1. Leg ANT XIII/4 Cape Town - Punta Arenas 17.03. - 20.05.1996

1.1 Summary und Itinerary

The Polarstern-cruise ANT XIII/4 started on March 17th, 1996 in Cape Town. The first part of the cruise consisted of multidisciplinary work with a focus on physical oceanography in the Weddell Sea, during the second part logistic tasks were carried out at King George Island and a benthological programme was performed in the Drake Passage. During the whole cruise, temperature measurements were made with a newly developed potassium temperature lidar, which was designed to measure the natural variations in temperature of the mesopause at different geographical locations and in different seasons. The high temporal and vertical resolution of the lidar together with the simultaneous observations of the potassium layer allowed better insight into dynamic processes in the upper atmosphere.

A major part of the deep and bottom waters of the global ocean are ventilated by the injection of waters from the Weddell Sea. Cooling in winter and sea ice formation, as well as the interaction between the ocean and the ice shelves, induce water mass modifications which generate water masses on the shelf which are dense enough to sink to the bottom of the Weddell basin. During their descent, they mix with ambient water masses and are carried with the cyclonic Weddell gyre circulation to the north. The formation of bottom and deep water determines the exchange of atmospheric carbon dioxide (CO_2) between the ocean and the atmosphere. Through the upwelling of CO_2-rich deep-water, CO_2 can be given up to the atmosphere, a process which counteracts the CO_2 flux due to cooling and biological processes at the surface. Thus the components of the CO_2 system were measured to determine whether the Weddell Sea is a source or a sink for atmospheric CO_2. The physical oceanography measurements of the cruise contribute to the World Ocean Circulation Experiment, (WOCE). The hydrographical sections are referred in the WOCE code as the repeat sections SR2 and SR4 and the Atlantic part of the S4-section. In order to better understand the processes and effects which are important in this area, the programme consisted of four components.

1. To determine the inflow from the Antarctic Circumpolar Current into the eastern Weddell Sea, a hydrographical section was worked from 24°41'E to 39°E, using a CTD-probe (Conductivity-Temperature with Depth) in connection with water samplers and an ADCP (Acoustic Doppler Current Profiler).

2. The outflow of the bottom water from the east into the western Weddell Sea was measured by a zonal hydrographical section along the eastward current in the north of the Weddell gyre from 0° to 24°41E.

3. The exchange between the eastern and western Weddell Sea was measured on a meridional hydrographical section through the Weddell gyre along the Greenwich Meridian. Here, in addition to the use of the CTD-sensor, water samplers and ADCP, moorings were also recovered and deployed.

4. To determine the inflow into the southern Weddell Sea from the east and the outflow in the north-west, a hydrographical section was performed through the southern Weddell Sea and moorings were deployed near Joinville Island.

Among other uses, these measurements will be used to validate models which simulate the circulation and water mass formation in the Weddell Sea. The isotopes of oxygen, including ^{18}O, nutrients and the tracers Freon-11, Freon-12, Freon-113 and CCl_4, as well as Tritium, ^3He, He and Ne give information about the water mass formation and spreading. Samples of the stable carbon isotope $\delta^{13}C$ were taken for paleo-oceanographic studies.

The marine organic chemistry group concentrated on the autumn distribution of dissolved and particulate phytosterols in the Weddell Sea to understand the fate of phytosterols and other trace organic compounds in the ocean starting with biosynthesis and input into the euphotic zone and ending with the possible final deposition into the bottom sediments of the deep sea.

Planktological studies focused on the distribution of some dominant zooplankton and micronekton species such as *Calanoides acutus* and *Rhincalanus gigas* (the two dominant Copepodes of the Antarctic), which show a clear dependence on the oceanographic structure of the Weddell gyre. These species very probably do not reproduce in the western Weddell Sea. Thus the population is maintained by the advection of individuals who have over-wintered in the Warm Deep Water and by local recruitment in the eastern Weddell gyre. The presence of antarctic krill, *Euphausia superba*, in the eastern Weddell gyre seems to play a important role in the maintaining of the krill population in the Atlantic sector of the southern polar seas. Krill can be brought into the Weddell Sea by the advection of krill-larvae with the inflow of Warm Deep Water, although adult krill are usually found at shallower depths. On this cruise, the formation of the over-wintering population of the larger calanoid Copepods and the abundance of the krill-larvae in the Warm Deep Water was measured using the Acoustic Doppler Current Profiler (ADCP) and an Optical Plankton Counter (OPC) in combination with conventional net sampling. The Chlorophyll-concentration at different depths along all the sections was measured and combined qualitatively with the phytoplankton determined from the water samples. Investigations of the antarctic zooplankton ecology focused on the completion of the reproductive periods of various species which shows a strong geographical variation. The transition of several dominant zooplankton species to over-wintering was studied in different areas of the Weddell Sea. Using the Multinet catches, the vertical distribution of the different stages of development of the Copepodes was determined.

The second part of the cruise concentrated on the investigation of the ecological relationship between the marine fauna of the Antarctic Peninsular and the southern-most part of South America. South America is the closest present-day land mass to Antarctica. Thus it is assumed that the exchange between South America and Antarctica has been longer and more intense than with the other continents. Due to bad weather, the benthological group were unable to fly to King George Island. Also the collection of material from the Dallmann laboratory, which is connected to the Argentinean Jubany-Station, could only be completed to a limited extent. The unfavourable weather conditions meant the activities planned for King George Island were cancelled and the work concentrated instead on the continental slope south of Terra del Fuego. During the "Joint Magellan VICTOR HENSEN Campaign 1994", a large number of samples were collected in shallow and deep water in the Magellan Straits (to a depth of 650 m), in the northwestern part of the Beagle Canal and from the eastern exit of the Beagle Canal to Cape Horn. On this cruise, along a section on the northern continental slope of Drake Passage, at different depths samples were taken with the Multicorer, the Multibox Corer, the Dredge and the underwater-camera to study the macro and meiozoobenthic structure, and to complete the available benthic samples with material obtained from greater depths. In addition, samples were taken for physiological, biological reproduction and population dynamic experiments. Finally, observations were made of behaviour patterns and material was gathered for genetic work. It appeared that the transition to the Antarctic is rather of a gradual nature than abrupt. Despite this fact, considerable differences remain between the Antarctic and this southernmost part of the Magellan region. This indicates that 20 million years of separation and isolation, despite some glacial periods of increased interchange, have led to rather distinct separation of two neighbouring marine ecosystems which originally had an identical fauna. Supporting hydrographic data was acquired with the CTD. The cruise ended in Punta Arenas on May 20th, 1996. The cruise track is displayed in Fig. 1.

2. Scientific programmes

2.1 Investigations of the atmosphere

2.1.1 Weather Conditions

Hans-Joachim Möller, Herbert Köhler (DWD)

The passage from Cape Town to 54°S 39°E was dominated by a subtropical high with moderate winds but many clouds. South of 50°S, the first frontal troughs were crossed. The following westward passage was characterized by the alternation of deep lows and small wedges of high pressure. Westerly winds between 25 and 35 knots were most frequent. While passing through gale centres and frontal troughs the wind increased up to Force 9 for a short time, but also decreased to Force 4 when passing through the wedges. The passage to the northeast to the mooring position in the oceanic Polar Front was favoured by a meridional trough, followed by a strong wedge of high pressure.

On the way to the meridional hydrographic section on the Greenwich Meridian the strong westerly wind regime prevailed. The following passage south was dominated by a large polar low, filled with cold air. For many days, showers with snow and soft hail occured. At the beginning of the second part of April, a cold air flow in the middle troposphere formed a meridional trough, which reached far north to the coast of Uruguay. This trough moved south-eastward, carrying cold antarctic air in its back. The corresponding surface low deepened rapidly to a gale with its centre between Bouvet Island and the Antarctic coast. The minimum pressure at the centre was less than 950 hPa, with RV "Polarstern" situated south of the it. For 36 hours, northeasterly to easterly winds of about 35 knots were observed with a heavy swell.

The first pancake ice was encountered at 69°09'S on April 21th about 30 nm north of the ice shelf edge. Before this time, only isolated icebergs had been passed, but now many bergs and growlers, frosted in the pack ice were observed. The wedge of a high pressure system, situated at the western Weddell Sea, extended more and more to the east. On April 24th, when we reached the Atka Bight, the finest calmy and sunny weather was experienced. For the next days, this high pressure zone influenced the Weddell Sea. At the end of April, a gale centre was formed in the Scotia Sea and consequently the southeasterly winds increased to gale force for a short time. The rising pressure, resulting from the following wedge, calmed the weather down rapidly.

