The Expedition ANTARKTIS VII/1 and 2 (EPOS I) of RV "Polarstern" in 1988/1989

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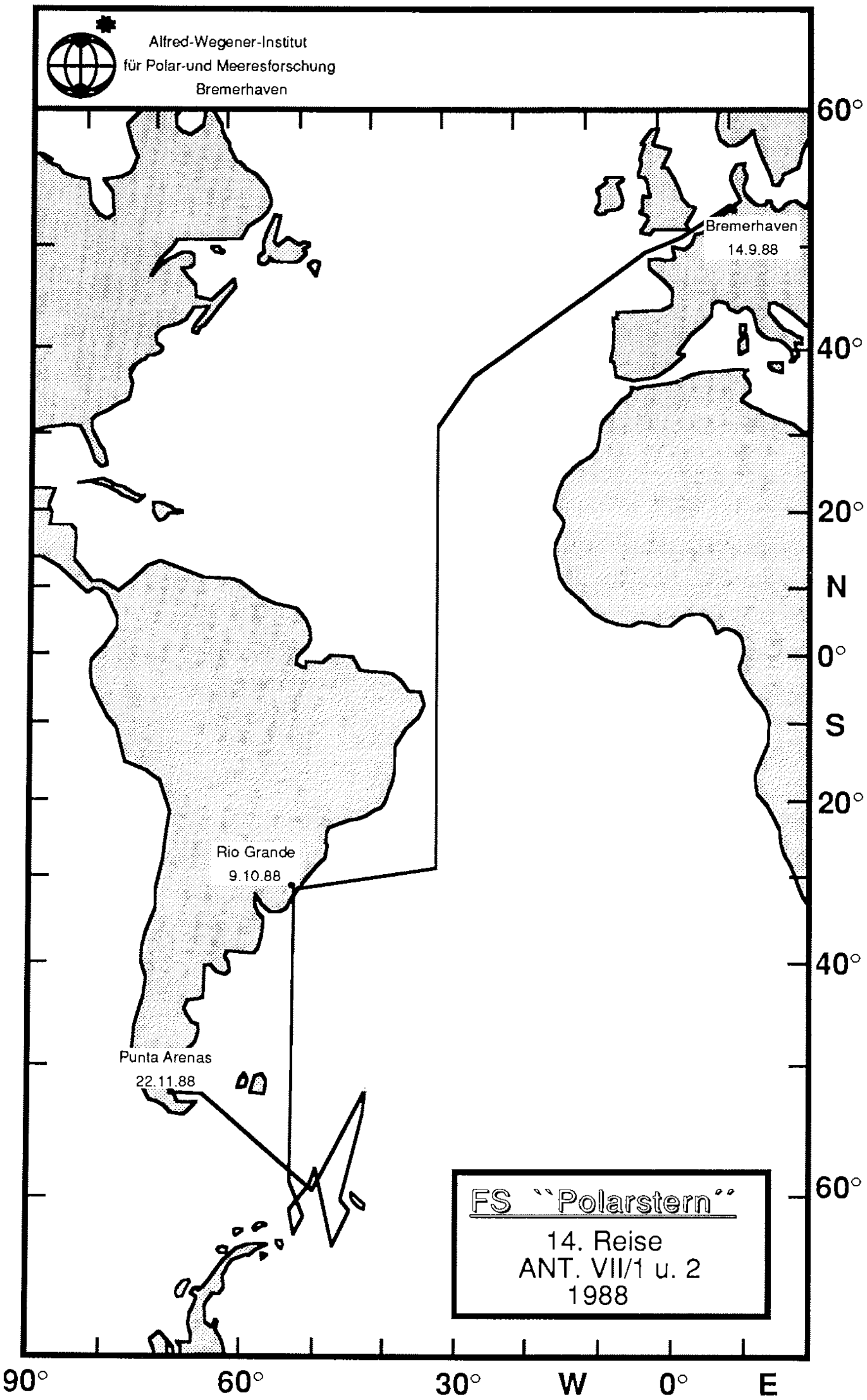


