lower levels, cellular and molecular functions. Inadequate oxygen supply likely is the first indicator of cold intolerance in both water and air breathers, however, compensatory mechanisms likely set in before such limits are reached. (Pörtner, 2001, 2002). These limits exert their effects on the growth rate of individual specimens and the abundance of a population thereby shaping the biogeography of a species (Pörtner and Knust, 2007). Nevertheless, thermal limitations are based on molecular functions and the integration of single molecules into functional and regulatory networks. Similarly, studying the temperature adaptation of organisms in a changing environment therefore needs to consider the functional integration of single molecules into higher organisational levels.

Evolutionary adaptation to various climates is addressed in our department "Integrative Eco-Physiology" in comparative studies carried out with populations of the same species in climatic gradients or with congeneric species living in different climatic zones. For example, member species of the fish family Zoarcidae (eelpouts) inhabit temperate, subpolar and polar waters and represent a model system for the study of evolutionary adaptation versus seasonal acclimatisation to temperature. Therefore, a reasonable number of publications of our department have been emerged from studies on Antarctic eelpout (*Pachycara brachycephalum*) and common eelpout (*Zoarces viviparus*). Furthermore, our previous studies have demonstrated the high conservation level of functional genes in different eelpouts from boreal and Antarctic waters, corroborating that these species are excellent models in comparative functional genomics studies (cf. Lucassen et al. 2003; Mark et al. 2006). On the other hand Notothenioidei represent the most important and most specialized fish group in the Southern Ocean, occupying all available habitats, but seem to be more sensitive to climate change. These species have been used in a number of studies for elucidation of general principles (e.g. Langenbuch and Pörtner, 2003; Mark et al., 2005; Deigweiher et al. 2008).

Work at sea

During the CTD measurement in the Drake Passage four fish traps were set up and the aquarium container system (AWI024) and a backup system in a cool container were installed and prepared to bring animals alive to the AWI laboratories in Bremerhaven. In the morning of 2 April the baited traps were brought out in the Admiralty Bay, at a water depth between 400 and 500 meters. Due to bad weather conditions and lost of station time before, the time at sea bottom had to be reduced to 24 hours approximately. The traps were recovered in the late morning of the 3 April (geographic position and station times are listed in the station book at the end of this cruise report, Stat. No.: PS73/255-1 to PS73/255-4). Before trap recovering a CTD measurement were carried out close the trap position to get information of water temperature and salinity (Stat. No.: PS73/258-1). In total more than 1000 specimens of the Antarctic eelpout (*Pachycara brachycephalum*) were caught and were brought into the aquarium system. Due to the enormous amount of fish a third aquarium system had to be installed in another cool container. Together with the fish und cephalopods, which were caught during the Jubany campaign (project Lucassen, project Mark), the animals will be kept in the aquarium systems at 0°C water temperature and are going to be transferred alive to Bremerhaven (ANT-XXV/5). During leg ANT-XXV/5 some fish will be acclimated to higher temperature for several days/weeks and tissue samples will be taken and flash frozen in liquid nitrogen for further molecular genetic and physiological analyses.

Preliminary results

The catch quantity is comparable to the results from further expeditions in the years 1998 to 2006 and indicate that the abundance of *Pachycara brachycephalum* is significant higher at King George Island/Isla 25 de Mayo than in the area of Scotia

Arc and in the high Antarctic waters of the Eastern Weddell Sea. After several days of keeping the fish in the aquarium systems the mortality rate is very low and the fishes recovered very quickly from catch stress and pressure difference of about 50 bar. The CTD measurement in the vicinity of the sampling stations showed a water temperature of +0.6°C at the bottom and a salinity of 34.4.