Further lows were encountered during the passage through the ice of the southern Weddell Sea. A southeasterly to southwesterly airflow was at their back, whilst northeasterly to northwesterly winds dominated at their front. The situation during May 4th/5th can serve as an example: Over the western Weddell Sea, a trough was generated. Warm air was advected southward at its front with northwesterly winds Force 6. The air temperature rose continuously, from -17° C in the morning until it reached its maximum of +1° C at 23.00 UTC. The warm air flow brought a high humidity, low stratus clouds and poor visibility. The passage of the trough at 00.00 UTC was accompanied by a decreasing westerly wind, but not by a change in temperature. The strongly backing, southwest wind caused a powerful cold air advection. The temperature dropped to -7° C in one hour, and after 12.00 UTC of May 5th to below -21° C, in spite of continual sunshine.

In the northern part of the Weddell Sea, mostly young ice up to 30 cm thick was observed. West of 50°W however, large first-year or multiyear ice floes with thickness between 3 and 5 m reduced the ship's speed considerably. The ice edge had been shifted far west-northwest by continuous southeasterly winds with a speed up to Force 8. Wind and tides exerted a strong pressure on the ice, restricting seriously the progress of the cruise. The ice edge was reached on May 11th at 18 UTC near 62.2° S 57°W. At this position in Bransfield Strait a chain of icebergs lined up the ice edge like a barrier.

The crossing of the Drake Passage was favoured by a zone of high pressure, which extended from Argentina via the Magellan region and the Drake Passage to the southern part of the Antarctic Peninsula. The high pressure system moved east only very slowly and dominated by weak winds until the middle of May. Then, a more cyclonic westerly situation developed, but strong westerly winds were not encountered until the very end of the cruise, because the pressure difference between the subtropical high and the polar trough was rather weak.

Westerly to northwesterly winds accounted for more than 40% of the hourly observations of ANT XIII/4. Wind forces 5, 6 and 7 were each recorded 20% of the time. Gales occured only 7% of the time, although the climatological value is nearly 20%. The frequency distributions of wind speed and direction is displayed in Fig. 2.

2.1.2 Temperature observations in the mesopause

Josepf Höffner und Veit Eska (IAPR)

Objectives

The major task of the IAPR-group was to test the new potassium temperature lidar of the Institute of Atmospheric Research at the Rostock university and to the make first measurements. Routine observations were planned to take place on ANT XIII/5 when better weather conditions were expected. Therefore we planned to build up a stable configuration for our untested lidar system.

The main part of our temperature lidar is a new high energy, narrow band, tuneable and pulsed alexandrite laser. The laser pulses are used for resonance scattering from free potassium atoms in the mesopause region. The backscattered photons are collected by a telescope and recorded by a photomultiplier. The scattering altitude is calculated from the time-of-flight of the light. It is possible to measure the Doppler broadening of the K(D1) fine structure by continuous spectral tuning of the alexandrite laser. This method allows an absolute air temperature determination in the scattering volume. Vertical wind velocities within the potassium layer are measured by Doppler shifted frequencies of the fine structure. A combination of Rayleigh backscattering and resonance scattering allows temperature measurements in the mesosphere and stratosphere down to 30 km.

Potassium acts as a tracer for our temperature measurements. Up till now, potassium measurements have been made with only three lidar systems. All took place in the northern hemisphere. Our measurements of the potassium layer are the first with a potassium temperature lidar in the southern hemisphere. The southernmost other temperature measurements in the mesopause at an altitude of 80 to 110 km, we are aware of, occured at 31°S in Australia. Our first measurements indicated, that enough potassium is present in the southern atmosphere for temperature measurements from somewhat less than 80 km up to 110 km height. This altitude range is the coldest in the whole atmosphere and thus very interesting. With our lidar system, we are able to continuously measure these temperatures. This is only possible with a ground/ship based lidar system.

Preliminary results

Observations of the potassium layer have been performed for 16 nights during the entire cruise. Eleven nights were suitable for temperature measurements in the mesopause. Temperature measurements require nearly 30 minuntes, whereas the potassium density can be determined in a few minutes. Several nights allowed us measurements of up to 12 hours and it was possible to observe changes in the temperatures on one night. These observations are the longest made with this lidar system.

The measured structure of the potassium layer is very similar to the that observed on the Isle Ruegen in spring 1995. It is a broad layer and extends from 78 km up to 120 km height. The density maximum is nearly 20 atoms/cm^3. At a height of 120 km the potassium density is only 0.01 atoms/cm^3. The column density is nearly 20 Mio. atoms/cm^2. We have not observed significant monthly differences in column density of potassium in April and May. On one of the first measured nights, we observed a peak in the potassium layer density. This could be a sporadic potassium layer, seen as a sudden rise in density. The extent of this layer is very small. The measurements were too short to observe this previously unknown phenomenon because of cloudy weather this night.

A measured backscattered profile collected during the night from May 2th to 3th is shown in Fig. 3 (left) and a temperature profile up to 106 km height in the same night in Fig. 3 (right). The mesopause temperature was distinctly higher than that of the reference atmosphere CIRA '89. Measurements on the other nights showed similar results. A second local minimum lies in 83 km height. The backscattered signal (Fig. 3, right) shows a Rayleigh backscattering within the potassium layer, which helps to determine temperatures down to 35 km in the stratosphere.

The dynamic variability of the potassium layer during one night is displayed in Fig. 4. The lower boundary of the layer moves up and down more than once during the night. The reason is probably wave activity. The shape and location of the layer change continously. The density maximum of the layer is higher at the end of the night than at the beginning. Similar tendencies also exist on the other measured nights. For more detailed analysis, we must improve and expand our software.

2.2 Physical Oceanography

2.2.1 Deep and Bottom Water Formation in the Weddell Sea

Eberhard Fahrbach, Janja Gorny, Andreas Hansjosten, Miriam de las Heras, Uta Horstmann, Markus Jochum, Leif Kolb, Ralf Meyer, Gerd Rohardt, Harald Rohr, Michael Schröder, Giok Nio Tan, Tanja Winterrath, Andreas Wisotzki, Hannelore Witte, Rebecca Woodgate (AWI).

Objectives

A major part of the deep and bottom waters of the global ocean are ventilated by an injection of waters from the Weddell Sea. Cooling in winter and sea ice formation, as well as the interaction between the ocean and the ice shelves, induce water mass modifications which form water masses on the shelf which are dense enough to sink to the bottom of the Weddell basin. During their descent, they mix with ambient water masses and are carried with the cyclonic Weddell gyre circulation to the north where they partly leave the Weddell Sea towards the Antarctic Circumpolar Current and partly recirculate, steered by topographic features.

The increase in density due to cooling in the Weddell Sea counteracts the decrease in salinity due to precipitation and melting of ice shelf or icebergs. This increase in freshwater can similarly be compensated by the inflow of salty, deep water from the Antarctic Circumpolar Current, a process which takes place predominantly in the eastern Weddell gyre. This water mass is observed as Warm Deep Water. During its path through the cyclonic gyre, it constantly loses heat and salt. The warm regime is typified by the relatively warm conditions in the southeast of the gyre, which are determined by the close proximity of the inflow in the eastern Weddell Sea. The cold regime in the northeast is created by the cooling of the Warm Deep Water in the course of its circulation through the gyre. The inflow is subject to intense fluctuations which are partly generated by the interaction of the flow with the bottom topography. The kinematics and dynamics of the fluctuations will be investigated to understand the variations of the inflow. In the Weddell Sea, these fluctuations are of importance because of their effect on the vertical stability and consequently vertical mixing in the open ocean. This can affect the sea ice cover to the extent of the generation of open ocean polynyas and the possibility of the formation of deep water.

To quantify these processes, measurements were carried out of the water mass characteristics and transport of the inflow in the eastern Weddell Sea, the exchanges between the eastern and the western Weddell gyre and the outflow into the Weddell-Scotia Confluence. The geostrophic transport determination will be optimized by quasi-synoptic measurements at various locations. The ageostrophic parts of the current field will be assessed by direct current measurements. To estimate the relevance of the results obtained, long-term measurements of the inflow, the mixing depth and the characteristics of the deep water were initiated. Because of the impact of the sea ice formation on the water mass modification, it is planned to measure the variations of the meridional profile of the sea ice thickness and concentration with moored instruments to identify possible interactions between sea ice and mixing variability. The measurements on the section will be repeated in part several times, to ascertain the longer time scale variations in the properties and distribution of the water masses.

The measurements will be used to validate models of the Weddell gyre circulation and the water mass formation. For this purpose, long time series of oceanic currents and water mass characteristics, as well as of the atmospheric forcing and the sea ice cover, are required to investigate the response of the system to variations of the forcing conditions. The measurements of the physical oceanography programme are a contribution the World Ocean Circulation Experiment (WOCE). The hydrographic sections represent a contribution to the WOCE-section S4 and the repeat-sections SR4 and SR2. The moorings in the western Weddell Sea are part of the international DOVETAIL (Deep Ocean VEntilation Through Antarctic Intermediate Layers) Project, which is part of the iAnzone Programme. Through these international projects, instruments are also provided from the Universitat Politecnica de Catalunya in Barcelona, Spain.

