Multidisciplinary Theme Open Ocean Processes

Netherlands participation in the Antarctic expedition aboard Polarstern in the International Polar Year

In the context of the 2007-2008 International Polar Year (IPY), 17 scientists from NIOZ and the University of Groningen joined an Antarctic expedition of overall 54 scientists and 42 officers and crew aboard the research ice-breaker Polarstern of the Alfred Wegener Institute for Polar and Marine Research (Germany). The aim of the expedition was to conduct an integrated research program of physical oceanography and sea-ice dynamics (Climate in Antarctica and the Southern Ocean; IPY-CASO) with the study of of trace elements and isotopes (IPY-GEOTRACES) in relation to the plankton ecosystem and the ocean carbon cycle.

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). During the expedition a large number of physical, chemical and biological parameters were measured using the NIOZ Titan Ultraclean sampling system and a conventional CTD sampling system. The team of The Netherlands focused on the trace metals iron (Fe), manganese (Mn) and aluminium (Al); the major nutrients N, P and Si; the increasing CO_2 inventory of the Southern Ocean due to uptake of CO_2 from the atmosphere; the effects of this elevated CO_2 accompanied by ocean acidification on the plankton ecosystem; the photoinhibition and photopigments composition of phytoplankton; and the role of viruses in plankton ecology.

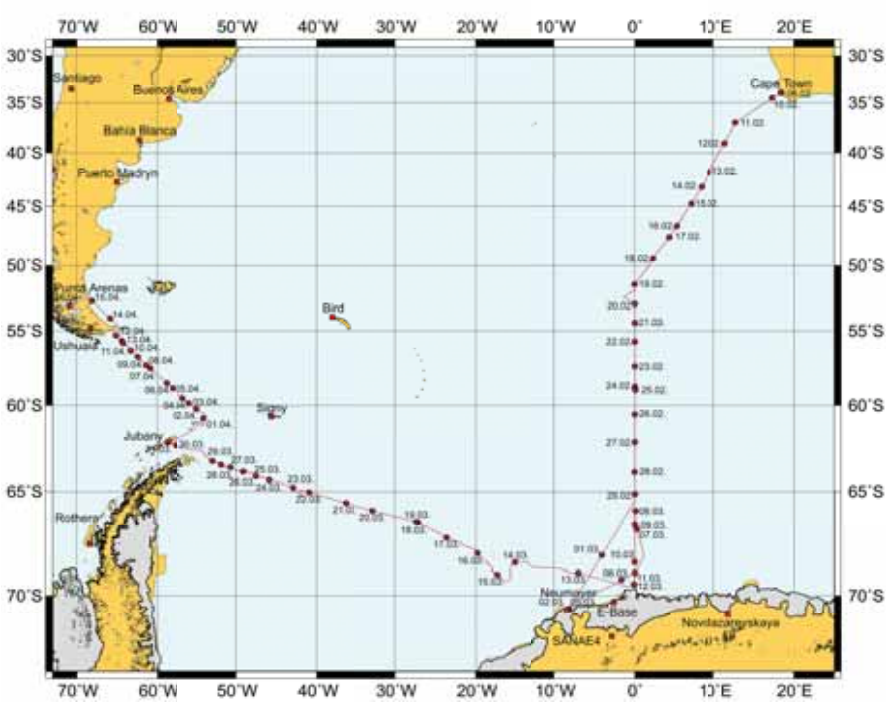

Fig. 1. Route of expedition ANT XXIV-3 aboard Polarstern, dots show days of the calender year 2008.

Fig. 2. First deployment of the Titan(ium) ultraclean frame with internal teflon coated PVC water samplers at 11 February at test station (37°S, 13°E) in still warm temperate region. Handling of the frame by ship's crew and NIOZ trace metal scientists; in the background Willem Polman (right) with the remote control leading the operation, next to boatswain Reiner Loidl (left) supervising. See Marine Chemistry (2008), 111, 4-21 for details of Titan system. Photograph courtesy Ilias Nasis.

