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Editorial

Introduction to physics, carbon dioxide, trace elements and isotopes in the Southern Ocean: The *Polarstern* expeditions ANT-XXIV/3 (2008) and ANT-XXIII/3 (2006)

1. Introduction

This special issue of *Deep-Sea Research II* comprises 17 research articles produced by shipboard scientists of *Polarstern* expedition ANT-XXIV/3 (2008) and their co-authors, and this includes four research articles based on the preceding *Polarstern* expedition ANT-XXIII/3 (2006) across Drake Passage. The respective cruise tracks are given in Figs. 1 and 2, and the complete cruise reports are available online, see references Fahrbach and De Baar (2010) and Provost (2007), respectively.

In the context of the 2007–2008 International Polar Year (IPY), the *Polarstern* expedition ANT-XXIV/3 left from Cape Town, South Africa, at 10 February 2008 and arrived at 16 April 2008 in Punta Arenas, Chile (Fig. 1). The aim of the expedition was to conduct an integrated research programme of physical oceanography and sea-ice dynamics (Climate in Antarctica and the Southern Ocean; IPY-CASO) with the study of trace elements and isotopes (IPY-GEOTRACES), in relation to the plankton ecosystem and the ocean carbon cycle. During the expedition a large number of physical, chemical and biological parameters were measured using the NIOZ Titan Ultraclean sampling system (Fig. 3) and a conventional CTD sampling system.

Along the Greenwich meridian, complete vertical profiles comprising 24 sampling depths were collected, for trace metals samples at stations at every full degree latitude, and for CO_2, alkalinity and nutrients at 44 stations at every half-degree. The close encounter with a group of three humpback whales (Fig. 4) cavorting around the ship for one hour was a further stimulus for studying the Antarctic Ocean ecosystem. The Greenwich meridian section was interrupted at 29 February for transit to the German Neumayer-II-Station on the Antarctic ice shelf in time to supply the base and exchange a few personnel.

Shortly after the early morning sunrise arrival at Sunday 2 March 2008 of *Polarstern* at the Atka Bay ice edge a helicopter left the ship bound for the Neumayer-II-Station. The helicopter crashed and two people in the front seats, the pilot Stefan Winter and NIOZ colleague Willem Polman lost their lives. At the back bench, the young scientists Alice Renault and Maarten Klunder were seriously injured and helicopter technician Carsten Möllendorf was moderately injured. Despite his injuries, the helicopter technician succeeded in removing the other injured persons from the helicopter and was able to make a radio call for help. Thanks due to their fast rescue and excellent medical treatment of injuries, the three survived and have fully recovered. Here and now we are most grateful that both Alice Renault and Maarten Klunder are lead authors of their two research articles in this issue.

The expedition was delayed until successful evacuation of the three injured passengers by airplane on Wednesday 5 March via the Russian base Novolazarevskaja (Fig. 1) to Cape Town (South Africa). At this date *Polarstern* continued her journey and the scientific programme also in honour of our lost colleagues. *Polarstern* returned at 7 March to 66°30′S at the Greenwich meridian to complete the transect to the ice edge. Helicopter technician Michael Stimac jointly with Sven Ober was able to continue the winch operations for ultraclean sampling throughout the remaining 7 weeks of the expedition. The second transect of stations commenced at 13 March and crossed the Weddell Sea. Several intended stations had to be cancelled due to slow ice-breaking in the heavy ice conditions vis-a-vis the need to be in time at 30 March at King George Island for another personnel change and cargo supply. Nevertheless, across the Weddell Sea 8 stations were sampled for trace metals and 38 stations for CO_2, alkalinity and nutrients. Moreover an amazing abundance of wild-life including Emperor penguins, seals and minke whales was observed. At King George Island part of the scientific crew was scheduled to be exchanged. The 8 new scientists were already at King George Island and boarded the ship. However the flight scheduled for the departing scientists was cancelled due to unsafe ice conditions on the runway. So with a somewhat crowded ship carrying 104 staff the final transect crossing of the Drake Passage commenced, ending at 16 April 2008 in Punta Arenas (Chile).

This issue comprises 13 research articles based on the ANT-XXIV/3 expedition in 2008 and 4 research articles based on the two repeat sections across Drake Passage of ANT-XXIII/3 in 2006.