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APPENDIX

A.1 PARTICIPATING INSTITUTIONS

A.2 CRUISE PARTICIPANTS

A.3 SHIP'S CREW

A.4 STATION LIST

A.1 TEILNEHMENDE INSTITUTE / PARTICIPATING INSTITUTIONS

	Address
AWI	Stiftung Alfred-Wegener-Institut für Polar- und Meeresforschung in der Helmholtz-Gemeinschaft Postfach 120161 27515 Bremerhaven Germany
DWD	Deutscher Wetterdienst Abteilung Seeschiffahrt Bernhard-Nocht-Straße 76 20359 Hamburg Germany
CEREGE	Centre européen de recherche et d'enseignement des géosciences de l'environnement Aixen-Provence France
CNES	Centre National d'Etudes Spatiales 14 avenue Edouard Belin 31000 Toulouse France
DTP	Dynamique Terrestre et Planétaire Observatoire Midi Pyrennées , 14 avenue Edouard Belin 31400 Toulouse France
Heli Service	Heli Service International GmbH Im Geisbaum 2 63329 Egelsbach Germany
INACH	Departamento de Geofisica, Cabina 7 Universidad de Concepcion Casilla 160-C Concepcion Chile
IUP	Institut of Environmental Physics University of Bremen Bremen Germany

	Address
KORDI	Korea ocean research and development institute Ansan PO Box 29 Seoul 425-600 Korea
LEGOS	Laboratoire d'Etudes en Géophysique et Océanographie Observatoire Midi Pyrénées 14 avenue Edouard Belin 31400 Toulouse France
LISA	Laboratoire inter-universitaire des systèmes atmosphériques Faculté des Sciences 61, av. du Gal de Gaulle 94010 Créteil Cedex France
LOCEAN	Laboratoire d'Océanographie et du Climat : Expérimentation et approches numériques Université Pierre et Marie Curie Tour 45-55 5^E 4 place Jussieu 75252 Paris cedex 05 France
SHN	Servicio de Hidrografia Naval Avenida Montes de Oca 2124 C1279ABV Buenos Aires CF Argentina
ULCO	Université du littoral Côte d'Opale Station Marine de Wimereux. Wimereux France
UCSC	Department of Chemistry and Biochemistry University of California Santa Cruz, CA 95064 USA
Laeisz	Reederei F. Laeisz (Bremerhaven) GmbH Brückenstraße 25 27568 Bremerhaven Germany

A.2 FAHRTTEILNEHMER / CRUISE PARTICIPANTS

Name/ Last name	Vorname/ First name	Institut/ Institute	Beruf/ Profession	
Balestrini	Carlos	SHN	Engineer, electronics	
Barré	Nicolas	LOCEAN, CNES	Ph.D. student, oceanography	
Beaufort	Luc	CEREGE	Biologist	
Beauverger	Mickael	LOCEAN	Engineer, oceanography	
Biancale	Richard	DTP, CNES	Senior researcher, geodesy	
Bianchi	Alejandro	SHN	Oceanographer	
Bodichon	Renaud	IPSL	Engineer, oceanography	
Boschat	Ghyslaine	LOCEAN	Ph.D. student, oceanography	
Brauer	Jens	HeliService	Helicopter mechanic	
Bruns	Thomas	DWD	Meteorologist	
Buchner	Jurgen	HeliService	Pilot	
Charo	Marcela	SHN	Engineer, physical oceanography	
Collomb	Aurélie	LISA U. Paris VII	Associate Prof., chemistry	
Gall	Fabian	HeliService	Helicopter mechanic	
Garçon	Veronique	LEGOS, CNRS	Oceanographer	
Gebler	Madlen	University Bremen	Ph.D. student, oceanography	
Hammrich	Klaus	HeliService	Pilot	
Hasson	Audrey	LOCEAN	Student, oceanography	
Henry	Françoise	ULCO	Oceanographer	
Hong	Chang Su	KORDI	Engineer, oceanography	
Huhn	Ollie	University Bremen	Physicist	
Hwang	Sang Chul	KORDI	Engineer, oceanography	
Juguet	Nicolas	LEGOS	Student, oceanography	
Kartavtseff	Annie	LOCEAN	Engineer, oceanography	
Knust	Rainer	AWI	Biologist	
Koschnick	Nils	AWI	Biologist	*from Jubany*
Lee	Jae Hak	KOR DI	Oceanographer	
Lucassen	Magnus	AWI	Biologist	*from Jubany*
Mark	Felix	AWI	Biologist	*from Jubany*
Mejia	Carlos	LOCEAN, CNRS	Engineer, informatics	
Melachroinos	Stavros	LEGOS CNES	Post doc student, geodesy	
Mioni	Cécile	UCSC	Post Doc, oceanography	
Nardi	Luigi	LOCEAN, UPMC	Ph.D. student, oceanography	
Osiroff	Ana Paula	SHN	Oceanographer	
Paris	Rodolphe	LISA U. Paris VII	Student, chemistry	
Piola	Alberto	SHN, UBA	Oceanographer	
Pouget	Guillaume	LOCEAN, CNES	Engineer, oceanography	
Provost	Christine	LOCEAN CNRS	Oceanopgrapher	
Rafizadeh	Mehrad	LOCEAN, CNRS	Engineer, oceanography	
Renault	Alice	LOCEAN, UPMC	Ph.D. student, oceanography	
Rodrigo	Cristian	INACH	Observer, oceanography	
Romero	Sivia	SHN	Engineer, oceanography	

