A. Cruise narrative
A.1 Highlights
A.1.a WOCE designation SR4
A.1.b EXPOCODE 06AQANTIX/2
A.1.c Chief Scientist Eberhard Fahrbach
Alfrd Wegener Institut fuer
Polar und Meeresforschung
D-2850 Bremerhaven, F.R.
Germany
phone: 49-471-4831-501
Fax: 49-471-4831-149
49-471-4831-425
Internet: efahrbach@awi.bremerhaven.de
A.1.d Ship RV Polarstern
A.1.e Ports of Call
A.2 Cruise Summary

Itinerary and summary by E. Fahrbach

On 17 November 1990 NPolarstern"-left Punta Arenas. In Drake Passage physical oceanography work was started with an XBT- transect (Expendable Bathymthermograph) across the Antarctic Circumpolar Current. An Acoustic Doppler Current Profiler (ADCP) recorded the current field in the upper few hundred meters. The bathymetry and geology programmes began with soundings of Hydrosweep and Parasound which were continued during the complete cruise. Chemical investigations from the first leg were continued with underway measurements. They concentrated on biogenic sulfur compounds and their reaction products in sea water and the marine atmosphere with particular interest in DMS (dimethyl sulfide). Concentrations of nitric acid, ammonia and ammonium nitrate and organobromine compounds were investigated in the marine atmosphere.

We reached the Polar Front on 19 November at 57 23 S, 61 14 W. The first logistic task of the cruise was to deposit three German scientists with more than 8 tons of supply goods at the Soviet station Bellinghausen on King George Island. One scientist returned with us after an eleven months stay. After measuring the first CTD-profile (conductivitys temperature, depth) and making a catch with the multinet, we approached Joinville Island at the northeastern tip of the Antarctic Peninsula. There, two hauls with the Agassiz-trawl provided material for comparative studies on the temperature dependence and kinetics of digestive enzymes in crustaceans.

Still in open water we reached the western end of our main hydrographic transect crossing the Wedded Gyre towards Kapp Norvegia where the first of 21 current meter moorings was deployed and the first of seven recovered. On the shelf the first biology station took place including measurements with quantameter and Secchi disk, two CTD casts combined with a rosette water sampler and catches with multinet, bongo net, and plankton net. The water samples were used for biogeochemical investigations with special emphasis on the silica and nitrogen cycles. For this reason incubations were carried out to Al the uptake of radioactive 14C, 32Si and 32p and stable 15N. The nitrogen flux in the Antarctic food Webb could be determined from the water column to the zooplankton. In this
context the phytoplankton biomass and species distribution as well as reproduction and life cycles of dominant copepods were studied.

On 22 November at about 150 km from the coast we met at 63 30 S, 51 30 W the ice edge. The winds calmed down with increasing distance from the coast and air temperatures did not drop below -4 C. Rather quickly the swell disappeared and the floes increased in size. However, due to a system of leads, we could proceed along our course as planned. On 26 November at 65 34 S, 38 52 W we reached a deep sea channel which was surveyed with hydrosweep and parasound along 500-km profiles over a distance of 144 km. The structure is 1 to 3 km wide with a depth of 60 to 100 m below the adjacent sea level of about 4650 m. It extends with large meanders from westnorthwest to east northeast. Due to the heavy ice cover, consisting of floes a few kilometers in diameter and up to a meter thick, the track line could not be maintained as straight as desirable.

Bottom samples were collected with a minicorer which was hung under the CTD. This instrument was newly developed. During initial trials a procedure was achieved which allowed its use without significant additional shiptime. After this phase it was used routinely on 37 stations. The first recovery of a current meter mooring (208) within the ice (70 ice cover) occurred on 29 November. Before the acoustic release of the mooring the floes of up to 500 m in diameter were broken into smaller pieces to allow the floats to reach the surface. After the release 40 minutes of intensive search were necessary to sight a float before the recovery could be successfully finished. At mooring 209 on 3 December no float reached the surface and a time consuming acoustic ranging and breaking of ice floes finally permitted the detection and consequent recovery after 8 hours. This tedious technique had to be applied during all further recoveries, whereas the deployment of moorings could be accomplished without any problem.

The center of the Weddell Gyre at about 66 16 S, 30 18 W is marked by a relatively shallow surface mixed layer. It was reached on 2 December. For a better localization of the center a transect of 150 nm length consisting of 7 CTD-stations perpendicular to the main transect was carried out. On the basis of those data absolute velocities will be determined using the Beta spiral concept. During the Winter Weddell Gyre Study (WWGS) '89 higher mixed layer temperatures and more intense biological activity were found in that area. This was not observed during the present cruise possibly due to the different season. On 7 December the investigations in the "beta cross" area were terminated and the main transect was continued to the southeast with CTD-profiles, biology stations, mooring recoveries and deployments. The ice conditions became less favourable due to larger floes of less triable ice and closed leads because of colder temperatures.