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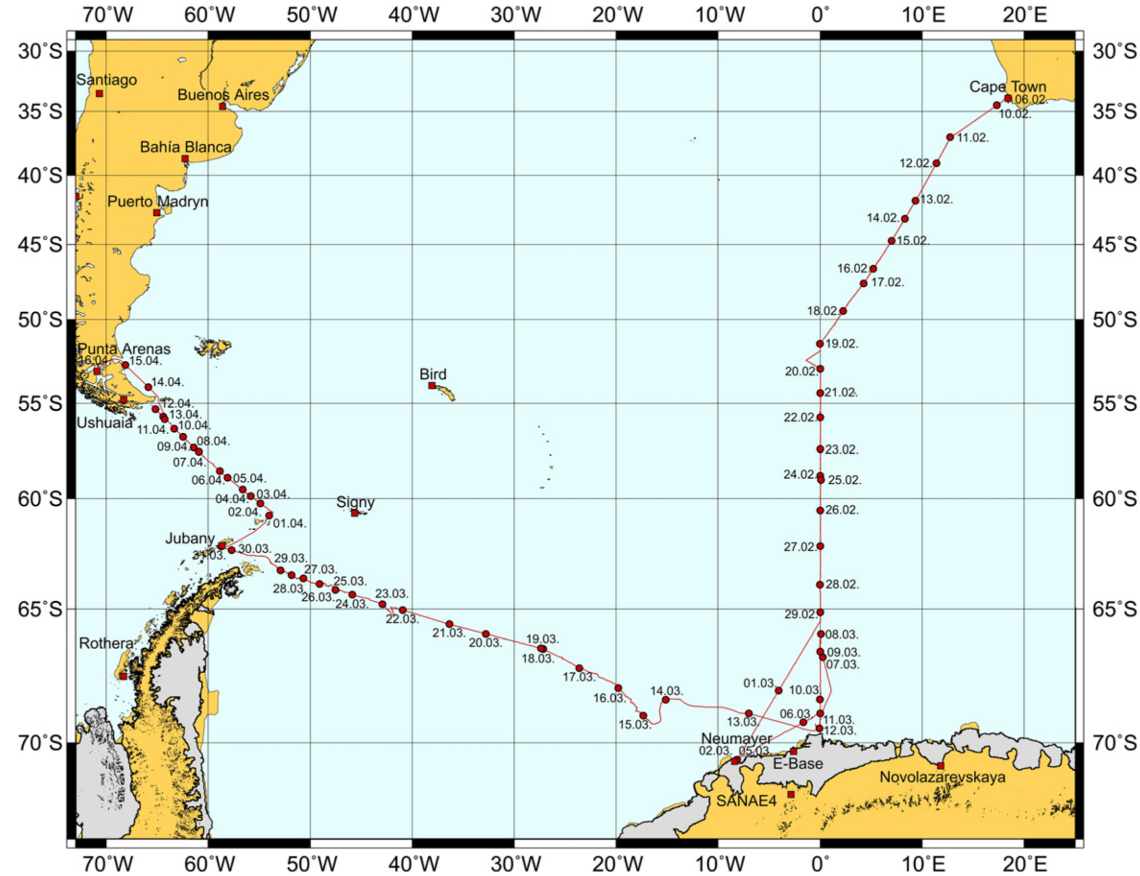

Fig. 1. Cruise track of *Polarstern* expedition ANT-XXIV/3 CASO and "Zero and Drake" from 10 February to 16 April 2008, Cape Town to Punta Arenas, comprising a section along the Greenwich meridian (or "Zero meridian"), followed by a section across the Weddell Sea and final section across Drake Passage.

2. Climate of Antarctica and the Southern Ocean (IPY-CASO)

As a contribution to the International Polar Year 2007/2008 the cruise was part of the CASO—(Climate of Antarctica and the Southern Ocean) and the GEOTRACES projects. It was the aim to measure ocean currents, temperature, salinity and concentrations of many trace substances in the Southern Ocean. The descending motions in the Southern Ocean are part of the worldwide oceanic overturning circulation. They affect the role of the ocean in climate change and biogeochemical cycles. Our measurements addressed the question as to whether the deep reaching, descending motion of the overturning would be subject to a measurable multi-annual fluctuation. Whereas the Warm Deep Water or Circumpolar Deep Water, which represents the water mass entering the Weddell gyre from the north is subject of a clear decadal fluctuation, the Weddell Sea Deep and Bottom Waters increase in temperature almost continuously over more than 20 years. Observations in Drake Passage allowed to identify the character and to understand the mechanisms of the fluctuations of the Antarctic Circumpolar Current.

It is of special interest that the evaluation of satellite data indicated clearly that the Antarctic summer 2007/2008 was the one with the largest ice extent on record (NSIDC, Fetterer et al., 2009). This trend, which is particularly strong in the Atlantic sector of the Southern Ocean, is in clear contrast to the Arctic where a strong decrease of the summer ice extend is observed. To find out if there are oceanographic conditions, which can explain the opposing trends in the Antarctic and the Arctic was one of the aims of our cruise. Because those changes occur over decades and are subject to significant spatial variations, the ships' cruises, like the one of *Polarstern*, are not enough to track them with sufficient accuracy in spite of the fact that we were able to measure 210 vertical profiles of water mass properties. Therefore we need comprehensive autonomous observing systems, which are moored or feely drifting. They are a component of the Southern Ocean Observing System (SOOS), which is under development. As a contribution to such a system we deployed, in international cooperation, 18 moored systems and recovered 20 of them. We deployed 68 vertically profiling floats. The ones, which were deployed in the Weddell Sea, are able to operate under the ice.

Long-term observations of the water mass properties in the Weddell gyre were extended during ANT-XXIV/3 by a further 3 years. The observed variations of the water mass properties in the deep waters of the Weddell gyre are induced by variations of the inflow of Circumpolar Deep Water at the boundary (Fahrbach et al., 2011). Due to asymmetric wind forcing at the northern and the southern limb of the gyre, variable in- and outflows occur at the open boundaries. Internal processes redistribute heat and salt in the gyre resulting in a long-term increase of the temperature and salinity in the whole water column. The transfer of heat to deeper layers assigns to the Weddell gyre the role of a buffer, with potential impact on the global climate. In the upper layers decadal variations were observed as well. Salinity variations in the Winter Water layer cannot be explained only by variable entrainment of underlying Warm Deep Water and by variations in sea-ice formation, but lateral advection of water and sea ice needs to be taken into account as well (Behrendt et al., 2011). Potential sources are melt water from the ice shelves in the western Weddell Sea or transport of water of low salinity entering the Weddell gyre from the east.