Name/ Last name	**Vorname/ First name**	**Institut/ Institute**	**Beruf/ Profession**	
Saraceno	Martin	CIMA	Oceanographer	
Sennechael	Nathalie	LOCEAN, MNHN	Oceanographer	
Sonnabend	Hartmut	DWD	Technician, weather station	
Strobel	Anneli	AWI	Biologist	*from Jubany*
Sudre	Joel	LEGOS, CNRS	Engineer, oceanography	
Thouron	Daniele	LEGOS, CNRS	Engineer, oceanography	
Windisch	Heidrun	AWI	Ph.D. student, oceanography	

A.3 SCHIFFSBESATZUNG / SHIP'S CREW

No.	Name	Rank
1.	Pahl, Uwe	Master
2.	Grundmann, Uwe	1. Offc.
3.	Farysch, Bernd	Ch. Eng.
4.	Hering, Igor	2. Offc.
5.	Janik, Michael	3. Offc.
6.	Reinstädler, Marco	3. Offc.
7.	Erich, Matthias	Doctor
8.	Koch, Georg	R. Offc.
9.	Kotnik, Herbert	2. Eng.
10.	Schnürch, Helmut	2. Eng.
11.	Westphal, Henning	2. Eng.
12.	Holtz, Hartmut	Elec. Eng.
13.	Dimmler, Werner	ELO
14.	Feiertag, Thomas	ELO
15.	Fröb, Martin	ELO
16.	Nasis, Ilias	ELO
17.	Clasen, Burkhard	Boatsw.
18.	Neisner, Winfried	Carpenter
19.	Burzan, Gerd-Ekkeh.	A.B.
20.	Hartwig-Lab., Andreas	A.B.
21.	Kreis, Reinhard	A.B.
22.	Kretzschmar, Uwe	A.B.
23.	Moser, Siegfried	A.B.
24.	Pousada Martinez, S.	A.B.
25.	Schröder, Norbert	A.B.
26.	Schultz, Ottomar	A.B.
27.	Beth, Detlef	Storek.
28.	Dinse, Horst	Mot-man
29.	Fritz, Günter	Mot-man
30.	Kliem, Peter	Mot-man
31.	Krösche, Eckard	Mot-man
32.	Watzel, Bernhard	Mot-man
33.	Fischer, Matthias	Cook
34.	Tupy, Mario	Cooksmate
35.	Völske, Thomas	Cooksmate

No.	Name	Rank
36.	Dinse, Petra	1. Stwdess
37.	Hennig, Christina	Stwdess/N.
38.	Hischke, Peggy	2. Stwdess
39.	Hu Guo Yong	2. Steward
40.	Streit, Christina	2. Stwdess
41.	Sun, Yong Sheng	2. Steward
42.	Wartenberg, Irina	2. Stwdess
43.	Ruan, Hui Guang	Laundrym.
44.	Langhinrichs, Jacob	Apprent.
45.	Waterstradt, Felix	Apprent.