The transect was finished on 15 December. The coastal polynya was only poorly established and highly variable. Because the biologists noted that there was no sign of a spring bloom, the planned stations were cancelled. The desert-like conditions in the water column, evidenced by a Secchi depth of 54 m were in sharp contrast to the abundant algae growth in the ice which gave rise to all colors from yellow to brown. Although small the narrow polynya was large enough for a haul with the Agassiz-trawl. The offshore ice belt of the polynya confirmed the term "ice- factory". It provided the heaviest ice conditions during the cruise and made the recovery of mooring 214 impossible. The last station on the transect was located in an inlet of 1 km length and 400 m width. In this inlet casts with CTD, multi- and bongo net were carried out in open water in the vicinity of the 25m high shelf ice front. After a hydrosweep survey of the continental slope in the aera of the Explorer-Escarpement we left on 16 December towards the Georgvon-Neumayevr-Station (GvN).
The work along the transect between Joinville Island and Kapp Norvegia amounted to 82 CTD and rosette stations, 7 biology stations, 21 mooring deployments and 7 recoveries. The established mooring network represents a gigantic flow meter which measures the volume of water and its heat content entering the Weddell Gyre in the northeast and leaving it in the northwest. South of our transect, cooling due to contact with the atmosphere and the shelf ice, together with salt release through ice formation, induces vertical descent of water masses to the bottom. Glacial meltwater has to be taken into account for a quantitative understanding of those processes. Because of the significance of deep reaching vertical mixing for the global abyssal circulation, our measurements are part of the World Ocean Circulation Experiment (WOCE).

The biogeochemical investigations of the cycles and budgets of various constituents represent a contribution to the international Joint Global Ocean Flux Study (JGOFS). They aim to explain the special role of the Weddell Gyre in the Southern Ocean and to estimate the significance of this area to the global carbon cycle. The contrast between the high nutrient availability and the low production remains unresolved. A chemical-biological project allowed for the first time, direct measurement of DMS-production of Antarctic phytoplankton and determination of the contributions of different species.

On 17 December we reached Atka-Bight. In the early morning "Polarstern" rammed into the fast ice to provide a safe platform for the unloading of about 100 tons of supply goods for the GvN-Station. First contacts with the female overwintering team had been established by a helicopter visit on 13 December to prepare the unloading procedure. The first trek with unloaded material left in the early afternoon towards the shelf ice edge and the station. Due to favourable conditions all loading was finished in the evening. "Polarstern" left the Atka-Bight at midnight of 18 December. On the way north air chemistry, XBT, hydrosweep and parasound measurements were continued. The ice edge was met at 68 00 S, 3 58 W where the ice concentration dropped within 30 nm from 70 to 10. Here the last biology station was carried out. On 23 December we reached 54 20 S, 3 23 W about 200 nm west of Bouvet Island were mooring BO1 was deployed with two sediment traps. The Polar Front was crossed on 24 December at 51 45 S, 2 24 E. Christmas Eve was celebrated with a merry ceremony in the "Blue Saloon" and a delightful buffet. The recovery of the last mooring PF 3 and deployment of PF4 was achieved in the morning of the 25 December. When we reached the 200 nm limit research was terminated. On 30 December 1990 at 01.00 "Polarstern" reached the bunker pier of Cape Town.

Physical Oceanography


Objectives

The aim of the physical oceanography programme is further understanding of the circulation in the Weddell Gyre and the related distribution of water masses. The operations contribute to a multiyear project, the Weddell Gyre Study, which is part of the World Ocean Circulation Experiment (WOCE). During this period a hydrographic survey along a transect from the northern tip of the
Antarctic Peninsula to Kapp Norvegia will be repeated four times, twice in summer and twice in winter, to measure the water mass distribution with its seasonal and interannual variability. The programme was initiated with a winter survey in 1989, the Winter Weddell Gyre Study (WWGS) '89, and will be continued with further surveys in austral winter 1992 and summer 1992/1993.

Simultaneously an extensive current meter mooring programme began with the deployment of seven current meter moorings. The data from those moorings will be used to estimate the volume transport in the Weddell Gyre. Direct current measurements are essential because they are the only way to obtain the barotropic flow which determines the net volume transport. From the measured mass, heat, and salt transports across the transect we can derive water mass formation rates. The transformation of Winter Water (WW) and Warm Deep Water (WDW) in the inflow to Antarctic and Weddell Sea Bottom Water (AABW, WSBW) in the outflow is of special interest, because it results from a deep vertical exchange which is relevant to the large scale abyssal circulation of the world ocean. Present estimates show that about 70% of the Antarctic Bottom Water spreading into the world ocean obtains its water mass characteristics in the Weddell Sea. Because the salt budget of the area is strongly influenced by ice formation and melting, special interest is focussed on the ice transport across the transect. Interaction with the ice shelves has to be taken into account for a quantitative understanding.

Work at sea

In order to obtain the water mass distribution, a hydrography section was carried out with 74 CTD-profiles (conductivity, temperature, depth) and discrete casts for temperature, salinity, oxygen, nutrients and tracers (helium, tritium and 18O). On the eastern slope the station distance was small enough to resolve topographic features such as the Explorer-Escarpement. Seven current meter moorings were recovered and 21 were laid (Tables 1 and 2). On six of them ice thickness will be measured by upward-looking sonars (ULS). The moorings will stay in position for two years. Vertical temperature and electrical conductivity profiles were measured with a Neil Brown Mark lil B CTD. The quality of the CTD-measurements was assured by reference measurements with a rosette sampler. Water samples were taken with a General Oceanic rosette composed of 24 bottles with 12 l volume each. Each time a water bottle was closed 50 cycles of pressure, temperature and conductivity were recorded with the CTD, quality controlled and averaged. Pressure and temperature measurements were corrected by means of a laboratory calibration carried out in the Scripps Institution of Oceanography before the cruise. A second calibration will be done after the cruise. Both calibrations will lead to a more elaborate correction of the data. However, the control by electronic as well as mercury reversing thermometers and pressure meters gives us confidence that the preliminary data have errors of less than 5 mK in temperature and 5 db in pressure.