Four papers describe the Antarctic Circumpolar Current (ACC) in Drake Passage on the basis of a dataset gathered by *Polarstern* in

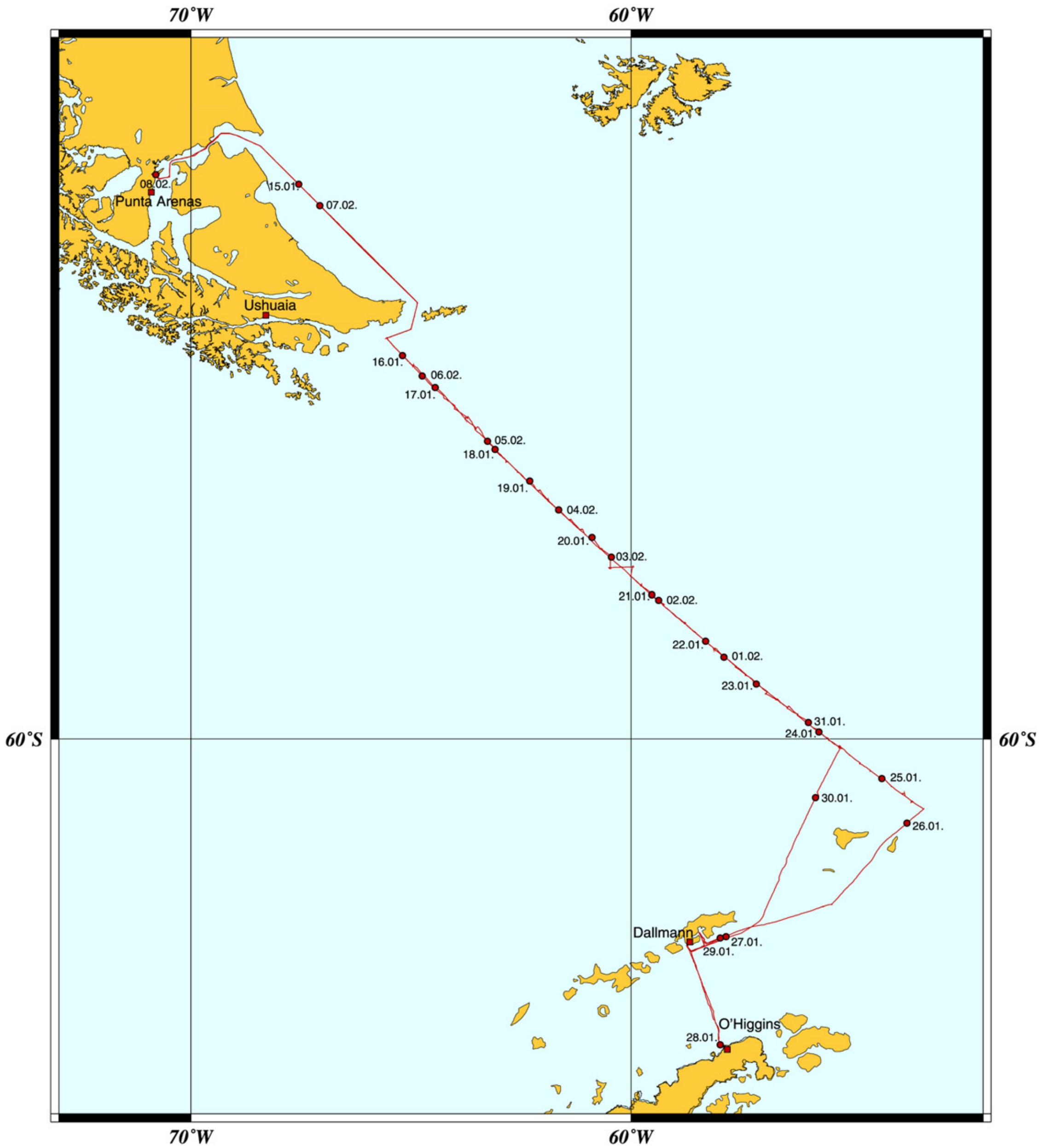

Fig. 2. Cruise track during Polarstern leg ANT-XXIII/3 from 14 January to 8 February 2006, Punta Arenas to Punta Arenas comprising station work on the way to Antarctica and back to Punta Arenas. The track is carefully positioned exactly under consecutive fly-overs of the Jason-1 satellite.

January–February 2006 during ANT-XXIII/3. A high-resolution, full-depth, hydrographic section across Drake Passage with tracers and horizontal velocity measurements was repeated within three weeks in austral summer 2006. This unique dataset allowed to study the intensive changes over such short times. Barré et al. (2011) used satellite altimetric data to provide the context both in space (the whole Drake Passage) and in time (15 years of altimetry). The positions of frontal branches, major meanders and eddies during the survey period are derived from sea-surface height maps. Distinct branches of the large scale fronts as there are the Sub-Antarctic Front (SAF), the Polar Front (PF) and the Southern Boundary of the ACC (SACCF) could be identified and the origin and fate of the two large eddies crossed by the 2006 cruise: a cyclonic eddy (N2) in the Yaghan Basin and an anticyclonic eddy (P10) in the Ona Basin were investigated. A comprehensive LADCP dataset provided new net total transport estimates of about 140 Sv on the southward leg and 125 Sv on the northward leg, with error bars between 8 and 10 Sv. The eddies P10 and N2 crossed during the cruise carried about 32 Sv each (Renault et al., 2011). Provost et al. (2011) focussed on the shallow water masses and showed that only part of the observed differences between the two sections is attributable to frontal or eddy displacements along the section. The other part results from the spatial heterogeneity of water properties upstream the section and the funnelling of the flow due to the topographic constraints of the Shackleton Fracture Zone (SFZ). The changes in the deep and bottom waters at the intersection between the SFZ and the West Scotia Ridge (WSR; 58.20°S) were studied by Sudre et al. (2011) by comparing the data obtained during the southward and northward legs by means of a multiparametric analysis. The normal vertical stacking of the deep water masses was disrupted in the first section while it was reestablished in the second section.