One day after leaving Cape Town at a test station (37°S, 13°E) in the South East Atlantic Ocean the Titan system was successful, confirming its correct functioning and cleanliness (Fig. 2). Hereafter, 4 more stations were sampled for trace metals and 6 more for CO_2, alkalinity and nutrients (and many other parameters by the other participants) before reaching the first station (51°30'S, 0°W) at the Zero Meridian on 19 February. Along the Zero Meridian, complete vertical profiles comprising 24 sampling depths were collected, for trace metals samples at 16 more stations at every full

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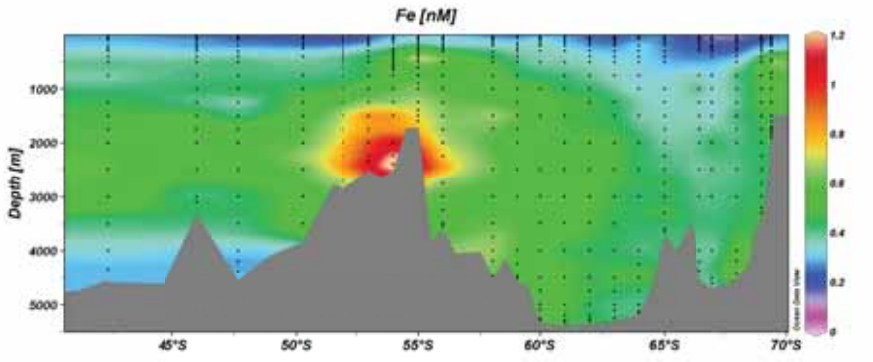
Fig. 3. Big is beautiful. One of three humpback whales visiting Polarstern for about one hour in a mingle of exciting water ballet show and apparent curiosity. Large they may be, their worldwide population of an estimated 30,000 humpback whales is modest compared to the smallest virus organisms in the sea whose total biomass would be equivalent to some 88 million humpbacks. Photograph courtesy Alexandra Gronholz.

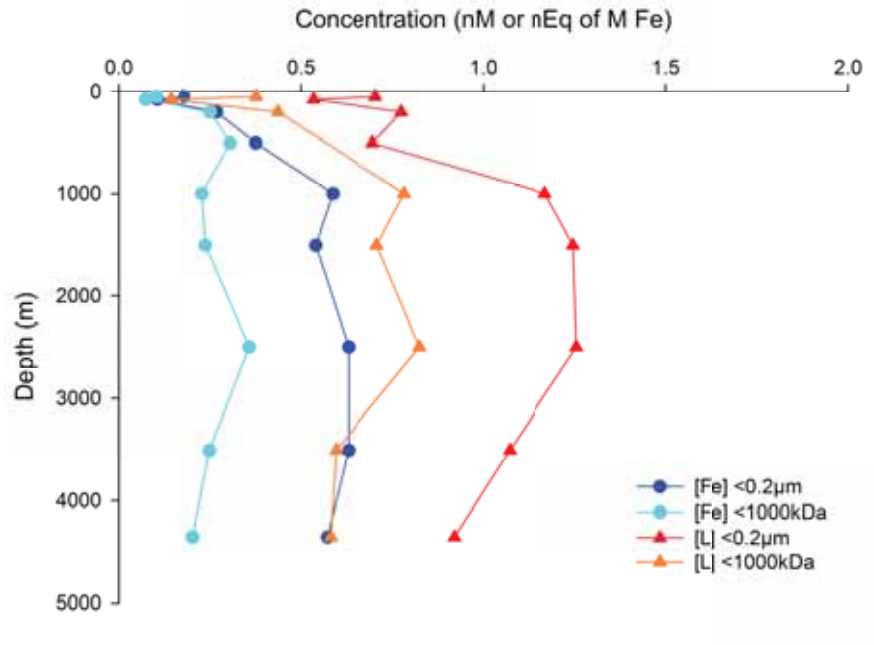
degree latitude, and for CO_2, alkalinity and nutrients at 44 stations every half degree. The close encounter with a group of three humpback whales (Fig. 3) cavorting around the ship for one hour was a further stimulus for studying the Antarctic Ocean ecosystem. The Zero Meridian section was interrupted at 29 February for transit to the German Neumayer 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 ice edge a helicopter left the ship bound for the Neumayer station. The helicopter crashed and the pilot and our colleague Willem Polman lost their lives. Maarten Klunder, PhD student of NIOZ, was among the three passengers on the back bench whom fortunately survived the accident thanks also due to their fast rescue and excellent medical treatment of injuries. "Many feelings hard to tell" was the introduction Hein de Baar used in his NIOZ colloquium in October 2008 about this special expedition. These exact words are valid here in the annual report where grief for the loss of Willem Polman and the pilot combines with gratitude for the full recovery of Maarten Klunder and the two other injured who have now all returned to work.