Work at sea

The programme consists of measurements from ship, using the CTD-probe (Conductivity and Temperature with Depth) connected to a water sampler, XBTs (eXpendable Bathythermographs) and both ship-borne and lowered ADCP (Acoustic Doppler Current Profiler). In addition, 3 moorings were recovered and 14 moorings deployed. The investigation is split into four geographical regions.

1. To determine the inflow from the Antarctic Circumpolar Current into the eastern Weddell Sea, a hydrographical section, consisting of 14 CTD and water sample casts, was performed from 39°E to 24°41'E (Figs. 5 and 6).

2. To determine the intensity of eddy activity in the transition region between the Antarctic Cirumpolar Current and the Weddell gyre, time series are collected over many years. To this aim, moorings were recovered and re-deployed (see Fig. 5, Tab. 1 and 2) and XBTs were used to measure between the CTD stations (Figs. 10 - 12).

3. The exchange between the eastern and western Weddell Sea will be derived from a zonal hydrographical section along the eastward current in the north of the Weddell gyre from 0° to 24°41E consisting of 15 stations and a perpendicular meridional hydrographical section of 32 stations through the Weddell gyre along the Greenwich Meridian from 55°S to the ice-shelf edge at 69°38.5'S (Figs. 5, 7 and 8). The Greenwich Meridian section was already sampled once in 1992. In addition, 8 moorings were deployed (Figs. 5 and 13, Tab. 1).

4. To determine the inflow into the southern Weddell Sea from the east and the outflow in the north-west, a hydrographical section of 36 stations was performed through the southern Weddell Sea (Figs. 5 and 9). This was the fourth repeat of this section since 1989. Six moorings were deployed near Joinville Island (Figs. 5 and 13, Tab. 3).

The hydrographical work was carried out using CTD-probes and water bottle release mechanism built by Falmouth Scientific Insturments (FSI). Two instruments of the type Triton ICTD, SN 1347 and SN 1360 were used. The water bottle rosettes used were a 24-(12-l)-bottle rosette from General Oceanics Inc. and a 36-bottle rosette from FSI. It turned out however that to obtain a steady sink rate for the 36-bottle sampler, such a high extra weighting was required that safe handling of the rosette was no longer possible and there was the fear of breaking the winch cable. Thus only the 24-bottle sampler could be used. However, due to the intense swell 120 kg of extra weight were needed as well to avoid wire problems. The additional weights were removed once the instrument was on deck to facilitate moving the rosette to the sampling room.

Despite these precautions, the CTD wire was damaged several times. During the comparatively long time taken to repair the wire, the CTD was deployed with the A-frame aft of the ship. The extreme pitching of the ship however put such strain on the rosette, that the water bottles were broken loose. This led to the loss of 23 water bottles, 9 electronic pressure sensors and 7 electronic thermometers. In addition, the conductivity cell on the CTD was damaged. This was repaired by converting a sensor from a mooring instrument. Until this repair was fully functioning, some profiles were either unusable or in need of serious correction. The high loading had affected the electric quality of the wire also and lead to errors in the data transmission, which was noticeable in readings from depths of 2000 m to 3000 m. In addition, electronic adjustment problems of the new CTDs lead to some profiles being noisy. These issues have resulted in a unexpected noisy data set which has to be cleaned with care. The noise affects all parameters. The removal is thus done for each profile separately, using an interactive graphic programme, which analyses the properties of the noise. Particular priority is given to obtaining reliable CTD values at the points where bottles were closed, so that a quality calibration correction can be made.

The accuracy of the dataset is determined from laboratory calibrations both before and after the cruise. Since each CTD is equipped with two temperature sensors, the stability of the sensors can be controlled from a comparison of these readings. For instrument no. 1347, the calibrations before and after the cruise were performed by the Scripps Institution of Oceanography and FSI. For both sensors, the temperature drift in the relevant temperature range was less than 1 mK. Thus the pre-cruise calibration coefficients were used. For instrument no. 1360, where the conductivity sensor was repaired, only a post-cruise calibration at Scripps was possible. One of the sensors shows a jump in calibration values. Thus the post-cruise calibration was used. In addition, calibration on-board ship was performed using 13 electronic thermometers until they were lost and subsequently mercury reversing thermometers, calibrated by the Institut für Ostseeforschung in Warnemünde were used. Deviations from the sensor readings occurred due to the scatter in the thermometer readings, so the accuracy of the laboratory calibration can be assumed to be the relevant error. When noise is also taken into account, this gives a final accuracy of 2 to 3 mK.

For CTD no. 1347, a pressure calibration was performed before and after the cruise at Scripps and at FSI. No change was recorded. For CTD no. 1360, a calibration at FSI was performed before and at Scripps after the cruise. The correction was of order 2db. The calibration of the pressure sensors is good to better than 2db.

The conductivity was corrected using salinity measurements from water samples. IAPSO Standard Seawater from the P-series P127 was used. A total of 2477 water samples were measured using a Guildline Autosal 8400B. For stations 18, 19, 20, 21, the CTD conductivity profile was unusable, so a salinity profile was reconstructed from water sample values. On the basis of the water sample correction, salinity is measured to an accuracy of 0.003.

In addition, the CTD also carried an altimeter from Benthos Undersea Systems Technology Inc. to determine distance above the sea floor and a transmissometer with a 25 cm light path from SeaTech Inc..

At all stations, oxygen samples were taken from the entire water column, (in total 2400 samples). The determination of oxygen was carried out in line with WOCE-standards for O_2-measurement, as per Carpenter, 1965. Two radiation counters from SIS were used. For more than 10% of the samples, doubles, covering the entire range of O_2-values (180-350 µmol/l), were also measured. Using this data, a percentage error of 0.2% was obtained. This is below the WOCE-standard of reproducibility of 0.5%. Oxygen profiles were not measured as oxygen sensors fail under freezing conditions.

To measure the stable isotope ^{18}O, 1713 samples were taken at 83 stations. For paleooceanographic investigations, 1350 samples for later analysis for $\delta^{13}C$ were taken at 67 stations.

Preliminary Results

The section from 39° to 4°41'E along 54° S reached from the foot of the Conrad Rise to the Southwest Indian Ridge (Fig. 5). In this area, the Antarctic Circumpolar Current has a strong southward component. This can be clearly seen in the distinct core layers of the Upper and Lower Circumpolar Deep Water (Fig. 6). The Southern Circumpolar Current Front is found at station 13 at 27° 23'E. The near-bottom layer, which reaches from the western slope to the Southwest Indian Ridge, is relatively cold due to the influence of Bottom Water, which flows out of the western Weddell Sea along the mid-ocean ridge to the east. As this core is not to be found on the slope of the Conrad Rise, it must exit into the Indian Ocean. The structure of the surface layers is resolved at the mesoscale from the XBT-section (Fig. 11).

The section from the Greenwich Meridian to the east (Fig. 7) follows the eastward current in the north of the Weddell gyre. At the depth of the Warm Deep Water, relatively cold temperatures, less than 0.3°C, show the cold regime. The boundary of the Weddell gyre, the Weddell Front, lies between stations 18 and 19. The temperature of the Weddell Sea Bottom Water of less than -0.7°C increases from west to east, reflecting the entrainment of surrounding water. The circulation perpendicular to the section is also evident from a doming of the isolines. This is caused by a northwards extension of the abyssal plain between 10 and 15°E (Fig. 5), and appears as a northwards current in the west of the section and a southward one in the east.

The section along the Greenwich Meridian (Fig. 8) cuts the cyclonic Weddell gyre meridionally. In the south, a deepening of the surface layer towards the continent and the onset of winter temperatures is observed. This part of the section was already covered with sea-ice and can be counted as the Antarctic Coastal Current. The warm regime occurs to the north, with temperatures in the Warm Deep Water of more than 1°C, caused by the proximity of the inflow of the Antarctic Circumpolar

Current. This warm regime is disturbed by Maud Rise, where noticeably colder temperatures are measured in the Warm Deep Water. The decrease in temperature further to the north signifies the cold regime, in which the eastward current is found. Near the bottom, cold temperatures show the flow of Bottom Water moving east out of the western Weddell Sea, leaning against the mid-ocean ridge. The Weddell Front lies at 55° 30'S, between stations 36 and 37.