Fig. 3. Upon its recovery from the sea, the Titan ultraclean sampling system is returned into its home clean air laboratory container, by 3 crew members (Andreas Bäcker, Uwe Schmidt, Uwe Wende) of *Polarstern* and at right hand side with remote control unit the late Willem Polman. In middle on top is overhead seen the black kevlar hydrowire coming in from the overboard block (not shown) to the white plastic 97 cm diameter horizontal pulley led into the large winch positioned beyond the clean container. At left is protective heavy steel barrier to prevent waves that come in from the side to damage the clean container van (Greenwich meridian, 19 February 2008; Photo: Hein de Baar).

Fig. 4. One of three humpback whales visiting *Polarstern* for about one hour in a mingle of exciting water ballet show and apparent curiosity. Greenwich meridian transect (0°W, 58°S) at 20 February 2008 (Photo: Alexandra Grönholz).

3. Changing carbon dioxide and effect on phytoplankton in the Southern Ocean

The increase of Carbon Dioxide (CO_2) in the atmosphere due to activities of mankind (combustion of fossil fuels, cement production, land use changes) leads to invasion of part of this anthropogenic CO_2 into ocean waters, with ensuing changes of the chemistry of seawater conceivably affecting the marine biota. By comparison of 10 successive cruises spanning 35 years in the 1973–2008 period, Van Heuven et al. (2011) were able to discern the increase of the concentration total dissolved inorganic carbon (DIC or C_T) in the Weddell gyre. The measured concentration of C_T in the Weddell Sea Bottom Water (WSBW) is shown to rise slowly but significantly at a rate of $+1.151 \pm 0.563$ μmol kg^{-1} decade^{-1}. The time trend in the Weddell Sea Deep Water (WSDW) is smaller and as yet non-significant, while the expected strongest time trend in the shallow waters (<200 m depth) do not allow for interpretation since these are strongly affected by seasonality.

Nevertheless the undoubtedly increasing concentration C_T in shallow waters, and associated increasing concentration dissolved CO_2 ($<1\%$ of C_T) may affect the inorganic carbon uptake of phytoplankton. Utilising the isotopic disequilibrium technique, Neven et al. (2011) were able to discern between uptake of CO_2 versus uptake of bicarbonate ion (HCO_3^-) by the resident phytoplankton communities. There was a positive correlation between the contribution of CO_2 to total inorganic carbon uptake and the ambient concentration of CO_2 in seawater, suggesting that Southern Ocean microalgae could increase the proportion of CO_2 uptake under future high atmospheric CO_2 levels. Otherwise the CO_2 is not limiting primary productivity, instead the interactions of iron limitation and light climate are deemed the major limitations of phytoplankton in the Southern Ocean (De Baar et al., 2005) where wind-induced vertical mixing reduces the total irradiance dose phytoplankton cells residing in the upper mixed layer receive (Mitchell et al., 1991; De Baar et al., 2005), but also periodically exposes phytoplankton cells to periods of excessive irradiance when residing near the surface. These rapid irradiance fluctuations may cause photodamage, the extent and characteristics of which were investigated in two studies reported elsewhere (Alderkamp et al., 2010, 2011).

4. Trace elements and isotopes in the International Polar Year (IPY-GEOTRACES)

The worldwide GEOTRACES programme aims to produce first-ever deep ocean sections of key trace metal elements, notably Fe, Al, Zn, Mn, Cd and Cu, in conjunction with key isotope systems, here the isotopes of Th and Pa as tracers of marine particles processes. The International Polar Year (2007–2008) did allow a flying start of fulfilling the deep ocean sections objectives of the GEOTRACES programme, and a suite of GEOTRACES expeditions has been performed in both the Arctic Ocean (e.g. Middag et al., 2009) and the Southern Ocean presented here. There have been 6 Arctic and 5 Antarctic GEOTRACES cruises sampling more or less of several trace elements and isotopes, with more or less intense and deep vertical sampling, and one Antarctic process study (Table 1). Among these the GEOTRACES components of the 2007 Arctic and 2008 Antarctic *Polarstern* expeditions ARK-XXII/2 (Schauer, 2008) and ANT-XXIV/3 (Fahrbach and De Baar, 2010) were initiated and organised jointly by M. Rutgers van der Loeff (Germany) and H. de Baar (The Netherlands).

Dissolved aluminium (Al) occurs in a wide range of concentrations in the world oceans. Middag et al. (2011-a) report the first systematic dataset of dissolved Al in the Southern Ocean, presenting overall 470 new data values from 22 full depth stations along the Greenwich meridian transect. The concentrations of dissolved Al are extremely low, actually lower than previously reported in the Southern Ocean. In contrast to the Arctic Ocean and several other ocean basins (Middag et al., 2009), there was no relationship observed between dissolved Al and silicate (Si).

The first comprehensive dataset (Middag et al., 2011-b; 492 samples) of dissolved Mn in the Southern Ocean shows extremely low values of 0.04 up to 0.64 nM in the surface waters along the

Table 1
Listing of implemented and completed IPY-GEOTRACES expeditions, comprising 6 Arctic and 5 Antarctic section cruises and 1 Antarctic process study, see also: (www.geotraces.org) site. For the original IPY-GEOTRACES science plan, see "International Polar Year GEOTRACES: an international study of the biogeochemical cycles of Trace Elements and Isotopes in the Arctic and Southern Oceans" at below websites: (http://www.ipy.org/development/eoi/proposal-details.php?id=35) (http://classic.ipy.org/development/eoi/proposal-details.php?id=35).