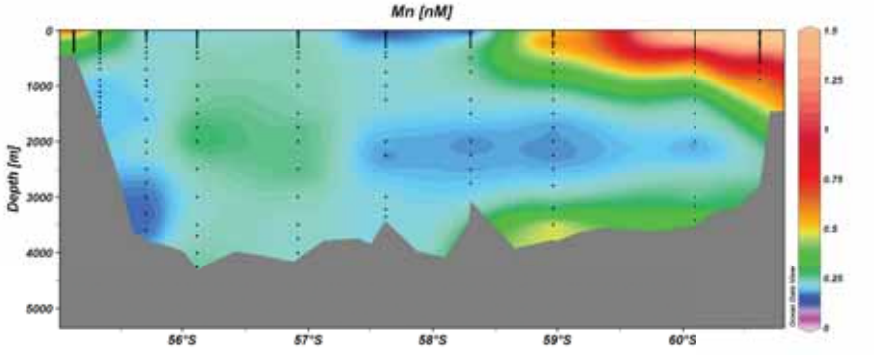
The expedition was delayed until successful evacuation of the three injured passengers by airplane on Wednesday 5 March upon which date Polarstern continued the journey and the scientific program also in honour of our lost colleagues. Polarstern returned at 7 March to 66°30'S, 0°W to the Zero Meridian to complete the transect to the



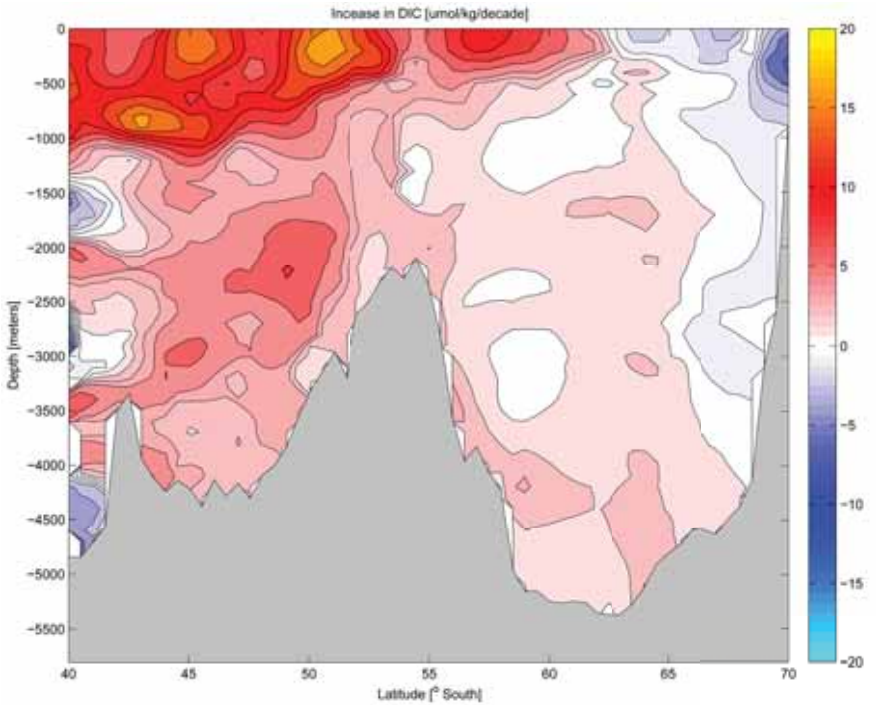
Vertical section of dissolved iron [10^{-9} mol L^{-1}] at the zero meridian including north of 51°30'S the four stations more to the east (1.5°E to 9°E) of the transit from Capetown. Shipboard analyses of 20 stations, comprising 24 sampling depths each, by Maarten Klunder and Patrick Laan. Notice plume of high iron over the mid ocean ridge (also found for manganese, not shown here) likely due to hydrothermal vent activity; extremely low values in surface waters at 67°S-68°S due to iron uptake by phytoplankton bloom.