The southern part of the Weddell gyre, in which the major water mass transformations occur, is separated from the inflow and outflow regimes by the section from Kapp Norvegia to Joinville Island (Fig. 9). The surface layer already shows winter conditions with temperatures around the freezing point. The deepening of the surface layer towards the coast, due to on-coastal Ekman transport and convection in the coastal polynya, is clearly visible on both sides of the section. The inflow of relatively warm Warm Deep Water can be seen in the east. The outflow in the west is noticeably colder. On the western slope, a layer of newly formed bottom water flows to the north.

The sections form part of the WOCE "Repeat sections" Programme. Comparison with the data of 1992 on the Greenwich Meridian Section and the 1989/1990/1992 sections through the western Weddell Sea show a clear change in the deeper layers. In the bottom water of the western Weddell Basin, a continual warming over this 6 year period is observed. This trend is confirmed by results from moored instruments. The warming is of order 0.01 K per year. The investigation of the cause of this warming is still on-going. However, the increase in temperature in the Warm Deep Water regime suggests a change in the inflow of water from the circumpolar current.

2.2.2 Tracer measurements

Klaus Bulsiewicz, Gerhard Fraas, Malte Runge, Björn Schlenker, Hiltrud Sieverding (IUPB)

Objectives and methods

Along the sections, the CFCs Freon-11, Freon-12, Freon-113 and CCl_4 were measured on board by ECD gas chromatography. This is the first time F113 and CCl_4 have been measured in this region over a complete section. F113 has been released into the atmosphere at a known rate since the early sixties and has been taken up by the oceans by the surface transfers. Therefore it can be used to characterize the younger water. Similarily CCl_4 has been released into the atmosphere since about 1920, so that it characterizes the older water. In addition to the analysis done on board, water samples for CFC measurements were stored in flame-sealed ampoules which will be analysed ashore and will provide reference measurements for the analysis carried out on board. Water samples for tritium and helium were taken also. They will be extracted after the cruise and analysed with a mass spectrometer. All gases will be extracted from the tritium samples which will then be stored for half a year. After this time, a sufficient amount of tritium will have decayed to ^3He so that it can be measured by the mass spectrometer. The data sets provide important information about circulation and renewal pathways for all relevant subsurface water masses.

Work at Sea

The water samples were taken from the rosette water sampler using flow-through containers consisting of a glass ampoule (CFMs), copper tubes (helium) and glass bottles (tritium). In total, 104 stations were sampled and 2016 water samples for the CFMs were analyzed during this cruise. In addition, 785 standard gas and blank measurements were taken periodically. In total, 1418 water samples were collected for analyses ashore, including 200 water samples for CFC, 623 water samples for helium (collected at 62 stations) and 595 samples for tritium (at 60 stations).

A special calibration cast was made in the Drake Passage in which all water bottles were closed at a depth of 3000 m. The water obtained is supposed to be free of CFCs, so that the overall blank can be checked. Apart from the apparatus blank, the blank of each individual water bottle is important for the evaluation of the data. On the cruise Meteor 11/5 in 1990 the CFMs F11 and F12 were not found. Now however, these CFMs could be detected in concentrations of 0.04 pmol/kg (F11) and 0.02 pmol/kg (F12). Only Freon-113 could not be detected (limit of detection: 0.001-0.002 pmol/kg) and therefore it can be concluded that the water bottles have not yet been contaminated with Freon-113.

Preliminary results

Preliminary data for Freon-11 are presented in Figs. 14 and 15. A quasi-zonal section from 35° E to the Greenwich Meridian is shown in Fig. 14. Between stations 12 and 18 the transition from the Circumpolar to the Weddell regime occurs. In the centre of the Circumpolar Deep Water (2000 m), the lowest concentrations (<0.17 pmol/kg) is measured, values which also occur in the Warm Deep Water at 1000 m depth and indicate older water with little renewal. The section from 55° S to Antarctica along the Greenwich Meridian is presented in Fig. 15 (top). This section can be compared with results from a previous cruise (ANT X/4, 1992). For example, the 0.2-pmol/kg isoline in the centre of the gyre at 62° S now reaches up to 2500 m, whereas in 1992 it occurred at a depth of up to 4000 m. The increase of the tracer concentration in the interior is consistent with upwelling in the Weddell gyre. On the slope of the North Weddell Ridge, bottom water with F11 > 0.5 pmol/kg is advected from the Antarctic Peninsula. Fig. 15 (bottom) shows the section across the southern Weddell gyre from Kapp Norvegia to the Antarctic Peninsula (Joinville Island). Along the slope of the Antarctic Peninsula, the newly formed bottom water is obvious from the high concentrations. Between 500 and 2000 m depth, a CFC-11-minimum (<0.15 pmol/kg) is indicative of relatively old water. In the depth range 300 to 1500 m, an inflow of Warm Deep Water in the Weddell basin occurs at Kapp Norvegia and the outflow of this water mass is obvious on the western side. At 3000 m, a tongue of fresh water stretches from the eastern slope into the central basin. This is an indication that the centre of the Weddell basin is also ventilated from the east. On the eastern continental slope, a core of young water (>0.5 pmol/kg) occurs at 4000 m. A similar core is present on the Greenwich Meridian section in 3000 m. This indicates that the source of this water is in the Enderby basin or even further to the east.

2.3 Marine chemistry

2.3.1 The carbon dioxide system in Antarctic waters

Mario Hoppema (AWI) and Michel Stoll (NIOZ)

Objectives

Modifications of the global carbon cycle, by the burning of fossil fuel and changes in land use, have led to an increase in atmospheric carbon dioxide (CO_2) which has the potential to increase the greenhouse effect of the atmosphere. The deep oceans are, in principle, able to take up almost all of this excess CO_2, but only on a time scale which is much longer than the one associated with the anthropogenic perturbations. This is related to the typical mixing and residence times of the deep and bottom waters of the oceans, which are of the order of 1000 years. Thus studies in areas where interactions between the deep and the surface ocean occur, such as the Weddell Sea, are vital for the study of CO_2 uptake and its distribution.

An objective of this project is to gain knowledge of the CO_2 distribution in the Weddell Sea, where the initial properties of a major part of the abyssal world oceans are generated. Another objective is to determine the potential of Antarctic waters to take up atmospheric CO_2. This is especially important for the frontal regions of the Antarctic Circumpolar Current (ACC) and for the regions with seasonal ice cover. Data from this cruise will be combined with data of previous cruises to address those questions

The ensuing CO_2 database of the Weddell Sea and the Antarctic Circumpolar Current may also be used in a modelling effort in which carbon transport and air-sea gas exchanges are calculated.

Work at sea

The CO_2 system has been investigated along four sections. Section I ran from Cape Town (SA) to 55°S 39°E, section II across the northeastern Weddell gyre from 39°E to 0°E, section III along 0°E and section IV from Kapp Norvegia to Joinville Island the western Weddell gyre.

Measurements of the CO_2 system in the entire water column were performed. TCO_2 (total inorganic carbon content) was determined by a high-precision coulometric method and automated sample stripping system. Briefly, the method is as follows. A sample of seawater is acidified with phosphoric acid and stripped with high purity N_2 gas. The carrier gas plus extracted CO_2 is passed through a solution containing ethanolamine and an indicator. This solution is electrochemically back-titrated to its original colour and the amount of Coulombs used is equivalent to the amount of CO_2 in the sample. Data obtained were processed onboard and calibrated against an internationally recognized TCO_2 standard (Dickson).

Continuous measurements of the partial pressure of CO_2 (pCO_2) in water and marine air were done using an infra-red analyzer (Li-Cor). A continuous water supply is passed through an equilibrator where approximately every 4 to 5 minutes the headspace gas is analyzed for its CO_2 content, thus giving pCO_2 in the surface water. Marine air was pumped continuously from the crow's nest into the laboratory and subsampled after every fourth equilibrator reading. The equipment was calibrated with reference gases, traceable against NOAA standard gases. The data obtained were processed onboard. Final data will be available pending recalibration of the reference gases ashore.

Preliminary results

Total carbon dioxide

In Fig. 16, the section on the Greenwich Meridian is shown for TCO_2. The boundary between the Antarctic Circumpolar Current and the Weddell gyre regime lies at approximately 55-56°S.

Generally, TCO_2 is low in the surface layer due to phytoplankton which utilizes CO_2. Below the thermocline, a TCO_2-maximum is found, associated with the temperature maximum of the Warm Deep Water. Near the bottom, where Weddell Sea Bottom Water is present, relatively low TCO_2 values were measured. This water mass originates partly from the shelf waters of the Weddell Sea, which are low in TCO_2. The large water volume of Weddell Sea Deep Water, which lies between the bottom water and the Warm Deep Water, is merely a mixture of these two source waters with corresponding TCO_2 values.