Code and name of expedition	Research vessel	Chief scientist	GEOTRACES principal investigator	GEOTRACES IPY number	Begin date	End date	Ocean or sea	Region
KH06 Sea of Okhotsk 1	Professor Khromov	Nakatsuka, Takeshi	Nishioka, Jun	IPY 9 section	2006-08-13	2006-09-12	Sea of Okhotsk (Arctic)	Western part
au0703 SAZ-SENSE	Aurora Australis	Griffiths, Brian	Bowie, Andrew	IPY 2 section	2007-01-17	2007-02-20	Sub-Antarctic & Polar Front	South off Tasmania
ATOS-1	Hesperides	Duarte, Carlos	Tovar-Sanchez, Antonio	IPY 10 section	2007–6-29	2007-07-27	Arctic	Iceland to Spitsbergen
ARK-XXII/2	Polarstern	Schauer, Ursula	Rutgers van der Loeff, Michiel	IPY 11 section	2007-07-29	2007-10-07	Arctic	Eurasian and central Arctic
KH07 Sea of Okhotsk 2	Professor Khromov	Nakatsuka, Takeshi	Nishioka, Jun	IPY 12 section	2007-08-05	2007-09-15	Sea of Okhotsk (Arctic)	Western part
au0701 SIPEX	Aurora Australis	Worby, Tony	Bowie, Andrew	IPY 3 section	2007-09-03	2007-10-17	Antarctica	East
MD166 Bonus GoodHope	Marion Dufresne	Speich, Sabrina	Boye, Marie	IPY 4 section	2008-02-08	2008-03-24	Southern Ocean	Atlantic sector
ANT-XXIV/3 Zero & Drake	Polarstern	Fahrbach, Eberhard	De Baar, Hein	IPY 5 section	2008-02-10	2008-04-10	Southern Ocean	Greenwich meridian, Weddell Sea, Drake Passage
au0806 SR3-GEOTRACES	Aurora Australis	Rintoul, Steve	Butler, Edward	IPY 6 section	2008-08-15	2008-09-28	Southern Ocean	Antarctica to Hobart
ISSS-08	Smirnitskyi	Semiletov, Igor	Andersson, Per	IPY 13 section	2008-08-15	2008-09-28	Arctic Siberian coast	Laptev Sea and East Siberian Sea
NBP0901 DynaLife	Nathaniel B. Palmer	Jacobs, Stan	De Baar, Hein	IPY 7 process study	2009-01-05	2009-02028	Antarctica	Amundsen Sea; Pine Island Bay
Beaufort Sea	CCGS Amundsen	Francois, Roger	Francois, Roger	IPY 14 section	2009-08-27	2009-09-13	Arctic Ocean	Canada Basin

Greenwich meridian, and a subsurface maximum with an average concentration of 0.31 nM. Similar trends were observed for major nutrients phosphate and nitrate, the first-ever observed co-variances of Mn with these major nutrients is the first dissolved tracer derived evidence of biological Mn uptake, where Mn is conceivably acting as co-limitation with dissolved Fe in the Southern Ocean. The Antarctic continent is unique in that its protruding continental ice-sheet by covering the extensive shelf shuts down the biogeochemical cycling, hence in contrast to all other continental shelves, there apparently is no supply of Mn (and Fe) into adjacent waters. As a result the southernmost Weddell gyre waters near the edge of the ice-sheet have extremely low Mn concentrations. On the other hand elevated Mn concentrations in deep waters over the Bouvet triple junction are due to hydrothermal vent supply.

Moreover another large dataset of both dissolved Al and dissolved Mn in Drake Passage, comprising 232 samples at 10 full depth stations, has been reported elsewhere (Middag et al., 2011a).

At the Greenwich meridian, the parallel comprehensive dataset of dissolved Fe comprising 482 values at 22 deep stations shows concentrations varying between 0.1 and 0.3 nM in the surface waters (Klunder et al., 2011). In deep waters there is a distinct maximum at lower latitude (42°S) due to inflow of Fe-elevated North Atlantic Deep Water (NADW). Moreover a distinct hydrothermal Fe plume, coinciding with above mentioned Mn plume, exists over the Bouvet triple junction. On the other hand the extremely low Fe in the southern part of the Weddell gyre confirms that the extending continental ice-sheet prevents the Antarctic continent to serve as Fe supply source. Overall the supply of Fe with hydrothermal vents in deep Antarctic and Arctic Oceans (Middag et al., 2011b) is deemed a far more important source to ocean waters than realized before these new findings were presented at several conferences (e.g. Klunder et al., 2008, 2009).

The strong (>99%) organic complexation of dissolved Fe is crucial in maintaining dissolved Fe in solution in seawater, hence affecting Fe availability for uptake by phytoplankton. Thuróczy et al. (2011) assessed Fe organic complexation along the Greenwich meridian, in the Weddell Sea and in Drake Passage. In general the excess of organic ligands over dissolved Fe tends to decrease with increasing depth, making dissolved Fe more vulnerable for loss from solution due to (oxidative) precipitation removal (scavenging). On the other hand more southwards the ratio Ligand/Fe tends to increase due to both lower dissolved Fe and changes in ligand characteristics.

An important part of the ongoing work on trace metal biogeochemistry is to understand the processes involved in the transformation between different chemical species. Superoxide (O_2^-) is a short lived oxygen radical, produced by photochemical or biological reactions, which is highly reactive with trace metals such as Fe and Cu leading to a redox cycle for those metals in seawater. During ANT-XXIV/3 work was performed on the decay kinetics of O_2^- throughout the water column (Heller and Croot, 2010). This work showed that Cu was the major sink for O_2^- in the Southern Ocean despite it being strongly organically complexed. Contrastingly the reaction between O_2^- and Fe was relatively slow suggesting that iron organic complexes do not react significantly. The importance of this work is that it elucidates a key redox transformation pathway for bioactive metals in seawater for the first time and upon publication it was highlighted as a featured news article in ES&T (Powell, 2009).

Titanium (Ti) is present in seawater at the 10–300 pM (10^{-12} M) level as similar to iron it is poorly soluble in seawater. However unlike Fe it is has no known biological usage and it subjected to only abiotic scavenging in the water column and has the potential to be used as a tracer of dust inputs to the open ocean. The ANT-XXIV/3 expedition provided the opportunity to make the first measurements of dissolved Titanium in the Southern Ocean, using a new catalytic voltammetric method that allows shipboard determination of Ti in seawater (Croot, 2011).