Figure 1 Itinerary FS "Polarstern" ANT VII/1 and 2

ANT VII/1 BREMERHAVEN - RIO GRANDE/BRAZIL 15.09. - 09.10.1988

FAHRTLEITER / CHIEF SCIENTIST

GUNTHER KRAUSE

INHALT / CONTENTS

1. ANT VII/1 BREMERHAVEN - RIO GRANDE (BRAZIL) 15.09. - 9.10.1988

1.1.1 ZUSAMMENFASSUNG UND FAHRTVERLAUF

G. Krause, U. Platt

Auf der Anreise in die Antarktis stellte die "Polarstern" diesmal ein schwimmendes Großlabor für die Untersuchung von Spurengasen in der maritimen Atmosphäre dar. 13 der insgesamt 18 Forschungsprojekte widmeten sich den komplizierten chemischen Reaktionen, die sich über der Oberfläche des Ozeans abspielen. So wurden Verteilungen von Kohlenwasserstoffen, Stickstoff- und Schwefelverbindungen ebenso gemessen wie photochemisch erzeugtes Ozon, Wasserstoffperoxyd und Jodoxydradikale. Hinzu kamen Messungen der UV-Strahlung und aller anderen Komponenten des Strahlungshaushalts über dem Meer.

Die umfangreiche Datensammlung über die genannten Spurengase soll die Kenntnisse über die Verteilung natürlicher und anthropogener Anteile erweitern, andererseits werden die Daten für Test und Weiterentwicklung photochemischer Reaktionsmodelle der ungestörten Atmosphäre benötigt.

Schließlich wurden im hydrographischen Schacht des Schiffes optische Eigenschaften des Wassers gemessen und Phytoplankton in Wasserproben bestimmt.

In Anbetracht der relativ kurzen Reisezeit und des erheblichen apparativen Aufwands zur Spurenstoffmessung im Konzentrationsbereich zwischen 10^{-9} und 10^{-12} war es das Hauptziel, gute Daten zu sammeln. Quantitative Ergebnisse liegen deshalb bisher noch nicht vor. Man kann grob sagen, daß in den Passatregionen die Konzentration anthropogener Spurenstoffe äußerst klein war und in einigen Fällen unter der Nachweisgrenze der benutzten Methoden lag. Wir erwarten deshalb, daß die Datensätze gute Einblicke in die natürlichen Spurenstoffprozesse über dem Meer liefern.

Am 15. September 1988 verließ "Polarstern" am frühen Morgen Bremerhaven. Nach einem kurzen Aufenthalt in Wilhelmshaven, wo das Schiff der Öffentlichkeit zu Besichtigungen freigegeben und Führungen für Mitglieder der wissenschaftlichen Institutionen und der Marine angeboten wurden, begann die Überfahrt über den Atlantik am 16. September.

Nachdem das Schiff die stürmische Nordsee verlassen hatte, wurde die Fahrt durch gutes Wetter begünstigt. Vor dem Erreichen der Passatregionen war die Windrichtung relativ zum Schiff jedoch für die zahlreichen Spurenstoffmessungen in der atmosphärischen Grenzschicht nicht immer günstig.

Am 22. September ankerten wir in der Nähe des Hafens von Ponta Delgada auf den Azoren, um 4 Techniker, die an den Winden, dem Doppler Sonar Log und dem integrierten Navigationssystem gearbeitet hatten, an Land zu lassen. Ein vorheriger harter Test von 3 neuen Winden war sehr erfolgreich verlaufen.

1.1.2 SUMMARY AND ITINERARY

G. Krause and U. Platt

On this year's transit to Antarctica "Polarstern" presented itself as a large laboratory for the investigation of trace gases in the maritime atmosphere. 13 out of 18 projects were centered around the complicated chemical reactions taking place over the sea surface. Thus the distribution of hydrocarbons as well as reactive nitrogen and sulfur compounds were measured together with the concentrations of photochemically generated oxidants like ozone, hydrogen peroxide, and iodine oxide radicals. The driving force of atmospheric photochemistry, solar UV-radiation was also recorded. Additionally, one group measured all the components which determine the total net radiation.