The TCO2 maximum is higher in the north (58-63°S) than in the south (66-69°S) and in addition is shallower in the former region. This division coincides with the cold and warm regions of the Weddell gyre, which are defined by the value of the temperature maximum. In the southern warm regime, the Warm Deep Water present has entered the Weddell gyre relatively recently. In its source area, the Antarctic Circumpolar Current, TCO_2 increases with depth. In the deep Weddell Sea, on the other hand, TCO_2 decreases with depth and thus a TCO_2 maximum is formed at the depth where the new Warm Deep Water meets the deep Weddell water. This deep TCO_2 maximum is observed at about 1500 m (66-69°S). In the northern, warm regime, Warm Deep Water is found which has already been circulating for a longer time in the Weddell gyre. The observed TCO_2 concentration is higher than in all waters of the warm regime and, since the Warm Deep Water is essentially the only source of water of the Weddell gyre, this implies that CO_2 enrichment has occurred in the Weddell Sea.

In the bottom layer at 60-63°S, a TCO_2 minimum was observed. This is probably due to the meeting of spatially separated bottom water masses with different TCO_2 content. Over the flanks and the crest of Maud Rise, TCO_2 values were different than to the north and south. For example, the 2255-ppm isoline, which normally occurs near the bottom of the thermocline, reaches much deeper to about 800 m. The deep TCO_2 maximum, characteristic for the warm regime, is also less pronounced over Maud Rise.

Toward the Antarctic continent (about 69°S) the isolines fall precipitously indicating a sharp frontal structure. This front separates the warm regime from the coastal regime.

Partial pressure of CO_2

The measurement of pCO_2 along the four sections resulted in a large, high spatial resolution data set. Along Section I, near-saturation values are generally observed, somewhat modified by the local hydrographic variations with a slight oversaturation in the south. Section II starts with an oversaturation and decreases to undersaturation. On crossing the frontal system between Antarctic Circumpolar Current and the Weddell Sea, an increase of about 15 ppm is observed.

The section along 0°E (III) is discussed in more detail (Fig. 17, top). A slight undersaturation is observed between 50 and 52°S. Then, going southwards, a sharp increase in the pCO_2 (about 10 ppm relative to atmospheric value) occurs, accompanied by a pronounced decrease in sea water temperature. Further south (about 56°S), the Weddell Front is characterized by a further increase in pCO_2 to values of 375 ppm. Regional hydrographic variations in the cold water regime of the Weddell Sea are reflected in the pCO_2 signal. In some areas the chlorophyll content is relatively high (65°S), which may be reflected in the pCO_2 signal (Fig. 17, bottom). However, the major influence on the observed signal appears to be water temperature (Fig. 17, top).

The cold water regime is generally characterized by oversaturation. The subsequent decrease in pCO_2 concentration, to equilibrium values and below, is correlated with crossing into the warm water regime. On the flanks and the crest of Maud Rise, the water column is different in structure. This might be reflected in the pCO_2 as shown by the steep gradients over the flanks. Generally, the warm water regime is characterized by undersaturation.

For the first time, the pCO_2 was measured on a long transect with ice-covered water (section IV: Kapp Norvegia - Joinville island). The newly designed water inlet on the box-keel ("Kastenkiel") made a fairly uninterrupted water supply possible. Also a slight modification to the equilibrator shower head was necessary. The observed undersaturation in pCO_2 (-10 to -15 ppm) is very likely caused by rapid cooling of the water which, after freezing, is prevented from equilibrating with the atmosphere. Only on nearing Joinville Island, where multi-year ice is found, oversaturation with higher values is observed (+20 ppm and over). This is caused by the upwelling of deep water, which is enriched in CO_2, into the surface water. During the next spring, when the ice cover retreats, phytoplankton will most likely use this excess CO_2 for growing.

2.3.2 Nutrient distributions in Antarctic waters

Karl Bakker (NIOZ), Michel Stoll (NIOZ) and Mario Hoppema (AWI)

Nutrient concentrations of silicate, phosphate, nitrite and nitrate were determined in all samples taken from the rosette. They were analyzed by a standard colorimetric method on a rapid flow "TRAACS" autoanalyzer (60 samples/hr) manufactured by Technicon. A standard range was used for all measurements (Tab. 4), while daily diluted stock standards were used for calibration. As a reference standard a so-called "cocktail" (100 fold diluted) containing a mixture of phosphate, silicate and nitrate was used. This standard was measured for statistical purposes and corrections on the data. The precision for the different properties are given in Tab. 4.

Tab. 4: Standard measuring ranges used for Si, PO_4, NO_2 and NO_3 and standard deviations.

	Range (µmol/l)	STD
Silicate	0 - 145	0.5
Phosphate	0 - 3	0.03
Nitrite	0 - 2	0.01
Nitrate	0 - 40	0.21

Preliminary results

As an example for the nutrient data obtained, four silicated sections are presented (Figs. 6 to 9). Generally, the nutrients are relatively low in the surface layer because of biological activity. In the Warm Deep Water below, phosphate and nitrate show a maximum, associated with the temperature maximum. Both decrease towards the bottom. The silicate maximum occurs deeper than the phosphate and nitrate maxima. It originates from the dissolution of biogenic silica, which takes place at a lower rate than the remineralisation of soft tissue, by which phosphate and nitrate are released.

In the eastern part of the section, the Warm Deep Water that entered the Weddell gyre relatively recently is recognizable by a phosphate maximum at 1000-1500 m. This structure is a continuation of the same structure on the Greenwich Meridian. Remnants of it can also be seen in the very west of the basin (200-400 km), indicating that the Warm Deep Water crosses the entire basin.

In the centre and west, the phosphate maximum is shallower and has a higher value. This area is comparable with the cold regime on the Greenwich Meridian. High phosphate and nitrate values are caused by sub-surface remineralization of biological material that sinks down. For silicate (Figs. 6 to 9) some specific features can be observed which cannot be detected in other tracer distributions. In the easternmost part of the section, the highest silicate values are found in the bottom layer. This may be due to an inflow of bottom water from the Enderby basin in the east, where silicate enrichment of the bottom layers is known to occur. In the central and western basin, bottom silicate values are much lower due to the presence of bottom water recently produced in the southern and western Weddell Sea. On the western slope, some young bottom water is identified by its very low silicate, phosphate and nitrate values. Earlier data showed that this band of low silicate did only reach the lower slope (until approximately 300 km of the section; Fig. 9). During this cruise, another cell of young bottom water (Si $<$ 100 µmol/kg) is found at the base of the continental rise (about 600 km), much further down the slope than during previous observations.

A very interesting new observation on this transect is the major silicate-minimum structure between 2500 and 4000 m, extending over the entire eastern part of the basin. Relatively low silicate values in the deep Weddell basin are associated with bottom water which indicates that significant ventilation of the deep Weddell Sea does not only take place via the bottom route, but also via the deep water route. Since such a silicate minimum can only come into existence when the deeper water shows an increase of silicate, this suggests that this deep ventilation originates from the east where the bottom layer has a high silicate concentration. The western boundary of this deep ventilation area appears to be visible in the phosphate distribution as well as a sharp, deep phosphate front at 1000-1100 km.

2.3.3 Marine Organic Chemistry

Anneke Mühlebach and Andreas Zimmermann (AWI)

Objectives and methods

The organic chemistry work aimed to determine the distribution of dissolved and particulate phytosterols in the Weddell Sea (autumn situation). This study will complement earlier studies undertaken in the western Weddell Sea during the spring bloom of phytoplankton (ANT X/7). The objective is to understand the fate of phytosterols and other trace organic compounds in the ocean, starting with their biosynthesis and input into the euphotic zone and their possible deposition in the bottom sediments. By choosing some well defined classes out of the pool of organic compounds, the processes appearing on a molecular level can be examined. This may yield further information about the stability of highly diluted dissolutions.

Water samples (20 l each) were taken along three sections and at various depths by a rosette water sampler joined to a CTD-probe. Dissolved and particulate parts were separated by filtration. Filtration was performed over glass fibre filters (GF/C, diameter 4.7 cm, retention rate 90% for particles > 1.2 µm; for larger volume samples (vol.> 20 l), diameter 15 cm). Filters were put in ampoules and test tubes respectively, covered with inert gas (argon) to prevent oxidation, sealed and stored at -30°C. After filtration, the seawater samples were spiked with Cholesterol-d6 as an internal standard. The dissolved lipophilic compounds were extracted with hexane. A volume of 20 l of sea water was shaken with 100 ml hexane. These extracts were put in ampoules, covered with argon, sealed and kept at -30°C. In Bremerhaven, further preparation and analysis of the samples will take place. Filters will then be extracted with acetone. Hexane and acetone extracts will be evaporated. After derivatisation yielding trimethylsilyethers, the phytosterols will be analysed by GC/MS. Concentrations in the lower (ng phytosterol)/ (l seawater) range are expected (for deep water).