Dissolved zinc (Zn) is perhaps the most challenging trace metal element in the oceans to analyse, this due to the risk of inadvertent contamination. The international collaboration combining ultraclean sampling and ultraclean analyses during ANT-XXIV/3 produced the first comprehensive reliable dataset of the distribution of dissolved Zn (Croot et al., 2011) and its chemical speciation (Baars and Croot, 2011) in the Southern Ocean.

Both at the Greenwich meridian section and across the Drake Passage, the dissolved Zn showed a strong increase in surface waters from the sub-Antarctic waters across the Polar Front into the Antarctic Ocean (Croot et al., 2011). Vertical profiles for dissolved Zn showed the presence of local minima and maxima in the upper 200 m consistent with significant uptake by phytoplankton and release by zooplankton grazing, respectively. In general, Zn and silicate were strongly correlated throughout the region and water column, further confirming strong control of the distribution of bio-essential Zn by biological processes.

Quite remarkably most of the dissolved Zn exists in the free inorganic Zn pool and only a small portion is bound as Zn–organic complexes (Baars and Croot, 2011). This finding is in contrast to previous Zn speciation studies in lower latitude regions where the dissolved Zn is predominantly bound as Zn–organic complexes. Only in the surface waters did the concentration of Zn complexing ligands exceed the dissolved Zn concentrations suggesting a biological source for these ligands.

Cadmium (Cd) is akin to Zn and along the Greenwich meridian the distribution of Cd and its stable isotope ratio $^{112}Cd/^{110}Cd$ is consistent with strong involvement of Cd in the biological cycle reported elsewhere by Abouchami et al. (2011). The relationships between Cd isotope ratios and Cd concentrations are quite different in the Antarctic Circumpolar Current (ACC) versus the Weddell gyre. The about twofold shift in biological isotope fractionation effect is likely due to different plankton communities in these two distinct ocean biogeochemical provinces.

The redox speciation of iodate (IO_3^-) and iodide (I^-) in high latitudes differs from the Iodine cycling in low latitudes (Bluhm et al., 2011). Surface concentrations of iodide were much higher than in deep waters, likely due to coupling with biological decomposition processes, also indicated by a positive correlation with nitrite. Elevated levels of iodide in Weddell Sea Bottom Water (WSBW) indicate slow oxidation kinetics relative to the formation rate of WSBW, hence iodide may have potential as a tracer for latter rate of WSBW formation.

The depletion in the upper ~100 m of the water column of radiogenic ^{234}Th with respect to its parent ^{238}U did allow the assessment of export with biogenic debris of ^{234}Th into deeper waters. Moreover by conversion with the POC/^{234}Th ratio of suspended particles, the downward settling export of particulate carbon was derived (Rutgers van der Loeff et al., 2011). This and additional underway measurements of dissolved and particulate ^{234}Th, revealed relationships with several indicators of biological activity, notably more or less light transmission as indicator of low or high plankton abundance, pCO_2 indicative of net photosynthesis, fluorescence as tracer of phytoplankton abundance, and distributions of bio-essential trace metal elements Fe and Mn. Notably the latter strong co-variances of ^{234}Th with trace metals confirm the elegance and strength of the integrated GEOTRACES approach.

The systematic studies of three Thorium isotopes ^{230}Th, ^{232}Th and ^{234}Th as well as ^{231}Pa in Drake Passage allow to better define the scavenging regimes, and the effects of the oceanic circulation on the fate of particulate material and on the Pa–Th distributions in the water column (Venchiarutti et al., 2011). Reversible scavenging modelling of both ^{230}Th and ^{234}Th gives estimates of particle

Table 2
The shipboard party of *Polarstern* expedition ANT-XXIV/3. Top are scientific party, bottom are officers and crew.

Scientists
Eberhard Fahrbach, chief scientist
Anne-Carlijn Alderkamp
Oliver Baars
Mickael Beauverger
Katrin Bluhm
Olaf Boebel
Carmen Boening
Babette Bontes
Klaus Bult
Pinghe Cai
Luisa Cristini
Peter Croot
Hein De Baar
Claire Evans
Erwin Frijling
Veronique Garçon
Madlen Gebler
Loes Gerringa
Lars Gremlowski
Alexandra Grönholz
Hans-Hilmar Heckmann
Maija Heller
Oliver Huhn
San Chui Hwang
Annie Kartavtseff
Olaf Klatt
Maarten Klunder
Patrick Laan
Marielle Lacombe
Jae-Hak Lee
Herve Legoff
Charlotte Lohse
Rob Middag
Thierry Monglon
Matthias Monsees
Carsten Möllendorf
Ika Neven
Ismael Nunez-Riboni
Sven Ober
Andrea Paz Martinez
Christine Provost
Alice Renault
Maya Robert
Gerd Rohardt
Hendrik Sander
Wolfgang Seifert
Nathalie Sennéchael
Hans Slagter
Aurelie Spadone
Torben Stichel
Ingrid Stimac
Mihael Stimac
Olaf Strothmann
Joel Sudre
Elizabeth Sweet
Stefan Theisen
Charles-Edouard Thuroczy
Steven van Heuven
Jan van Ooijen
Cees van Slooten
Celia Venchiarutti
Crew
Stefan Schwarze, master
Andreas Bäcker
Tilo Becker
Bärbel Czyborra
Heike Dugge
Klaus Elsner
Holger Fallei
Bernd Farysch
Martin Fröb
Hans-Jürgen Gaude
Hartmut Guse
Manfred Hagemann
Ernst-Uwe Hartmann
Andreas Hecht
Frank Himmel
Irene Hölger
Wu-Mei Huang
Michael Ipsen
Monika Jürgens
Reiner Loidl
Hans-Ulrich Minzlaff
MichaelMartens
Wolfgang Möller
Helmut Muhle
Ralf-Dieter Müller-Homburg
Ilias Nasis
Lutz Peine
Lutz Pinske
Uwe Preußner
Lutz Reise
Marc Schäfer
Uwe Schmidt
Manfred Scholz
Carmen Silinski
Frank Silinski
Herbert Sokoll
Hein-Werner Stutz
Steffen Spielke
Stefan Sümnicht
Ringo Vehlow
Bernd Voy
Uwe Wende
Michael Winkler
Chi Lung Wu