Vertical profiles collected on 13 February at (42°20'S, 9°E) versus depth [metres] of 0.2 micrometer filtrate dissolved Fe (dark blue), the smaller 1000 kiloDalton filtrate dissolved Fe (light blue), and the concentration of iron-binding organic ligand (in units of equivalent of Fe) in the same two filtrates (red and yellow, respectively). Units are nanomol per Litre [nM] which is 10^{-9} mol per Litre, or nEq per Litre for the organic ligand L. The Fe-binding Ligand L is always in excess of the dissolved Fe. The dissolved Fe in itself is very unstable in seawater and tends to be removed as iron-oxide particles, but the excess organic ligand L keeps some dissolved Fe in solution. Data by Loes Gerringa and Charles-Edouard Thuroczy.



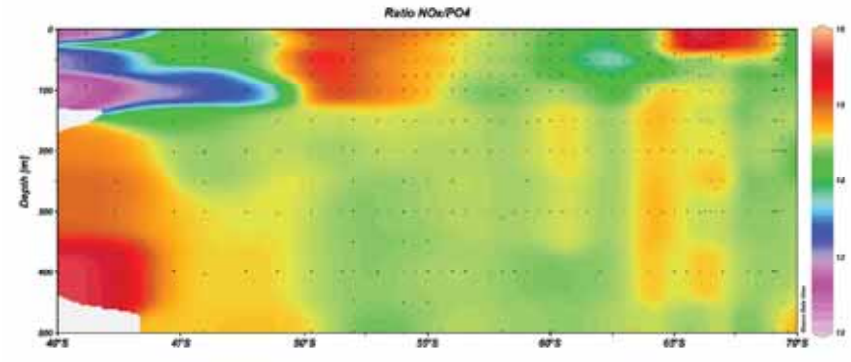
Vertical section of dissolved manganese [10^{-9} mol L^{-1}] across Drake Passage. Shipboard analyses by Rob Middag and Cees van Slooten. Notice elevated values near the Antarctic peninsula due to dissolution of Mn within anoxic sediments of the extensive shelf. In contrast the more rocky shelf of Tiera del Fuego hardly gives rise to elevated values.



The rate of increase of Dissolved Inorganic Carbon (DIC) in units of micromoles per kg seawater per decade [10^{-6} mol kg^{-1} $decade^{-1}$] at the Zero Meridian in the Southern Ocean (latitude 42°S to 69°S) calculated from observations of 12 expeditions in the 1984-2008 period. This increase shows the slow invasion of anthropogenic CO_2 from the atmosphere into the ocean, also giving rise to ocean acidification. Based on data by Steven van Heuven and Hans Slagter.

ice edge. Helicopter technician Michael Stimac (Germany) 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. Here another 10 stations were sampled for trace metals and 30 more stations for CO_2, alkalinity and nutrients.