The quality of the extraction and the further processing is checked by the addition of various internal standards (stable isotopes). Before the extraction, 200 ng Cholesterol-d6 in 1 ml ethanol were added to the water sample. Surface samples were spiked with 2000 ng, since in surface samples higher sterol concentrations are expected. The hexane used for extraction was spiked with benz(a)anthracene-d12 to determine the hexane recovery (200 ng/100 ml). Just before the injection into the GC/MS system, a deuterated decachlorbiphenyl standard will be added to the sample to check the performance of the instrument.

Samples taken during the cruise

Section 1 - part a (stations 3 to 16) from Conrad Rise to the southwestern Indian Ridge:

Six profiles were taken, three at the slope of the Conrad Rise (stations 3,5,7), one in the centre of the basin (station 10), and two at the slope of the Southwest Indian

Ridge (stations 14,15). At each station, seven samples (20 l each) were taken. Samples were taken close to the bottom, 100 m above bottom, 600 to 800 m above bottom, at about 1500 m depth, at the temperature maximum (Circumpolar Deep Water), at the temperature minimum (Winter Water), and at the surface. All samples except the surface samples were taken from the rosette water sampler. The surface sample was provided by the Klaus-pump.

Section 1 - part b (stations 16 to 31) along the northern Weddell gyre:

Five profiles were taken at a separation of 180 sm, starting at station 19 (stations 19, 22, 25, 28, 31). Again, seven samples were taken at each station. Samples were taken close to the bottom, 100 m above bottom, 600 to 1000 m above bottom, at 2500 m depth, at the temperature maximum and minimum, and at the surface.

Polar and Weddell Front:

Profiles were taken at both station 33 (Weddell Frontal) and station 34 (Polar Front). These samples are not influenced by the Weddell regime and the newly formed bottom water respectively, and can serve as a reference.

Section 2 along the Greenwich Meridian (stations 35 to 67):

11 profiles (each some 7 samples) were taken along the section from 55°S to the continent. Four of the profiles were situated close to Maud Rise (one at the northern edge, one at the southern edge, two at the shallowest points we crossed). Between the North Weddell Ridge and Maud Rise, samples were taken every 120 sm close to the bottom, 100 m above the bottom, at 4500 m depth, at 2500 m depth, at the temperature maximum and minimum as well as at the surface. Every 60 sm, an additional surface sample was taken (Klaus-pump). On the slopes and above Maud Rise in shallower water, the station separation decreased, additional samples were taken from 1000 m depth. Profiles were taken at stations 35, 38, 44, 48, 52, 54, 56, 57, 60, 62, 66.

Section 3 - western Weddell Sea (stations 69 to 103) from Kapp Norvegia to the Antarctic Peninsula:

Samples were taken at the following depths: close to bottom, 100 m above bottom, 3000 m, 1500 m, 500 m, temp. maximum, and at the surface and 40 m, respectively. Profiles were taken at stations 69, 71, 75, 79, 83, 86, 90, 94, 99, 101, 102, 103. Additionally samples were taken close to the bottom at stations 95, 96, 97, 98, 100. In the newly formed bottom water, relatively high sterol concentrations may be found depending on the contact of the water mass to the open sea and on the half life of the sterols. In addition, sterols may be extracted from the sediment into the overlying water. The data gathered on section 3 may be compared to data from a former study along this track (ANT X/7). Then, a region with very low sterol concentrations was found in the central basin (concentration of brassicasterol < 0.5 ng/l, for example). This observation will be verified by samples from this cruise.

Along each section, various surface samples with a volume of 80 l were taken (Klaus-pump). This will allow the identification and quantification of sterols present in trace amounts in seawater. In addition, various experiments were performed to improve the methods applied, especially with respect to the recovery of the internal standard Cholesterol-d6.

2.4 Marine Biology

2.4.1 Plankton investigations

Anke Bittkau (AWI), Corinna Dubischar (AWI), Jochen Nowaczyk (AWI), Vassili Spiridonov (ZMMU)

Objectives and methods

Zooplankton and micronekton distribution in the Weddell gyre depends largely on oceanographic structures in this region. During ANT XIII/4, two main questions were addressed by our planktological studies:

1. How are horizontal and vertical distributions of zooplankton and micronekton determined by the different oceanographic regimes in the Weddell Sea (i.e.: the frontal system between the Antarctic Circumpolar Current and the Weddell Sea; the warm regime; the cold regime, and the coastal current) ?

2. How do the dominant zooplankton and micronecton organisms switch to over-wintering modes in these different regimes?

To answer these questions, our studies focused mainly on phytoplankton, zoo-plankton and micronekton species composition, abundance and distribution as a function of oceanographic structures. For precise measurements of the vertical distribution of larger zooplankton and micronekton, an Optical Plankton Counter (OPC) was used in addition to the net catches. This OPC was attached directly to the multinet. The continuous photometric measurement of particle size and number enables us to assess particle distribution parallel to the multinet-catches with a high resolution. In the following section, the methods used, as well as some preliminary results will be described in more detail.

Phytoplankton distribution

Chlorophyll a determination:

Phytoplankton biomass in the water can be detected by fluorometric measurement of the phytoplankton pigment chlorophyll a (Chla). Two different approaches were used:

1. Underway surface (8 m water depths) fluorescence of phytoplankton pigments (expressed as chla) was recorded by means of a Turner Design (TD 10) fluorometer attached to the seawater system with the ship's membrane pump. Data were obtained every 10 seconds and averaged in 5 min intervals and subsequently stored on the ship's data logging system (POLDAT) together with the appropriate ship's position and other physical, chemical and meteorological data. Every 4 hours, and also at the stations, triplicates of normally 1 l of seawater, but occasionally more (drained from a bypass to the fluorometer system), were filtered

onto Whatman GF/F glassfibre filters for calibration of the instrument. The chla and phaeopigment values were obtained after extraction with 90 % aceton/water. The determination limit was 0.001 µg chla/l.

2. At stations Cchlorophyll a measurements were done from the Niskin bottles of the CTD rosette. At 49 stations, water from 20, 40, 60, 80, 100 and 200 m was taken. If OPC measurements and multinet samples indicated high particle concentrations in deeper water layers, additional samples were taken from water depths down to 500 m. Along the transects 3 and 4, chla-concentrations in the < 20 µm and the >20 µm size fraction were measured separately.

To determine the chla-concentrations, 2 l of seawater were filtered onto Whatmann GF/F-glassfiber filters. Pigments were extracted with 10 ml 90% acetone and measured thereafter directly on board using the method by Evans *et al.* (1987). Parallel to the sampling for chla measurements, 2 l seawater per depth level were filtered onto precombusted (24 h at 500°C) Whatmann GF/F-filters for later analyses of particulate organic carbon and nitrogen (POC/PON). These filters were deep-frozen (-20°C). Measurements will be carried out at AWI using an Carlo-Erba CHN Analyzer.

For determination of phytoplankton concentration and species composition, 200 ml of seawater were taken from the same depths as for chla and POC/PON-measurements and fixed with hexamethylentetramin-buffered 20% formalin (end concentration 0.6%). These samples will be processed using the Utermöhl-counting technique (1958) at the home laboratory. Additional samples were taken with an Apstein-net (mesh size 20 µm) to concentrate larger phytoplankton from the upper 10 m of the water column.

Zooplankton and micronekton distribution

Zooplankton organisms were sampled using a Multinet (Hydrobios, Kiel) with mouth opening of 0.25 m^2 and mesh size of 100 µm. An OPC was mounted on the net frame. The OPC photometrically records the distribution and size of particles in the water column. Each half a second, the data are transferred to the deck unit, yielding in an exact pattern of the vertical distribution of plankton organisms parallel to the multinet tow. The multinet was towed with a speed of 0.5 m sec^{-1}. At all stations, the multinet tows were conducted down to 1000 m (or in the shelf areas nearly to the bottom). Five depth strata were chosen according to the thermohaline structure of the water column.

In total, 31 successful multinet stations were performed: 3 stations on the zonal transect along 54°S (transect 2a), 6 on the transect across the Weddell cold regime (transect 2b), one station in the Polar Front, 12 on the transect along the Greenwich Meridian (transect 3), and 9 stations on the transect across the western Weddell Sea from Kapp Norwegia to the Antarctic Peninsula (transect 4).

After towing, each sample was split into 2 subsamples using a 2 l Folsom splitter. One half was immediately preserved in 4% hexamine buffered formalin, while another was used for size fractioning and subsequent preparation for biomass measurement. Before fractioning, we checked a subsample for rare or taxonomically interesting specimens. Simultaneously, several specimens of the dominant species (mostly *Calanoides acutus*, *Calanus propinquus*, and *R. gigas*) were selected for the determination of carbon and nitrogen (C,N) content and ratio, and fatty acids composition of lipids.