A.4 STATIONSLISTE / STATION LIST PS 73

Station PS73	#	Date	Time (start)	Time (end)	Position (Lat.)	Position (Lon.)	Depth (m)	Gear
213-1	1	22.03.09	12:16	12:27	52° 36.61' S	68°33.14' W	19.6	CTD/rosette
214-1	2	22.03.09	13:16	13:24	52° 35.76' S	68°32.08' W	32.5	CTD/rosette
215-1	3	22.03.09	14:24	14:32	52° 33.72' S	68°31.21' W	44	CTD/rosette
216-1	4	22.03.09	15:08	15:17	52° 32.57' S	68°30.00' W	4.5	CTD/rosette
217-1	5	22.03.09	15:53	16:02	52° 30.48' S	68°29.00' W	59.3	CTD/rosette
218-1	6	22.03.09	16:45	16:57	52° 28.86' S	68°28.05' W	59.6	CTD/rosette
219-1	7	22.03.09	17:36	17:45	52° 27.30' S	68°27.15' W	60.7	CTD/rosette
220-1	8	22.03.09	18:15	18:24	52° 25.69' S	68°26.04' W	44.5	CTD/rosette
221-1	9	22.03.09	18:53	19:02	52° 24.48' S	68°25.30' W	40.6	CTD/rosette
222-1	10	24.03.09	15:16	15:26	54° 45.79' S	64°49.15' W	84.6	CTD/rosette
223-1	11	24.03.09	16:20	16:33	54° 44.42' S	64°56.04' W	133.3	CTD/rosette
224-1	12	24.03.09	17:27	17:37	54° 43.07' S	65° 3.93' W	61.6	CTD/rosette
225-1	13	25.03.09	11:45	12:23	55° 6.81' S	65°31.80' W	375.2	CTD/rosette
226-1	14	25.03.09	13:35	14:32	55° 13.95' S	65°22.30' W	1027.3	CTD/rosette
227-1	M1	25.03.09	15:37	16:26	55° 19.66' S	65°11.42' W	1513.6	Mooring
228-1	15	25.03.09	16:54	18:35	55° 18.88' S	65° 8.07' W	1654.7	CTD/rosette
229-1	16	25.03.09	20:31	22:05	55° 23.85' S	65° 4.30' W	2083.8	CTD/rosette
230-1	17	26.03.09	0:34	2:53	55° 32.92' S	64°49.67' W	3099.8	CTD/rosette
231-1	18	26.03.09	4:21	6:53	55° 38.24' S	64°38.41' W	3756.8	CTD/rosette
232-1	19	26.03.09	8:30	11:00	55° 45.08' S	64°28.16' W	3784.2	CTD/rosette
233-1	M2	26.03.09	11:24	13:10	55° 43.37' S	64°24.82' W	3824	Mooring
234-1	20	26.03.09	19:55	22:29	55° 57.12' S	64° 6.54' W	3938.8	CTD/rosette
235-1	21	27.03.09	1:16	4:05	56° 10.00' S	63°46.80' W	4116.8	CTD/rosette
236-1	22	27.03.09	6:56	9:48	56° 25.13' S	63°18.36' W	3977.2	CTD/rosette
237-1	M3	27.03.09	12:01	14:15	56° 6.25' S	63°44.06' W	4272.9	Mooring
238-1	M4	27.03.09	21:06	0:14	56° 55.91' S	62°21.81' W	4093.8	Mooring
239-1	23	28.03.09	2:59	6:04	56° 36.63' S	62°55.65' W	4050.9	CTD/rosette
240-1	24	28.03.09	10:17	13:04	56° 52.07' S	62°31.68' W	4131.1	CTD/rosette
241-1	25	28.03.09	16:03	18:46	57° 2.50' S	62°10.18' W	3898.9	CTD/rosette
242-1	26	28.03.09	21:22	23:56	57° 15.48' S	61°43.66' W	3841.3	CTD/rosette
243-1	27	29.03.09	2:41	5:27	57° 29.72' S	61°34.65' W	4027.8	CTD/rosette
244-1	28	29.03.09	7:02	10:00	57° 36.87' S	61°17.55' W	4399.2	CTD/rosette
245-1	M5	29.03.09	12:10	14:35	57° 37.69' S	60°56.62' W	3362.2	Mooring
246-1	29	29.03.09	16:03	19:04	57° 45.40' S	60°59.46' W	4421.5	CTD/rosette
247-1	30	29.03.09	21:24	0:30	57° 52.72' S	60°34.78' W	4224.7	CTD/rosette
248-1	31	30.03.09	16:20	19:28	58° 2.64' S	60°15.26' W	3691.5	CTD/rosette
249-1	32	30.03.09	21:20	0:39	58° 2.48' S	59°44.90' W	4566.2	CTD/rosette
250-1	33	31.03.09	3:17	6:10	58° 15.75' S	59°12.35' W	4030.7	CTD/rosette
251-1	34	31.03.09	8:18	11:05	58° 35.94' S	59°12.06' W	4314.5	CTD/rosette
252-1	35	31.03.09	17:07	19:34	59° 31.30' S	58° 1.21' W	3522.5	CTD/rosette
253-1	36	31.03.09	22:33	1:17	60° 0.07' S	57°29.93' W	3865.2	CTD/rosette
254-1	37	01.04.09	6:28	10:01	60° 49.74' S	57°40.03' W	5027.7	CTD/rosette
255-1	T1	02.04.09	12:27	13:24	62° 11.34' S	58°21.11' W	463.2	Trap, fish