The total productivity of this expedition was 930 measurements for dissolved iron, 931 for dissolved aluminium, 939 for dissolved manganese and some 2700 measurements for CO_2, alkalinity and



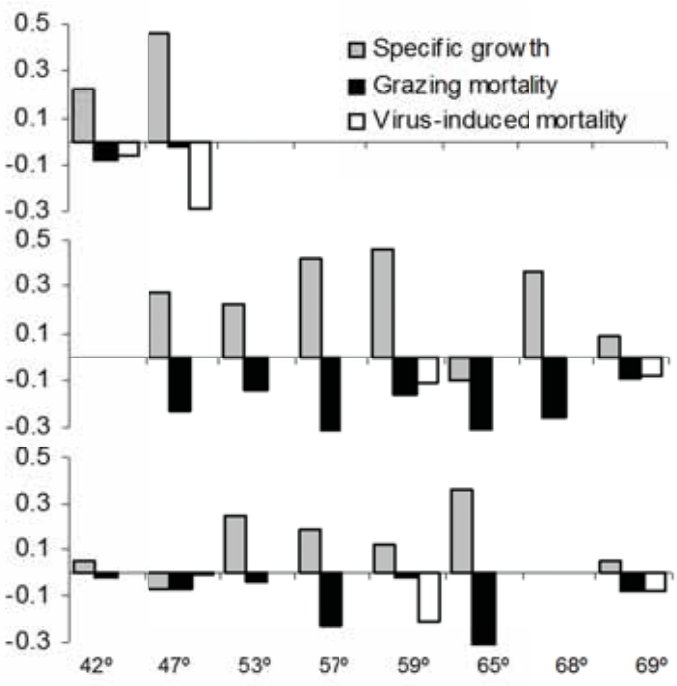
The Redfield ratio nitrate/phosphate at the Zero Meridian. High accuracy determinations by Jan van Ooijen permit to discern natural variability partly due to regional iron limitation hampering the uptake of nitrate, relative to phosphate, by phytoplankton. The high ratio values in surface waters at 67°S-68°S are consistent with the local iron deficiency hampering nitrate uptake by phytoplankton such that left behind in seawater is a high ratio value.

Carbondioxide incubation experiments under controlled laboratory conditions to mimic the effect of CO_2 on the plankton community during the last glacial maximum (190 10^{-6} atm), present (380 10^{-6} atm) and the future acidified ocean (750 10^{-6} atm). This project of the Netherlands Polar Program (NWO) is a collaboration between NIOZ and the University of Groningen (Ocean Ecosystems and Ecophysiology of Plants) on the Southern Ocean in a High-CO_2 World. Shipboard research by Babette Bontes and Ika Neven, photograph by Ika Neven.

nutrients. Together with similar size dataset for our preceding 2007 Arctic IPY GEOTRACES expedition, the world dataset for dissolved iron in deep ocean waters has become threefold larger. For manganese and aluminium a similar spectacular increase of the world dataset was achieved. Nine stations in the three transects were sampled to measure the speciation of Fe (the distribution over chemical and physical forms). Moreover very many ultraclean samples were collected for shipboard colleagues investigating other trace metals, as well as for delivery to various home laboratories for determination of trace metals and also their stable isotopes, notably the isotope systematics of cadmium and of iron. Additionally, several hundreds of samples were analysed for CO_2, alkalinity and nutrients in the biological experiments for effect of ocean acidification.