For biomass measurement, a subsample was screened subsequently through 2000 µm, 1000 µm, 500 µm, 200 µm, and 100 µm meshes. Each of the fractions obtained was then filtered onto preweighted GF/C filters and dried at 50°C for 24 h. In case of the presence of abundant phytoplankton, subsamples for biomass determination were not fractioned but preserved in formalin separately. Zooplankton biomass in these samples will be estimated from size spectra of major taxa using length/weigth regressions. Salps from the biomass subsample were measured and dried on filters or deep frozen separately according to a size grouping.

For determination of C,N content, the organisms were identified, staged and measured under a stereomicroscope with an accuracy of 0.1 mm, rinsed in distilled water and deep frozen individually (or for young copepodite stages of large calanoids in groups of 2-3 specimens) in Eppendorf caps. Measurements will be carried out using a Carlo Erba CHN analyzer.

For the study of fatty acids composition of body lipids, we selected 3 to 5 specimens of particular developmental stage of certain species and placed them into precombusted tubes with 10 ml conserving solution (Dichlormethan/methanol in a proportion of 2:1). These tubes were then stored under -20°C.

Micronekton was collected using a Rectangular Midwater Trawl with two nets, the larger one with an mouth opening of 8m^2, the smaller one with an opening of 1m^2 (RMT 1+8) which was towed obliquely from the depth of ca. 450 m to the surface. The volume of water filtered was estimated using flowmeters mounted in the mouth of both nets. Four RMT tows were performed on transect 2b across the Weddell cold regime waters, 7 tows were done on the Greenwich Meridian (transect 3) and one additional tow was performed in the Bransfield Strait. The fresh catch of the big (8 m^2) net was sorted into major taxonomic groups, i.e. coelenterates, polychaets, pteropods, cephalopods, euphausiids, hyperiids, decapods, chaetognaths, thaliaceans and fishes, which were preserved in 4% formalin and later counted. The sample of the small (1 m^2) net was preserved without sorting. Further processing of the RMT samples will be done in the AWI and the Zoological Museum of the Moscow University.

Several vertical Bongo net (200 µm and 500 µm mesh size) tows were performed in order to obtain alive animals for experiments and for further DNA/RNA analyses.

Preliminary results

In the following section, the results of the on-line chlorophyll measurements during the transects 2a, 2b and 3 are shown. Because of the permanent ice cover during transect 4, no surface chla data are available. Table 5 gives some general information concerning the positions etc. of the transects.

Tab. 5: Characterization of the transsects carried out during ANT XIII/4.

Date	Stat.	Position Start	Position End	Name
17.3.-23.3.	01-02	Cape Town	54°00.0' S 38°59.8' E	**Transect 1**
23.3.-28.3.	03-15	54°00.0' S 38°59.8'E	54°00.0' S 25°44.4' E	**Transect 2a**
28.3.-5.4.	15-32	54°00.0' S 25°44.4"E	59°27.5' S 3°10.5' W	**Transect 2b**
12.4.-22.4.	35-66	55°00.0' S 0° W	69°38.5' S 0°07.4' W	**Transect 3**
25.4.-8.5.	68-102	71°01.0' S 11°36.6' W	63°20.1' S 52°47.6' W	**Transect 4**

Transects 2a/2b:

In general, very low chla concentrations were measured during both transects, which was in accordance to expected values during late autumn in this area (Figs. 18 and 19). Background values were between 0.1 and 0.2 µg Chla/l. On transect 2a, a distinct chla maximum was measured between 29° und 30°E, east of a significant increase of surface salinity and a decrease in surface temperature. Further to the west, an increase of the chla-concentration to a maximum value of about 0.5 µg/l was detected. These relatively high concentrations persisted in the connecting transect 2b between 25°E and 19°E. These positions coincide with the site of an extensive frontal system in this region. Further analyses of phytoplankton composition and detailed investigations on hydrographic conditions are needed to detect possible reasons for this higher phytoplankton biomass.

Transect 3:

Transect 3 followed the Greenwich Meridian from 55°S to the ice shelf edge. During this transect, very low chla-concentrations were found (Fig. 20). Chlorophyll a-concentrations in the north were higher than those further south. Two maxima at about 60°S are particularly noticable. Further investigations of, for example, phytoplankton species composition are needed to explain these patterns.

Fig. 21 shows some of the vertical profiles registered by the OPC attached to the multinet. The particle concentrations showed very pronounced peaks in the upper water layers (ca. upper 150 m), but varied significantly between the different profiles. Generally the particle concentrations of up to 12000 particles m^{-3} were surprisingly high. Further investigations of the multinet catches will reveal the characteristics of the particles.

Sediment traps

Some of the particles produced in the upper ocean layers, e.g. phytoplankton aggregates and faecal pellets, may reach relatively high sinking velocities, leading to their sinking out of the surface layers. Sediment traps have been attached to the following moorings to assess this particle flux qualitatively as well as quantitatively: 227/2, 227/3, BO-5, BO-6 and PF-8. These sediment traps are equipped with 20

Tab. 6: Recovered sediment traps:

Mooring: 227/2 at 59°27.5 S and 3°11.2 E
deployed on 26.12.1994
recovered on 05.04.1996

Depth of the trap	565 m	3709 m
Time of deployment	27.12.1994 - 10.08.1995	27.12.94 - 11.01.96
Sampling interval	19 days	19 days
Number of samples	15	20

Mooring: BO-5 at 54°20.6 S and 03°17.6 W
deployed on 27.12.1994
recovered on 07.04.1996

Depth of the trap	531 m	2268 m
Time of deployment	31.12.1994 - 15.01.1996	31.12.1994 - 08.12.1995
Sampling interval	19 days	19 days
Number of samples	20	18

Mooring: PF-8 at 50°11.1 S and 05°53.7 E
deployed on 29.12.1994
recovered on 09.04.1996

Depth of the trap	687 m	3110 m
Time of deployment	31.12.1994 - 15.01.1996	31.12.1994 - 15.01.1996
Sampling interval	19 days	19 days
Number of samples	20	20

Tab. 7: Newly deployed sediment traps:

Mooring: 227-3 at 59°01.8 S and 0.0° E deployed on 04.04.1996

Depth of the trap	3373 m
Time of deployment	06.04.1996 - 27.03.1997
Sampling interval	14 days

Mooring: BO-6 at 54°20.6 S and 3°17.0 W deployed on 07.04.1996

Depth of the trap	2280 m
Time of deployment	08.04.1996 - 27.03.1997
Sampling interval	14 days

sampling containers and are therefore able to collect the sinking material in 20 different time intervals. To prevent degradation of the material in the sediment trap by microbial activities and zooplankton grazing, the sampling containers were poisoned with mercury dichloride. The deployed and recovered sediment traps are summarized in Tab. 6 and 7.

2.4.2 Benthos investigations

Wolf Arntz (AWI), Alexander Buschmann (AWI), Kai Horst George (FBZO), Dieter Gerdes (AWI), Matthias Gorny (AWI), Marco Antonio Lardies Carrasco (UACH), Katrin Linse (IPÖ), Americo Montiel (UMAG), Erika Mutschke (UMAG), Martin Rauschert (AWIP) and Carlos Rios (UMAG)

Objectives

During the second part of the cruise, the investigations carried out by RV "Victor Hensen" in October/November 1994, were continued to study the marine fauna and flora in the Magellan region to compare it with Antarctic conditions and to detect latitudinal clines in population dynamics, reproductive biology and other life strategy components from the high Antarctic to the Strait of Magellan. These two areas separated only recently in geological terms (<20 Ma) and are supposed to have had more intense interchange than other continents around the Antarctic. In addition they should have had a similar history of glaciation.

Faunistic and floristic overlaps have often been suspected between the Antarctic Peninsula and the Magellan region, which essentially comprises Patagonia and Tierra del Fuego with their vast system of channels and fjords. This view seems to hold true for some faunal groups, however it cannot be confirmed for other taxa, or at least there are major doubts. The principal reason for these uncertainties is the lack of adequate sampling in the Magellan region and on the adjacent continental slope of the Drake Passage.

In the past years major efforts have been made to improve the knowledge on both the Antarctic and Magellan fauna and flora. From recent work at the "Dallmann" laboratory, an annex to the Argentinian base Jubany, and other stations shallow-water fauna and flora in the Bransfield Strait near King George Island are fairly well known. During the "Joint Magellan 'Victor Hensen' Campaign 1994" substantial samples were taken in shallow and deep waters of the Strait of Magellan (to 650 m depth), in the northwestern branch of the Beagle Channel and south of the eastern entrance of the Beagle Channel down to Cape Horn. The preliminary result of that cruise was that the ecosystems on the two sides of the Drake Passage, despite certain coincidences in common faunal and floral groups on genus and species levels, have developed very distinct structures.