Station PS73	#	Date	Time (start)	Time (end)	Position (Lat.)	Position (Lon.)	Depth (m)	Gear
256-1	38	03.04.09	11:07	12:04	62° 25.37' S	58°24.39' W	1122.7	CTD/rosette
257-1	39	03.04.09	13:16	14:27	62° 22.16' S	58°23.61' W	1479	CTD/rosette
258-1	40	03.04.09	16:01	16:31	62° 10.83' S	58°22.59' W	519.2	CTD/rosette
259-1	41	04.04.09	5:45	7:27	60° 51.79' S	56°23.78' W	1952.6	CTD/rosette
259-2	MST	04.04.09	7:29	8:39	60° 51.62' S	56°22.71' W	1918.6	MST
260-1	42	04.04.09	10:10	12:32	60° 42.00' S	56°35.85' W	3443.1	CTD/rosette
260-2	MST	04.04.09	12:36	13:08	60° 41.95' S	56°35.82' W	3437.4	MST
261-1	43	04.04.09	17:34	18:59	60° 30.95' S	56°57.73' W	1642	CTD/rosette
261-2	MST	04.04.09	19:02	20:07	60° 31.03' S	56°56.91' W	1726.8	MST
262-1	44	04.04.09	22:20	23:45	60° 17.04' S	57°30.00' W	1704.8	CTD/rosette
263-1	45	05.04.09	2:25	4:02	60° 2.98' S	58°15.17' W	2127.2	CTD/rosette
264-1	46	05.04.09	6:36	8:00	59° 45.57' S	58°55.13' W	1775.8	CTD/rosette
264-2	MST	05.04.09	8:03	9:07	59° 45.97' S	58°55.08' W	1713.5	MST
265-1	47	05.04.09	11:57	13:27	59° 30.03' S	59°41.94' W	2135.4	CTD/rosette
266-1	48	05.04.09	16:59	18:50	59° 7.24' S	60°32.98' W	2898.3	CTD/rosette
266-2	MST	05.04.09	18:51	19:51	59° 7.17' S	60°29.24' W	2940.1	MST
267-1	49	05.04.09	21:59	23:21	58° 55.77' S	60°59.74' W	1734.4	CTD/rosette
268-1	50	06.04.09	1:29	3:46	58° 44.43' S	61°29.88' W	3265.9	CTD/rosette
268-2	MST	06.04.09	3:50	5:09	58° 44.27' S	61°28.00' W	3163	MST
269-1	51	06.04.09	6:52	8:57	58° 38.94' S	61°56.87' W	2988.6	CTD/rosette
270-1	52	06.04.09	10:40	13:04	58° 33.02' S	62°23.82' W	3590.1	CTD/rosette
271-1	53	06.04.09	15:54	18:04	58° 23.05' S	63°13.80' W	3257.6	CTD/rosette
271-2	MST	06.04.09	18:07	19:03	58° 22.86' S	63°12.82' W	3136	MST
272-1	54	06.04.09	21:40	0:01	58° 8.38' S	63°58.87' W	3173.6	CTD/rosette
273-1	55	07.04.09	2:37	4:27	57° 54.57' S	64°36.90' W	2493.3	CTD/rosette
274-1	56	07.04.09	8:34	10:50	57° 36.04' S	65°32.96' W	3218.2	CTD/rosette
275-1	57	07.04.09	16:30	19:07	56° 44.90' S	66° 4.89' W	3909	CTD/rosette
275-2	MST	07.04.09	19:09	19:24	56° 45.49' S	66° 4.40' W	3913.7	MST

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