The salinity data are given in PSU. They are based on the CTD conductivity measurements from which salinity was calculated using the Unesco Practical Salinity Scale (PSS78). The values were compared with the salinities from water bottle samples which were measured with a Guildline Autosal 8400 A in reference to 1.A. P.S.O. Standard Seawater. The number of samples
per profile, the mean difference between the samples and the CTD measurements as well as its standard deviation are shown in Preliminary data presented in this report were corrected with a constant offset of 0.023 to an accuracy of 0.005. The final data will be corrected in conductivity for time and depth dependence of the deviations. Afterwards salinity will be recalculated.

Oxygen was determined with an automatic titration unit, using the Winkler method with a photometric endpoint determination. The error in the oxygen determination is estimated to 1. This results from intercomparisons at selected stations between the chemical oceanography group from the Oregon State University and the AWI group both using different instruments. Duplicate samples from the same water bottle were analysed during the complete cruise as a measure of precision.

Preliminary results

The hydrography features measured along the transect are presented as sections of potential temperature and salinity. Below a shallow surface layer of WW which deepens significantly towards the shelf edge a temperature and salinity maximum due to the WDW is found. It is more pronounced at the boundaries than in the interior with temperatures up to 0.8°C in the east and 0.4°C in the west evidencing the inflow in the east and the outflow in the west. The largest part of the water column with potential temperatures between 0 and -0.8°C and salinities from 34.67 to 34.64 is classified as AABW. Below we find WSBW with temperatures colder than -0.8°C which extends in the west in a shallow layer over the continental slope indicating the outflow of this freshly formed water mass. The young age of this water mass is suggested by the high oxygen content.

In the forthcoming analysis we will quantify the transformation which occurs south of our transect of inflowing water masses in the east into the outflowing ones in the west. Seasonal changes on that transect are most evident in the near surface layers. Relatively warm air temperatures and weak winds indicate the onset of spring. A comparison of surface layer temperatures and salinities measured in September and October during WWGS ‘89 with the ones obtained during the present cruise indicates a much more pronounced springtime warming in the west than in the east. The salinity decrease due to ice melting was more intense in the east than in the west. In the deeper layers fluctuations of a wide spectral range are expected to be at least as intense as the seasonal cycle. Consequently no seasonal change can be identified in the comparison of the two sections.

From CTD data on a straight section only geostrophic current shear can be estimated. Absolute currents can be obtained by the use of mass conservation of geostrophic currents in and out of a closed area or by the Beta-spiral method. Therefore, in the area of the gyre centre, which is indicated by the doming of the isotherms, a second section normal to the main section was carried out with a length of about 275 km. The estimate of absolute geostrophic current velocities by use of the Beta-spiral method will yield additional information on the location of the gyre center complementary to the moored current meter data. However, this method requires the calculation of the second derivative of isopycnals with respect to horizontal and vertical coordinates and is very sensitive to fluctuations. Thus, quantitative estimates need to be carried out with the final data.

The transects of the potential temperature along the Beta-cross show smoothly inclined isolines which seem to reflect the doming of the Weddell Gyre. The temperature maximum of the WDW increases towards the north. This can be taken as an indication that there is a southward component in this level and
consequently the center of the gyre has to be located further to the west.

The interaction with the ice shelf was studied by means of a CTD profile which was measured in an inlet of the Quarisen northeast of Kapp. The temperature profile shows cold-WW above a slightly warmer layer centered at 200 m depth which tops a colder bottom layer. The salinity increases from top to bottom. Presently it is not possible to conclude if the deeper layer is the remnant of a WW-layer which reached to the bottom and is separated from a slightly warmed surface layer by an intrusion of warmer water from offshore, or if it represents water which emanates from under the ice shelf. Tracer data measured from the water samples will be used to answer this question.

Weather conditions by H. Erdmann, Jg. Kohler, and H. Sonnabend

At the beginning of the cruise the main cyclonic activity was located west of the Antarctic Peninsula. On 17 November, the steering cyclone moved slowly eastward with a minimum pressure below 960 hPa. Secondary lows passed the Drake Passage quickly and affected "Polarstern" with northwesterly winds Bft 8 and seas up to 5 m. South of the Polar Frontal Zone, visibility deteriorated due to northerly winds Bft 7. On 20 November, "Polarstern" reached Bellingshausen Station with northwesterly winds Bft 7 and snow showers. Due to catabatic influence, the wind increased up to Bft 9 near the station; in spite of the unfavourable weather conditions, helicopter service was possible.

Due to the permanent influence of the wide-spread and stable lowpressure system with minimum pressure still below 960 hPa at the southwestern part of Bransfield Strait, wind turned from northwest to southeast Bft 5 on 21 November, while "Polarstern" left Bransfield Strait heading for the Weddell Sea. Snowfall coming up caused bad visibility later on and a decrease of air temperature down to -4°C. In the early evening, "Polarstern" approached an area densely covered with sea ice. During the following next four days, the ship operated within a low pressure area between the steering Weddell Sea cyclone and secondary lows in the north and northeast. Therefore, the pressure gradient as well as the winds were generally weak. Cold air mass advection gave rise to good visibility but was accompanied by some snow showers. On 26 and 27 November, the dominant cyclone remained stable over the northwestern part of the Weddell Sea and began to fill slowly. Therefore, "Polarstern" was affected by stronger cold air advection in the northwestern section accompanied by numerous polar cumulonimbus clouds and heavy snow showers.