dynamics in the upper 1500 m. The well-known generally southwards upwelling of deep waters strongly controls the ^{230}Th distribution along the Drake Passage section. This is also true for ^{231}Pa but only in the upper $\sim$1500 m. Below this depth, ^{231}Pa vertical profiles exhibit contrasting concentrations at stations in the northern part of ACC and to the south of ACC. These N–S differences of ^{231}Pa are attributed to different origins of water masses.

Acknowledgments

This issue is dedicated by the full shipboard party (Table 2) to the memory of our lost colleagues. We are most grateful to Captain Schwarze with his officers and crew for their excellent support throughout the expedition. The crews of the Neumayer-II-Station and building Neumayer III have been very supportive for which our gratitude forever. The dedication of overall 3 medical doctors and 2 nurses of combined Neumayer-II-Station and *Polarstern* staff have made the difference for the eventual full recovery of the 3 injured colleagues. The pilots of the Basler BT-67 and the jet plane are gratefully acknowledged for the courage and professionalism to utilise brief meteorological time windows for repatriation via Novolazarevskaja base to Cape Town. Many thanks are to the many colleagues at our home institutions for their marvellous dedication to assist us at all times throughout the expedition.

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References

Abouchami, W., Galer, S.J.G., De Baar, H.J.W., Alderkamp, A.-C., Middag, R., Laan, P., 2011. Modulation of the Southern Ocean cadmium isotope signature by ocean circulation and primary productivity. Earth and Planetary Science Letters 305, 83–91.

Alderkamp, A.-C., de Baar, H.J.W., Visser, R.J.W., Arrigo, K.R., 2010. Can photoinhibition control phytoplankton abundance in deeply mixed water columns of the Southern Ocean? Limnology and Oceanography 55, 1248–1264.

Alderkamp, A.-C., Garcon, V., De Baar, H.J.W., Arrigo, K.R., 2011. Short-term photoacclimation effects on photoinhibition of phytoplankton in the Drake Passage (Southern Ocean). Deep-Sea Research I 58, 943–955.

Baars, O., Croot, P.L., 2011. The speciation of dissolved zinc in the Atlantic sector of the Southern Ocean. Deep-Sea Research II 58, 2720–2732.

Barré, N., Provost, C., Renault, A., Sennéchael, N., 2011. Fronts, meanders and eddies in Drake Passage during the ANT-XXIII/3 cruise in January–February 2006: a satellite perspective. Deep-Sea Research II 58, 2533–2554.

Behrendt, A., Fahrbach, E., Hoppema, M., Rohardt, G., Boebel, O., Klatt, O., Wisotzki, A., Witte, H., 2011. Variations of Winter Water properties and sea ice along the Greenwich meridian on decadal time scales. Deep-Sea Research II 58, 2524–2532.

Bluhm, K., Croot, P.L., Huhn, O., Rohardt, G., Lochte, K., 2011. Distribution of iodide and iodate in the Atlantic sector of the southern ocean during austral summer. Deep-Sea Research II 58, 2733–2748.

Croot, P.L., Rapid determination of picomolar titanium in seawater with catalytic cathodic stripping voltammetry. Analytical Chemistry, in press. [doi:10.1021/ac201450k].

Croot, P.L., Baars, O., Streu, P., 2011. The distribution of dissolved zinc in the Atlantic sector of the Southern Ocean. Deep-Sea Research II 58, 2707–2719.

De Baar, H.J.W., Boyd, P.W., Coale, K.H., Landry, M.R., Tsuda, A., Assmy, P., Bakker, D.C.E., Bozec, Y., Barber, R.T., Brzezinski, M.A., Buesseler, K.O., Boye, M., Croot, P.L., Gervais, F., Gorbunov, M.Y., Harrison, P.J., Hiscock, W.T., Laan, P., Lancelot, C., Law, C.S., Levasseur, M., Marchetti, A., Millero, F.J., Nishioka, J., Nojiri, Y., van Oijen, T., Riebesell, U., Rijkenberg, M.J.A., Saito, H., Takeda, S., Timmermans, K.R., Veldhuis, M.J.W., Waite, A.M., Wong, C.S., 2005. Synthesis of iron fertilization experiments: from the Iron Age in the age of enlightenment. Journal of Geophysical Research—Oceans 110, C09S16.

Fahrbach, E., De Baar, H. (Eds.), 2010. The expedition of the research vessel "Polarstern" to the Antarctic in 2008 (ANT-XXIV/3)/ed. by Eberhard Fahrbach and Hein de Baar, Berichte zur Polar- und Meeresforschung=Reports on polar and marine research, vol. 606, 232 pp. 〈http://epic.awi.de/Publications/Fah2010a.pdf〉.

Fahrbach, E., Hoppema, M., Rohardt, G., Boebel, O., Klatt, O., Wisotzki, A., 2011. Warming of deep and abyssal water masses along the Greenwich meridian on decadal time scales: The Weddell Gyre as a heat buffer. Deep-Sea Research II 58, 2509–2523.