The original idea to fly the seven German and four Chilean participants plus two Chilean observers to King George Island failed because of bad weather, and "Polarstern" was ordered to Puerto Williams to pick up the participants on Navarino Island. Thus the activities had to be restricted to the northern slope of the Drake Passage (south of Nueva Island), leaving the intended work in the Bransfield Strait and the southern slope of the Drake Passage to a future cruise. With the reduced programme on the northern slope of the Drake Passage, the benthos group pursued the following objectives:

- To assess the macro- and meiofaunal zoobenthic structures on the northern slope of the Drake Passage and the south Chilean shelf, using gear that had been deployed formerly in the high Antarctic, off the Antarctic Peninsula and in the Magellan region;

- to complement existent benthos samples by material from the areas mentioned above, above all from greater depths;

- to carry out physiological, reproductive, and population dynamic investigations and ethological studies on "key species" and to compare the results with those of related species from lower and higher latitudes.

Work at sea

The original idea was to work on a transect between 1500 m depth on the Patagonian continental slope and 200 m on the shelf south of Isla Nueva, to complete the samples obtained during the "Joint Magellan 'Victor Hensen' Campaign 1994". Part of this transect should have been done during that expedition, but this had to be abandoned due to bad weather.

On ANT XIII/4, 5 working days were available to complete the work south of Nueva. "Polarstern" encountered calm weather but, quite unexpectedly, very rough bottom topography. The layer of fine sediments, if existent, was much thinner than at the stations worked with "Victor Hensen" in the eastern mouth of the Beagle Channel in 1994. For this reason the stations, originally planned on a transect between 2500 and 100 m, had to be chosen where topography, thickness of sediments and currents allowed the use of trawled gear and corers. Even so, by no means all equipments could be deployed at all stations. The final list includes 10 Agassiz trawl (AGT) catches (2 for collecting experimental material only), 3 hauls with the epibenthic sledge (EBS), 9 catches with the small Rauschert dredge (D), 3 multibox corer (MG) stations with 21 macro and 2 meiofaunal samples, 4 multicorer (MUC) stations with 30 meiofauna samples, and 380 pictures with the underwater camera at 5 stations. A CTD rosette registered temperature, salinity and dissolved oxygen between the surface and the seafloor. A large number of macrofaunal organisms were photographed alive, and fish and crustaceans were kept in the cool containers for physiological experiments.

Preliminary results

All samples obtained during this cruise, except for live experimental material, were preserved (for methods, cf. cruise report of the "Victor Hensen" Campaign, Arntz & Gorny 1996) and require detailed analysis in the laboratories of the participating institutions. Definite results will be presented during the IBMANT/97 workshop to be held at the Universidad de Magallanes in April 1997. The following preliminary faunal results, based principally on the sorting of the AGT catches on deck, can be summarized at this time:

A first look at the meiofauna obtained from the filtrate of the multicorer samples and from other gears revealed the following groups to occur (in decreasing abundance): nematodes; copepods (calanoids presumably from the water column, harpacticoids, siphonostomatoids); polychaete larvae; ostracods; and foraminiferans. Other groups are to be expected from further microscopical analysis of the samples.

The macrobenthic endofauna of the multibox corer samples from 100 to 1200 m depth showed low densities which decreased even more with depth. At the shallower stations the seafloor was covered with a biogenic layer of shells as well as bryozoan and hydrozoan debris, and the dominant faunal elements were ophiuroids, echinoids and crustaceans. At the deeper stations, the substrate (if any) was fine sand, and the only identifiable organisms were small sedentary polychaetes.

The benthic macro and megafauna from AGT and small dredge was richest in number and biomass at medium water depths between 200 and 600 m. Total catch weights in shallow water were high but consisted mainly of dead shells. The deeper seafloor in the area of study seems to be characterized by a generally thin sediment layer which resulted in a large number of gear failures and was further reflected in the dominance of hard-bottom dwellers, in particular gorgonarians. Larger stones came aboard from all depths and were often strongly overgrown with sponges, hydrozoans, bryozoans and gorgonarians whereas bivalve molluscs and brachiopods were missing on the stones altogether.

On the northern slope of the Drake Passage, too, the result from the "Victor Hensen" expedition is valid that there are no such rich, three-dimensional epifaunal suspension feeding communities as in many parts of the Antarctic. However, the occurrence of sponges, bryozoans and gorgonarians revealed a distinct increase as compared with the Strait of Magellan, the Beagle Channel and the eastern mouth of the Beagle Channel, and crinoids (although small and brittle) were found only in this southernmost part of the Magellan area. The scarceness of colonial and solitary ascidians as compared with the Antarctic was confirmed, and actinians were also relatively scarce. Hydrozoans remained common south of Nueva despite the non-occurrence of its principal substrate, the brown alga *Macrocystis pyrifera,* due to greater water depths. Hydrocorals were found frequently on shells and stones.

Asteroids turned out to be much scarcer and smaller than in the Magellan area further to the north. Regular echinoids were at about the same level whereas irregular sea urchins were of much lesser importance than further to the north, particularly in the Beagle Channel, presumably because of the scarceness of soft substrates. The great variety and abundance of ophiuroids on the shelf was further increased by the large gorgonocephalans which contribute an important share to the echinoderm biomass. The find of crinoids has been mentioned already.

Molluscs, especially bivalves, played a minor role south of Nueva except for the scallops *(Chlamys)* which were found to be abundant at some shallower stations. The scarceness of bivalve molluscs, which resembles the conditions in the Antarctic, was unexpected after the dominance of molluscs found in the Strait of Magellan and in the eastern mouth of the Beagle Channel; however, the reason (as for the missing of scaphopods) may again be the lack of soft bottoms. Bivalve species composition was similar to the fauna further north if the taxodont soft-bottom dwellers are not considered. Among the prosobranch gastropods there were some species which had not been found in the regions further to the north. Chitons and octopods were present at a low abundance level. Brachiopods which in the Antarctic "replace" the bivalves as hard-bottom fauna, were only found in a few small specimens, contrary to our results in the Magellan Strait.

The various "worm" groups can be judged only after more thorough analysis. It seems, however, that the scarceness and small size of echiurids and sipunculids stated during the "Victor Hensen" campaign was confirmed, and priapulids were missing altogether (at least on macro level). Polychaetes were common, but always small, and often colonise gorgonarians, bryozoans and hydrocorals.

For the small crustaceans, there is as yet no information available since all material was preserved immediately after trawling. Among the larger forms, balanoids were by no means as common in shallow waters as further north. However, at the deepest stations a large barnacle was found which strongly resembled the Antarctic genus *Bathylasma*. Isopods, in particular Sphaeromatidae, were considerably less common than to the north. Arcturidae and Serolidae, dominant groups in the Antarctic, were found in low numbers but yielded some species we had not seen before. Among the amphipods which dominated the small dredge catches, all families occurred which had been registered for the Weddell Sea and the Antarctic Peninsula area, with Eusiridae, Lysianassidae and Ischyroceridae as dominant groups. Also Stilipedidae, which had never been found in the Magellan region before, were quite common. Among the amphipods and isopods there were no giant types as described for the Antarctic. The same is true for the pycnogonids, and in all three cases this is valid for the whole Magellan region. Several new types of parabioses were detected, e.g., Caprellidae among the spines of lithodid crabs and Ischyroceridae in epizoic bryozoans (*Flustra* type) on majid crabs.

Reptant decapods, in particular of the cancrid and sea spider brachyuran types, were no longer dominant in the area of study. The Galatheidae *(Munida)* still occurred regularly but were much less common than in the eastern mouth of the Beagle Channel. The palinuran lobster *Stereomastis* two specimens of which had been found in the Beagle Channel during the "Victor Hensen" campaign occurred in a single specimen. Caridean shrimps were gaining importance in relation to the reptants but never reached Antarctic levels. Dominant genera are *Campylonotus* and *Austropandalus* as well as surprisingly, at the deep stations, also the Antarctic genus *Nematocarcinus*. As rarities among the decapods first finds of two genera, *Glyphonotus* and *Pontophilus*, have to be mentioned.

Summarizing, the working area on the northern slope of the Drake Passage, south of Nueva Island, revealed a greater similarity to the Antarctic benthic fauna than the Strait of Magellan, the Beagle Channel and the area immediately south of the Beagle Channel. We might cautiously conclude that the transition to the Antarctic is rather of a gradual nature than abrupt. Despite this fact, considerable differences remain between the Antarctic and this southernmost part of the Magellan region. This indicates that 20 million years of separation and isolation, despite some glacial periods of increased interchange, have led to rather distinct separation of two neighbouring marine ecosystems which originally had an identical fauna. A closer look at these phenomena will be taken during the IBMANT/97 workshop in Punta Arenas.