On 28 November a new gale center developed in the western part of the Drake Passage and moved to the South Shetlands. On 29 November its frontal systems approached "Polarstern" near 66-S, 37-W while activity was decreasing. Therefore, wind turned northeasterly while decreasing to Bft 3 to 4. Occasionally occurring snowfall diminished visibility until the end of November. At the beginning of December, a flat high developed in the central Weddell Sea. Therefore, the wind was light and varying, the visibility very good and the clouds dissolved. A small-ranged but heavy cyclonic development north of "Polarstern"s" operating area caused heavy snowfall on 3 December, which was accompanied by strong easterly winds up to force Bft 7. Therefore, helicopter service was not possible on this day. During the night of 4 December, the cyclone moved south while decreasing and crossed the position of "Polarstern" to the west. The wind was backing to the north and caused low level warm air advection with rising dew point...
near 0 C. As a consequence, fog persisted for about 4 hours. On the same day, another but stronger cyclonic development evolved near South Georgia. This new storm center moved quickly southeast; with its rear and southerly gales up to force Bft 9 it affected "Polarstern" in the central Weddell Sea during 4 December. The maximum wind speed measured on board at the marine meteorological station was 55 knots within gusts. The chill temperature was -27 C and rendered open air work almost impossible. A small wedge within the advanced polar air gave rise to better weather conditions on December but caused decreasing temperatures with morning minimum temperatures near -8 C. In the course of the next 3 days, weather remained fair, sometimes even sunny with only light winds generally from west, due to the influence of a relatively high pressure center north of the ship's position. During the night hours, ice covering fog patches developed due to heat loss and disappeared when sun rose.

In the eastern section of a quasi-stationary but developing low, strong warm air advection mainly in the upper troposphere produced widespread snowfall also in the operation area of "Polarstern" near 67 S, 23 W on 9 December. During the next 24 hours, temperatures rose to 0 G and wind turned northerly with force up to Bft 7. From 10 to 14 December, a dynamic high developed above the northern part of the Antarctic continent with its center (1004 hPa) near 70 S, 05 W. Therefore, a strong inversion near 1000 m-level caused overcast stratocumuli with some snow showers and light winds. On 15 December "Polarstern" reached Kapp Norvegia in sunshine and light winds produced by the still stationary high near Neuschwabenland.

The weather conditions were still good when "Polarstern" was stationed at the shelf ice near Georg-von-Neumayer-Station for unloading. In spite of overcast sky with a ceiling near 800 feet and occasional "whiteout" conditions, helicopter service was not affected. When "Polarstern" left for Cape Town on 19 December, the synoptic situation changed. The dominant high at Neuschwabenland moved southwest while weakening and the low system east of South Georgia moved east. Therefore an easterly wind increased up to force Bft accompanied with some snowfall and bad visibility.

On 20 December "Polarstern" left the closely packed sea ice near 68 S 03 W. On the southern edge of a heavy steering low near 60-S, 05 W (958 hPa), which moved east-southeast very slowly, wind increased up to force Bft 7 to 8 while turning from east to southeast for some hours. Next day wind turned southwest while decreasing slowly. Wind seas and swell of about 3 m affected the voyage of "Polarstern" only little. On 24 December a new low developed northeast of South Georgia moving southeast slowly. Its frontal systems affected "Polarstern" on 25 December north of Bouvet Island with northerly gales Bft 8 to 9 northwest but decreasing slowly. Shortly before arrival in Cape Town, light winds, sunshine and warm temperatures were encountered.

Ice conditions by H.-J. Brosin and D. Zippel

Visual observations of the ice conditions were performed between 22 November and 20 December according to instructions given by the Glaciological Section of the Alfred-Wegener-Institute. Altogether 236 observations were realized together with an additional 70 observations on the distribution of algae in the ice. The first iceberg was observed on 20 November at the position 62 12 S, 57 56 W, the last one on 23 December. The ice edge was crossed at 63 30 S, 51 30 W 150 km distant from the nearest shoreline on 22 November. It was passed again at the position 68 S, 04 W on 20 December. The shelf ice edge was reached for the first time at 71 07 S, 11 23 W on 15 December. The portion of white ice amounted to 40 to 100
of the total ice cover. The thickness mostly varied between 0.5 and 1.5 m and was estimated to be up to 2 m in a few cases. A distinct increase of the size of Ice floes to a diameter of more than 1 km was observed at the position 65 39 S, 39 W, an evident reduction of the floe size occured only close to the end of the observations at 70 25 S, 13 25 W. The thickness of the snow cover on the ice varied between 20 and 50 cm. Marked melting effects at the bottom layers of ice floes were observed for the first time at the position 66 22 S, 29 32 W on 2 December. Local new ice formation (nilas, grey-white ice) were repeatedly observed after a larger decrease in air temperature.

A wide spread occurrence of icebergs was observed particularly at the western edge of the working area between 64 and 65 50 S, 49 and 40 W (up to 41 icebergs within the field of view) and at the southeastern edge from 69 15 S to 70 30 S, 16 45 to 10 W (up to 52 icebergs seen simultaneously).