Daily depth profiles to determine the abundance of eukaryotic algae, cyanobacteria, bacteria and viruses were made. Approximately 20 serial dilution experiments were conducted along the Zero Meridian and the Drake Passage to determine the *in situ* phytoplankton growth rates, grazing pressure and virus-induced mortality. Measurements of bacterial production were conducted at approximately 40 sites along the cruise track in parallel with experiments to determine bacteriovory and virus-induced bacterial lysis. Furthermore, samples were collected at all experimental stations to examine the diversity of viruses and their microbial hosts. Preliminary results indicate that whilst viral lysis is an important regulator of bacteria, algal populations are predominantly controlled by grazing by microzooplankton. Besides this, in a joint project with Stanford University, short term (20 minutes) sunlight exposure experiments were done to study photoinhibition and recovery of algae in combination with investigation of photoprotective versus light-harvesting photopigments. Moreover 6 phytoplankton experiments were conducted of which 3 on the Zero Meridian, 2 in the Weddell Sea and 1 in the Drake Passage. In these experiments the local phytoplankton community was exposed to different CO_2 levels to assess the response of algae to past, present and future CO_2 conditions. An effect of the different CO_2 levels on the carbon uptake mechanism was observed, however no unequivocal effect on the growth rate was observed. Changes in the composition of the phytoplankton community are still being assessed in stored samples.

The CO_2 was measured as total inorganic carbon in full depth profiles over the water column and the measurements were in good agreement with results from previous cruises. The CO_2 data con-



Results of the dilution experiments conducted along the Zero Meridian. Growth rates and rates of grazing and viral-induced mortality of the Cyanobacteria and Picoeukaryote groups I and II are plotted against latitude. Data by Claire Evans and Erwin Frijling.

Group photo of the team of The Netherlands at the helicopter deck at the end of the Weddell Sea section. Missing are Willem Polman (deceased 2 March) and Maarten Klunder (evacuated 5 March). From left to right: Hans Slagter, Jan van Ooijen, Sven Ober, Babette Bontes, Patrick Laan (back) and Charles-Edouard Thuroczy, Rob Middag, Hein de Baar, Loes Gerringa, Erwin Frijling, Cees van Slooten, Ika Neven, Steven van Heuven, Anne-Carlijn Alderkamp, Claire Evans.

tributes significantly to the detection of trends in the CO_2 inventory of the Southern Ocean over the 1984-2008 time interval of high accuracy measurements. The total alkalinity helps in separating the anthropogenic contribution to observed trends in the CO_2 inventory of the Southern Ocean from natural variability.

The trace metal work showed some interesting results. For the first time a direct *in situ* correlation was observed in the surface waters between dissolved manganese on the one hand and biological production and nutrients on the other hand. The concentrations of dissolved aluminium were lower than previously reported in the literature for the Southern Ocean and provide new information on the global aluminium cycle and its intimate relation to the silicate cycle driven by diatom algae which have silicon skeletons. The concentration of dissolved iron was relatively constant in the deep waters of the Weddell Sea. Elevated dissolved iron concentrations related to continental shelf and/or hydrothermal inputs were observed in conjunction with elevated manganese concentrations. Surface water concentrations of dissolved iron were generally low and appeared to be related to iron uptake in phytoplankton growth. In one region of the surface waters of the Zero Meridian, all three trace metals showed a relation with an apparently recent event of deposition of atmospheric dust coming from land. Aerosol dust samples have also been collected and are being analyzed to confirm this.

Iron is kept in the dissolved form by dissolved organic molecules, preventing Fe to precipitate and to be scavenged out of the water column. At all stations these organic molecules had concentrations higher than the dissolved Fe concentration. The ratio of the concentration of these organic molecules versus Fe is high in the surface (up to 20) and decreases with depth to a value close to 1 in the deep waters in the total dissolved fraction (<0.2µm); these molecules become saturated with Fe with depth. In the smaller fraction (<1000kDa) this ratio is always higher than in the total dissolved fraction. This means that small organic molecules govern the reactivity of iron in the deep ocean.

The cruise was scientifically very successful and the major findings are written into manuscripts for several PhD theses and a dedicated special issue of Deep-Sea Research II. For those who returned home, the wondrous impressions of Antarctica remain but are dominated by the tragic events of 2 March and the memories of our lost friends remain etched into our minds.