Fetterer, F., Knowles, K., Meier, W., Savoie M., 2009. Sea Ice Index. Boulder, CO: National Snow and Ice Data Center. Digital media.

Heller, M.I., Croot, P.L., 2010. Superoxide decay kinetics in the Southern Ocean. Environmental Science and Technology 44 (1), 191–196. [doi:10.1021/es901766r].

Klunder, M.B., Middag, R., Thuróczy, C.-E., Gerringa, L.J.A., De Baar, H.J.W., 2008. Distribution and sources of dissolved iron in the Arctic Ocean. In: SCAR-IACS IPY Conference, St. Petersburg, Russia, July 2008.

Klunder, M.B., Laan, P., Bakker, K., Ober, S., De Baar, H.J.W., 2009. IPY-GEOTRACES: sources and distribution of dissolved iron in the Arctic and Southern oceans. In: ASLO Aquatic Sciences Meeting, Nice, January 2009.

Klunder, M.B., Laan, P., Middag, R., De Baar, H.J.W., Van Ooijen, J.C., 2011. Dissolved iron in the Southern Ocean (Atlantic sector). Deep-Sea Research II 58, 2678–2694.

Middag, R., De Baar, H.J.W., Laan, P., Bakker, K., 2009. Dissolved aluminium and the silicon cycle in the Arctic Ocean. Marine Chemistry 115 (3–4), 176–195.

Middag, R., Van Slooten, C., de Baar, H.J.W., Laan, P., 2011a. Dissolved aluminium in the Southern Ocean. Deep-Sea Research II 58, 2647–2660.

Middag, R., De Baar, H.J.W., Laan, P., Cai, P.H., Van Ooijen, J.C., 2011b. Dissolved manganese in the Atlantic sector of the Southern Ocean. Deep-Sea Research II 58, 2661–2677.

Middag, R., De Baar, H.J.W., Laan, P., 2011a. The effects of continental margins and water mass circulation on the distribution of dissolved aluminium and manganese in Drake Passage. Journal of Geophysical Research(Oceans).

Middag, R., De Baar, H.J.W., Laan, P., Klunder, M.B., 2011. Fluvial and hydrothermal input of manganese into the Arctic Ocean. Geochimica et Cosmochimica Acta 75, 2393–2408. [doi:10.1016/j.gca.2011.02.011].

Mitchell, B.G., Brody, E.A., Holm-Hansen, O., McClain, C., Bishop, J., 1991. Light limitation of phytoplankton biomass and macronutrient utilization in the Southern-Ocean. Limnology and Oceanography 36, 1662–1677.

Neven, I.A., Stefels, J., Van Heuven, S.M.A.C., De Baar, H.J.W., Elzenga, J.T.M., 2011. High plasticity in inorganic carbon uptake by Southern Ocean phytoplankton in response to ambient CO_2. Deep-Sea Research II 58, 2636–2646.

Powell, S.C., 2009. Redox effects of superoxide in polar waters. Environmental Science and Technology 43 (23) 8710–8710.

Provost, C. (Ed.), 2007. The Expedition ANT XXIII/3 of the Research Vessel Polarstern in 2006. Berichte zur Polar- und Meeresforschung=Reports on polar and marine research, vol. 558, 68 pp. 〈http://epic.awi.de/Publications/Pro2007a.pdf〉.

Provost, C., Renault, A., Barré, N., Sennéchael, N., Garçon, V., Sudre, J., Huhn, O., 2011. Two repeat crossings of Drake Passage in austral summer 2006: short term variations and evidence for considerable ventilation of intermediate and deep waters. Deep-Sea Research II 58, 2555–2571.

Renault, A., Provost, C., Sennéchael, N., Barré, N., Kartavtseff, A., 2011. Two full-depth velocity sections in the Drake Passage in 2006—transport estimates. Deep-Sea Research II 58, 2572–2591.

Rutgers van der Loeff, M., Cai, P.H., Stimac, I., Bracher, A., Middag, R., Klunder, M.B., Van Heuven, S.M.A.C., 2011. ^{234}Th in surface waters: distribution of particle export flux across the Antarctic Circumpolar Current and in the Weddell Sea during the GEOTRACES expedition ZERO and DRAKE. Deep-Sea Research II 58, 2749–2766.

Schauer, U. (Ed.), 2008. The expedition ARKTIS-XXII/2 of the research vessel "Polarstern" in 2007/Ed. by Ursula Schauer, Berichte zur Polar- und Meeresforschung=Reports on polar and marine research, vol. 579, 271 pp. 〈http://epic.awi.de/Publications/Sch2008ae.pdf〉.

Sudre, J., Garçon, V., Provost, C., Sennéchael, N., Huhn, O., Lacombe, M., 2011. Short-term variations of deep water masses in Drake Passage revealed by a multiparametric analysis of the ANT-XXIII/3 bottle data. Deep-Sea Research II 58, 2592–2612.

Thuróczy, C.-E., Gerringa, L.J.A., Klunder, M.B., Laan, P., De Baar, H.J.W., 2011. Observation of consistent trends in the organic complexation of dissolved iron in the Atlantic sector of the Southern Ocean. Deep-Sea Research II 58, 2695–2706.

Van Heuven, S.M.A.C., Hoppema, M., Huhn, O., Slagter, H.A., De Baar, H.J.W., 2011. Direct observation of increasing CO_2 in the Weddell Gyre along the Prime Meridian during 1973–2008. Deep-Sea Research II 58, 2613–2635.

Venchiarutti, C., RutgersvanderLoeff, M., Stimac, I., 2011. Scavenging of ^{231}Pa and thorium isotopes based on dissolved and size-fractionated particulate distributions at Drake Passage (ANTXXIV-3). Deep-Sea Research II 58, 2767–2784.

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