A.2.a Geographic boundaries

A.2.b Total number of stations

A.2.c Floats and drifters deployed

A.2.d Moorings deployed or recovered

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**Abbreviations:**
- AVTPC: Aanderaa current meter with temperature, pressure and conductivity sensor. In brackets instruments with poor data quality.
- S: Sediment trap
- ACM-2: Acoustic current meter, Neil Brown
- ADCP: Acoustic doppler current meter
- ATR: Recording unit for thermistor chain
- UCM: Acoustic current meter, Simtronics
- ULS: Upward Looking sonar
- WLR: Water level recorder

A.3 List of Principal Investigators for all Measurements
A.4 Scientific Programme and Methods
A.5 Major Problems and Goals not Achieved
A.6 Other Incidents of Note
A.7 List of Cruise Participants
Table 3: Cruise Participants

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*See Table 4 for list of Institutions

Table 4: List of Institutions

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Bernhard-Nocht-Str. 76
2000 Hamburg 4
Germany

FGB
Universitat Bremen
Fachbereich Geowissenschaften FB5
Postfach 33 04 40
2800 Bremen 33
Germany

FiW
Forschungsstelle FuerWirbeltierforschung
Akademie der Wissenschaften der DDR
Am Tierpark 125
0-1136 Berlin
Germany

FPB
Universitat Bremen
Fachbereich Physik FB1
Postfach 33 04 40
Germany

HSW
Helicopter-Service
Wasserthal GmbH
Katnerweg 43
2000 Hamburg 65
Germany

IfMG
Johann Wolfgang Goethe-Universitat
Institut fuer Meteorologie und Geophysik
Feldbergstr 47
Postfach 11 19 32
6000 Frankfurt am Main 11
Germany

fIfMW
Institut fuer Meereskunde
Akademie der Wissenschaften der DDR
Seestr. 15
0-2530 Rostock-Warnemunde
Germany

RUB
Ruhr-Universitat Bochum
Fakultat fuer Chemie/ Physikalische Chemie
Postface 10 21 48
4630 Bochum 1
Germany

TA
TERRAQUA
Indersdorfer Str. 16
8061 Arnbach
Germany

ITBA
Instituto Technologico de Buenos Aies
Avda Enardo Madero 351/99
1106 Buenos Aires
Argentina

VUM
Vrije Universiteit Brussels
Laboratory for Analytical Chemistry
Pleinlaan 2
B-1050 Brussels
Belgium
B. Underway Measurements

B.1 Navigation and bathymetry

B.1.a Bathymetry by U. Goldkamp, J. Monk and S. Vucelic

Rise and heading for Cape Town until the end of the leg. After reaching the known position of the channel at 65-40 S and 38 45 W and passing the first turning points of the survey pattern, the track had to be modified, because the ice conditions made it impossible to follow a prescribed course. Nevertheless, the width of the channel was recorded in its whole extent along the channel axis from east to west which was possible because frequently leads were alligned along the channel axis. At the eastern part of the survey, large ice floes prohibited following the course of the channel. The hydrosweep screen on the bridge allowed changes in the course to be made in a way, that the survey of this part of the channel was achieved despite the ice cover. The channel was surveyed over a total length of 144 kilometers with a track line of 500 kilometers.

On the shelf and the continental slope off Kapp Norvegia, several hydrosweep profiles could be run in spite of unfavourable ice conditions to supplement data in the area east of the Wegener Canyon. The route to Atka Bight was used to run a profile parallel to former courses.

For the passage to Cape Town a course was chosen so as to cross over the eastern slope of Maud Rise from south to north. The online constructed 'soiine-plot showed small cone-like structures in this area, even above Maud Rise.

During the complete leg, GPS-satellites could be used for positioning. Offsets, positioning errors and failing data were recorded, which were
due to changes in position of the satellite, inter-satellite constellation and the time free of GPS. Offsets and positioning errors were corrected within one day, which resulted in a more exact ship's position. Therefore, postprocessing results in an exact positioning of the fansweep profile of Hydrosweep as well as good agreement in the isobaths crossing the fansweep profiles.

B.2 Acoustic Doppler Current Profiler (ADCP)

B.3 Underway dissolved oxygen, fluorometer, etc

B.4 XBT and Thermosalinograph


Objectives

The Antarctic Circumpolar Current is subject to a wide range of temporal and spatial variability. The repeated crossings of "Polarstern" are used to obtain a data set which is suitable to address longer term variability of the thermal field and spatial variability of the velocity field. The temperature profiles are inserted in the Integrated Global Ocean Services System (IGOSS).

Work at sea

This goal approached by usage of the Vessel Mounted Acoustic Doppler Current Profiler (VM-ADCP, manufactured by RD Instruments, San Diego) which allows us to monitor the current profile in the upper 350 m of the water column from the ship moving at full speed. Sea surface temperature and salinity is recorded by a thermosalinograph. By use of the ADCP a cross section of the upper ocean velocity profile through the Circumpolar Current was recorded through Drake Passage to the Antarctic Peninsula. A set of calibration data were collected by running a cross-shaped course pattern on the shelf of the Antarctic Peninsula. During the calibration courses the ADCP was operated in its bottom track mode; a variety of control parameter settings were used during the measurements in order to optimise the instrument's performance. The data sampled were transferred to the ship's VAX computer for processing and plotting. During the measurements the ADCP was run without the occurrence of major problems. However, during a later phase of the cruise no more data were obtained for two reasons:

First, in its mode of operation the ADCP's transducer sits at hull depth (approx. 11 m) in the ship's well without any protection against mechanical damage by ice floes pushed under the ship. When the ship moves through the ice the transducer is protected by a lid consisting of two stainless steel sheets of 8 mm thickness. With the transducer behind the protective lid the ADCP not able to function. Consequently, no ADCP measurements of current profiles could be obtained along the Weddell Sea cross section.

Second, it appeared that the protective lid was not strong enough to withstand the collisions with ice floes. When we tried to reactivate the ADCP in ice-free waters after having left the GvN-Station, we noticed that the lid was deformed by the impacts from ice floes and the transducer
Assembly was severely damaged. All four transducer heads were scoured off at their outer periphery, and in one case the metal cage embedding the transducer face was torn. Moreover, two of the transducer heads were loosened from their proper connection to the transducer electronics housing because the connecting bolts had been lengthened by leverage, leading to gaps of up to 3 mm wide between the transducer heads and the electronics housing. Through these gaps seawater flooded the electronics housing. Because of the severeness of the damages, there was no way of repairing the transducer assembly on board of the ship and to employ the ADCP during the further parts of the cruise.

The thermal structure of the upper 700 to 800 meters was measured by 194 XBT-profiles which were recorded with a Nautilus-system. Times and locations of the individual profiles are given in Table 5. Comparison between 8 XBT and CTD measurements at the same stations confirmed the accuracy of 0.2 K given by the manufacturer. Sea surface temperature and salinity were recorded continuously in the bow thruster channel at about 5 m depth with a thermostalinograph supplied by Meerestechnik-Electronik (ME). The data were controlled by salinity samples taken at the inlet to the instrument and the temperature measurements of the CTD. The following corrections have to be applied to the recorded data:

\[
\begin{align*}
T_{\text{true}} &= 0.921 T_{\text{recorded}} - 0.253 \\
S_{\text{true}} &= 0.949 S_{\text{recorded}} - 1.772
\end{align*}
\]

The corrected data will then be accurate to 0.03 K and 0.03. However, it has to be taken into account that occasionally a water-ice mixture is flowing in sensor head which results in erroneous data. The error is obvious by the reduced conductivity due to the ice. Therefore we do not use the thermostalinograph data along the transect but refer to the CTD-data in 10 m depth.

Table 5: XBT's

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211  0322  40 45 13 22 4626
B.5 Meteorological observations

B.6 Atmospheric chemistry

C. Hydrographic Measurements

C.1 Helium and Tritum

Tritium and Helium measurements by R. Well

Objectives

Within the scope of the physical oceanography programme the tritium and helium-isotope contents of the water samples serve as tracers for water mass characteristics. In addition, they can yield information about the time scales of exchange of the water masses within the Weddell Gyre. On this cruise - for the first time - we degassed water samples at sea. This procedure is expected to reduce the contamination caused by longtime storage and can simplify the handling of the sample containers. For this purpose we tested new degassing equipment on board and will compare the results with those obtained with the traditional method.

Work at Sea

We took water samples at 6 CTD-stations on the shelf and continental slope of the Antarctic Peninsula in water depths of about 400, 1000, 2200, 2500, 3550 and 4200 m, at 3 CTD-stations in the central Weddell Sea at water depths of about 4700, 4760 and 4860 m and at 4 CTD-stations on the eastern continental slope off Kapp Norvegia in water depths of about 4400, 2400, 1600 and 500 m. Altogether about 50 double-samples were taken. One half of them were degassed on board, the other half will be degassed after our return in the laboratory, the helium- and neon-isotope contents will be compared.

Preliminary Results

As the measurements of the samples have to be done with a mass spectrometre in the laboratory we can not present data or quantitative results of the intercomparison here. The degassing technique on board did not show serious technical problems. Some problems occurred with the melting off procedure of the glass ampoules so that presently we cannot generally guarantee that the extracted gas is well caught in the glass ampoule.

C.2 Natural radioactive isotopes in the water column by E. Schoffmann and M. Seal
Objectives of.

Investigations on sediment samples from the area off West Africa and from the Polar Front show that in areas with high biological activity, the flux of radioisotopes such as 10Be and 230Th to the sediments increases the production of the isotopes. This is due to scavenging of the isotopes by settling particles. This causes a concentration gradient of the isotopes from high to less productive areas which might allow former biological activity to be deduced.

Work at sea

To quantify these effects, samples for 10Be measurements were taken on 4 stations of the Weddell Sea transect. The investigations on these samples will be linked to investigations on 230Th in the Weddell Sea by the geochemistry group of the AWI, and to results of measurements of 10Be and 230Th in the South Atlantic by the FBG.
To get the 30 of water needed for a 10Be analysis, water from different depths within the same water layer was combined. A well known amount of 9Be carrier was added and Be, together with Mg and other elements, was precipitated at a pH of 8 - 9. The water was decanted, and the precipitate will be prepared for measurements with the accelerator mass spectrometer of the ETH Zurich.
Additionally at all the minicorer-stations 10 Be samples have been taken from the sediment surface.

C.3 Postinstallation work on the computer system by H. Pfeiffenberger-Pertl

Objectives

A new central computer system and two local area networks were installed aboard "Polarstern" in October 1990. Five VAX-VMS systems of different capabilities, configured as a cluster, replace one older VAX-VMS computer. The local area networks, using ethernet and LocalTalk cabling, provide the possibility to connect PCs and Workstations in all locations used for scientific purposes to each other, the central system and its resources, i.e. printers, plotters, etc.
The most important objective of the work at sea was to observe this rather complex system under real conditions, in order to see if the concepts leading to its hardware- and software-configuration do work, and how the system is utilized by the scientists and how its utility could be improved, which problems are encountered and how, to fix them. The result of this work should be a users manual for scientists and support personnel on board that provides advice on this specific installation in the most compact way possible.

Work at sea

The information necessary to meet the objectives was collected while giving advice or help to scientific users and support personnel. Some programming was necessary to fix problems, support routine operation of the system and to meet requests from scientists for access to specific data. The documentation most urgently needed was written.

Preliminary results

In general the VAX systems worked as planned. The single most important task, namely quasi-realtime data logging and processing on one of these machines, worked without problems.
The disc and file services for PCs are made available on board in the same way as at the institute in Bremerhaven. Due to a much higher demand for data transfer between VAX-, IBM-compatible and Macintosh systems, problems up to now unknown appeared. They could be solved by a file conversion utility and some documentation giving recipes.

Observations on the use of the publicly available PCs led to the conclusion that these will produce more work for the support personnel (or less utility to the scientists) than the VAX-systems, if their users are not very disciplined and they are managed as personal PCs. Further work has to be done on this problem.

C.3 Distribution of dissolved inorganic nutrients in the water column: by J. M. Krest and A. A. Ross

Objectives

By obtaining high quality nutrient data from late winter and early spring, we will improve on the sparse historical data set of the central Weddell Sea. The repeated "Polarstern" transects should permit the seasonal and interannual variability of the major water masses to be assessed. This data set will be used to study the evolution of WW which is the mixed layer beneath the seasonal pack ice. WW properties change with length of time under the ice due to continuous mixing of warmer, higher nutrient waters (WDW) from just below the pycnocline. From the analysis of nutrients in this surface layer, we plan to extend and refine our earlier estimates of net primary productivity in the Weddell Sea.

Work at Sea

At 88 CTD casts, water samples were taken and analyzed for Silicic Acid, Phosphate (Ortho-Phosphate), Nitrate + Nitrite (N+N), Nitrite, and Ammonium. Analyses were performed using the ALPKEM RFA-300 continuous flow analysis system. The entire water column was sampled for nutrients, but at this time, only the surface water in the primary northwest-to-southeast transect has been cursorily examined for silicic acid, phosphate and N+N.

Preliminary Results

Contour plots of nutrients in the upper 500 meters show a fairly well defined layer of WW from approximately 50 W to 14 W. In the WW-layer which occupies the top 100 meters of the water column silicic acid concentrations range from 70 to 80 uM, N+N concentrations from 28 to 30 AM, and phosphate concentrations from about 2.0 to 2.1 uM. Underlying this WW-layer is a reasonably strong nutricline, varying in depth from 100 to 150 meters. In this nutricline, silicic acid increases in concentration to 110 micromolar, N+N increases to 33 uM, and phosphate increases to 2.3 uM.

For all three nutrients, concentrations are most elevated in the center of this gyre, indicating a general upwelling trend. At two locations, 40 and 32- W, the contour plots for all three nutrients indicate strong vertical mixing between the WW and the underlying water mass. At the western and eastern boundaries, intense vertical mixing causes nearly vertical nutrient
isolines. In the WSBW a tongue of low concentration silicic acid can be seen which extends laterally more than halfway across the Weddell Sea Basin at a depth of approximately 4500 to 5000 meters. Initial comparisons were made with data obtained by Oregon State University's group during WWGS '89 and show good agreement.

C.4 CTD
CTD Measurements during AQANTIX/2

CTD temperature sensor: Rosemount Platinum Thermometer
resolution: 0.0005 deg C
accuracy: +/- 0.005 deg C

CTD pressure sensor: Paine Model
resolution: 0.1 dbar
accuracy: +/- 6.5 dbar

CTD conductivity sensor: EG&G NBIS
resolution: 0.001 mmho
accuracy: +/- 0.005 mmho

Software: EG&G Oceansoft MkIII/SCTD Acquisition Version 2.01
CTD postprocessing Version 1.12
Time lag: 0.13 s

Pressure pre-cruise calibration coefficients
a1 = -1.1552376e+1
a2 = 7.014388e-3
a3 = -1.236572e-5
a4 = 7.641595e-9
a5 = -2.052136e-12
a6 = 2.544142e-16
dp = a1 + a2*p + a3*p**2 + a4*p**3 + a5*p**4 + a6*p**5
p = p + dp

Temperature pre-cruise calibration coefficients
a1 = -2.99299
a2 = -7.18462e-4
a3 = 4.44174e-5
a4 = -1.43668e-6
a5 = 2.67305e-8
dt = a1 + a2*t + a3*t**2 + a4*t**3 + a5*t**4
t = t + dt

The post-cruise calibration data are the same

correction of the CTD-conductivity data with the bottle-samples
( conductivity of the salinometer data )
evaluation of the coefficients of each station
--------------------------------------
CD = ( CONDUCTIVITY SALINO - CONDUCTIVITY CTD ) * 1000
COND := CONDUCTIVITY SALINOMETER
--------------------------------------
CD = A0 + A1*COND + A2*PRES + A3*PRES**2
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\[ CD = A0 + A1 \cdot \text{COND} + A2 \cdot \text{PRES} + A3 \cdot \text{PRES}^2 \]

\[ C(\text{ctd}) = C(\text{ctd}) + dc/1000. \]

correction of the CTD-conductivity data with the bottle-samples
evaluation of the coefficients with the running mean of 10 stations

--------------------------------------

\[ CD = A0 + A1 \cdot \text{PRES} + A2 \cdot \text{PRES}^2 + A3 \cdot \text{PRES}^3 + A4 \cdot \text{PRES}^4 \]
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\[
dc = A0 + A1 \cdot \text{PRES} + A2 \cdot \text{PRES}^2 + A3 \cdot \text{PRES}^3 + A4 \cdot \text{PRES}^4
\]

\[
C(\text{ctd}) = C(\text{ctd}) + \frac{dc}{1000}.
\]

CTD-Files column 5: number = -9: unknown data, it was not possible to restore this data

NOTES ON THE NUTRIENT DATA FILES FOR SWGS 90 (ANTIX/2)

From:
M. Consuelo Carbonell-Moore
Joe C. Jennings, Jr.
Louis I. Gordon

STATIONS WITH MISSING NUTRIENTS:

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</table>
NOTES ON NITRITE (NO2) AND AMMONIUM (NH4):

Because deep ocean nitrite and ammonium values are usually near the limit of detection, small shifts in baseline and/or blank levels can lead to the calculation of concentrations which are negative. Although these negative nitrite and ammonium values are physically impossible, we report them as an indication of the imprecision associated with the analysis.

NOTES ON PHOSPHATE (PO4):

Low phosphate values in stations 050 and 051 might be doubtful as there was an equipment change after station 049. Values at station 053 agree with those at station 049.

There is a wide spread in deep phosphate values: 2.19 micromol/liter to 2.42 micromol/liter, many stations showing high values, higher than those from Wepolex and Ant V/2 cruises in the same region, but lower than WWGS 89. Deep phosphates increase in concentration from station 60 through station 83, increase which we cannot account for. These high values might be an artefact from a change in blank values due to changes in either the deionized water or in the low nutrient seawater used to prepare standards. There is no information in the laboratory notebooks, logs or recorder charts that allows us to either correct or delete these data. However, they are of doubtful quality. The increase of phosphate values in these stations is 0.1 micromol/liter. Nitrate concentration values did not show the same trend.

D. Acknowledgements

When we left "PolarsternH in Cape Town, we felt that we have had an extremely successful cruise and a enjoyable life on board. We are aware that master Jonas with his officers and his crew took good care of our needs with engagement and patience which garanteed effective work and good humour.

public of Germany

E. References
Several data files are associated with this report. They are the ANTIX.sum, ANTIX.hyd, ANTIX.csl and *.wct files. The ANTIX.sum file contains a summary of the location, time, type of parameters sampled, and other pertinent information regarding each hydrographic station. The ANTIX.hyd file contains the bottle data. The *.wct files are the ctd data for each station. The *.wct files are zipped into one file called ANTIX.wct.zip. The ANTIX.csl file is a listing of ctd and calculated values at standard levels.

The following is a description of how the standard levels and calculated values were derived for the ANTIX.csl file:

Salinity, Temperature and Pressure: These three values were smoothed from the individual CTD files over the N uniformly increasing pressure levels using the following binomial filter:

$$t(j) = 0.25t_i(j-1) + 0.5t_i(j) + 0.25t_i(j+1) \quad j=2,...,N-1$$

When a pressure level is represented in the *.csl file that is not contained within the ctd values, the value was linearly interpolated to the desired level after applying the binomial filtering.

Sigma-theta (SIG-TH: KG/M3), Sigma-2 (SIG-2: KG/M3), and Sigma-4 (SIG-4: KG/M3): These values are calculated using the practical salinity scale (PSS-78) and the international equation of state for seawater (EOS-80) as described in the Unesco publication 44 at reference pressures of the surface for SIG-TH; 2000 dbars for Sigma-2; and 4000 dbars for Sigma-4.

Gradient Potential Temperature (GRD-PT: C/DB 10^-3) is calculated as the least squares slope between two levels, where the standard level is the center of the interval. The interval being the smallest of the two differences between the standard level and the two closest values. The slope is first determined using CTD temperature and then the adiabatic lapse rate is subtracted to obtain the gradient potential temperature. Equations and Fortran routines are described in Unesco publication 44.

Gradient Salinity (GRD-S: 1/DB 10^-3) is calculated as the least squares slope between two levels, where the standard level is the center of the standard level and the two closes values. Equations and Fortran routines are described in Unesco publication 44.

Potential Vorticity (POT-V: 1/ms 10^-11) is calculated as the vertical component ignoring contributions due to relative vorticity, i.e. $pv = fN^2/g$, where $f$ is the coriolius parameter, $N$ is the buoyancy frequency (data expressed as radius/sec), and $g$ is the local acceleration of gravity.

Buoyancy Frequency (B-V: cph) is calculated using the adiabatic leveling method, Fofonoff (1985) and Millard, Owens and Fofonoff (1990). Equations and Fortran routines are described in Unesco publication 44.
Potential Energy (PE: J/M²: 10⁻⁵) and Dynamic Height (DYN-HT: M) are calculated by integrating from 0 to the level of interest. Equations and Fortran routines are described in Unesco publication 44.

Neutral Density (GAMMA-N: KG/M³) is calculated with the program GAMMA-N (Jackett and McDougall) version 1.3 Nov. 94.

G. Data Quality Evaluation