The comprehensive data set of trace gas concentrations will not only enhance our knowledge about the distribution of man-made and natural species in the remote atmosphere, but will also be used to test our models of the chemical interactions in the undisturbed atmosphere.

Finally, using the hydrographic well of the ship, various optical parameters of sea-water were measured in relation to the water masses, and phytoplankton was determined in water samples too.

In view of the relative short duration of the cruise and the large amount of work required to install and to maintain the rather complicated experimental equipment for the detection of trace gases in a range of concentrations between 10^{-9} and 10^{-12}, the main aim was to collect data. Quantitative results cannot yet be reported. However, it can be said, that in the trade wind regions the concentration of man-made substances was extremely low, in some cases beyond the resolution of the methods. Therefore we expect that the data sets gathered will provide a good insight into natural processes which trace gases undergo over the ocean.

Additionally, the cruise offered itself to perform various intercalibration exercises, because several groups measured the same compounds with various methods. Again, this can only be done after extensive data processing in the home laboratories.

"Polarstern" left Bremerhaven in the early morning of September 15, 1988. After a brief stopover in the port of Wilhelmshaven with an "open ship" for the public and guided tours for members of scientific institutions and the navy, the transit across the Atlantic began on the 16th September.

After leaving the stormy North Sea the cruise was favoured by fine weather. Nevertheless, before reaching the trade winds, the wind direction relative to the ship was not always in favour of the numerous experiments to measure trace gases in the marine atmospheric boundary layer.

On the 22nd of September we anchored close to the harbour of Ponta Delgada on the Azores to disembark 4 technicians who had worked at the winches, the Doppler Sonar Log and the integrated navigation system. A previous severe test of 3 new winches was very successful.

From the Azores we proceeded to 30°N,30°W and headed due south to 30°S, 30°W. On the 9th of October we arrived in the port of Rio Grande.

1.2 REPORTS OF THE WORKING GROUPS

1.2.0 WEATHER CONDITIONS DURING THE EXPEDITION

H.D. Behr, H. Köhler, R. Schmidt, D. Winterkemper

After leaving the harbour of Wilhelmshaven on 16.09.1988, a depression which developed in the polar frontal zone at the northeasterly flank of an anticyclone over Western Europe crossed the track of RV "Polarstern". During the southwest bound cruise through the Channel to the Azores RV "Polarstern" reached the high with light to moderate northeasterly winds and remained in it until the passage of the ITCZ on 29.09.1988.

The tropical storm HELENA passed far south of the track of RV "Polarstern" on the 22.09.1988 and went to the Carribean Islands. At no time RV "Polarstern" was influenced by this depression.

South of the equator RV "Polarstern" was again under high pressure influence with moderate northeasterly winds.

At 05.10.1988 a change of the weather situation took place: A low coming from Uruguay crossed the track of RV "Polarstern" and concluded the end of the tropical weather conditions. In fresh northwesterly winds RV "Polarstern" reached Rio Grande do Sul.

At each full degree of latitude during the cruise a radiosonde was started. Figs. 2 and 3 show the vertical distribution of air temperature and wind velocity from 30°N to 30°S. The following characteristics could be taken from the pictures:

1) the tropopause has a minimum temperature of -79°C at the 17 km height near the equator,
2) the subtropical jetstreams at 23°N and 18°S are at 13 km and amount to 24 m/s. The Berson Winds (easterly winds) at 12°N reach 26 m/s at 23 km height.

Table 1: Statistics of weather elements during ANT VII/1
According to the observations of the German Weather Service.
Total number of cases: 105

Wind

Force	0	1	2	3	4	5	6	7	
% of cases	-	1	6	14	32	37	10	0	
direction	calm	N	NE	E	SE	S	SW	W	NW
% of cases	0	16	35	34	5	4	2	1	3

Sea and Swell

Height	0 m	1 m	2 m	3 m	4 m
% of cases	17	32	50	1	-

Cloud Cover

Okta	0	1	2	3	4	5	6	7	8
% of cases	2	9	15	11	9	9	11	19	15

Appendix:

Weather situation at: 16.09., 21.09., 26.09., and 04.10.1988

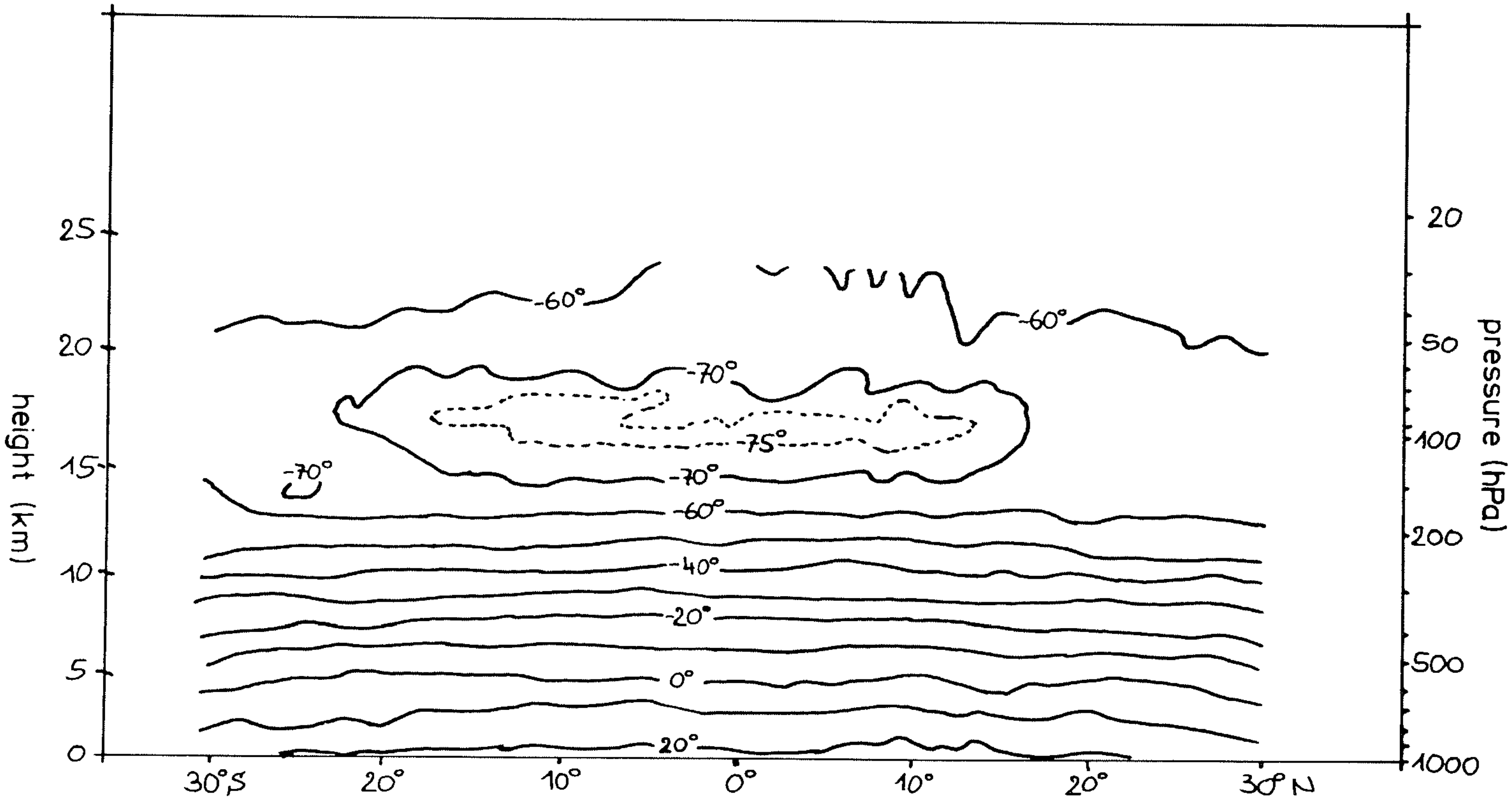


Fig.2 Vertical cross section of temperature (in °C) along 30°W, obtained during ANT VII/1

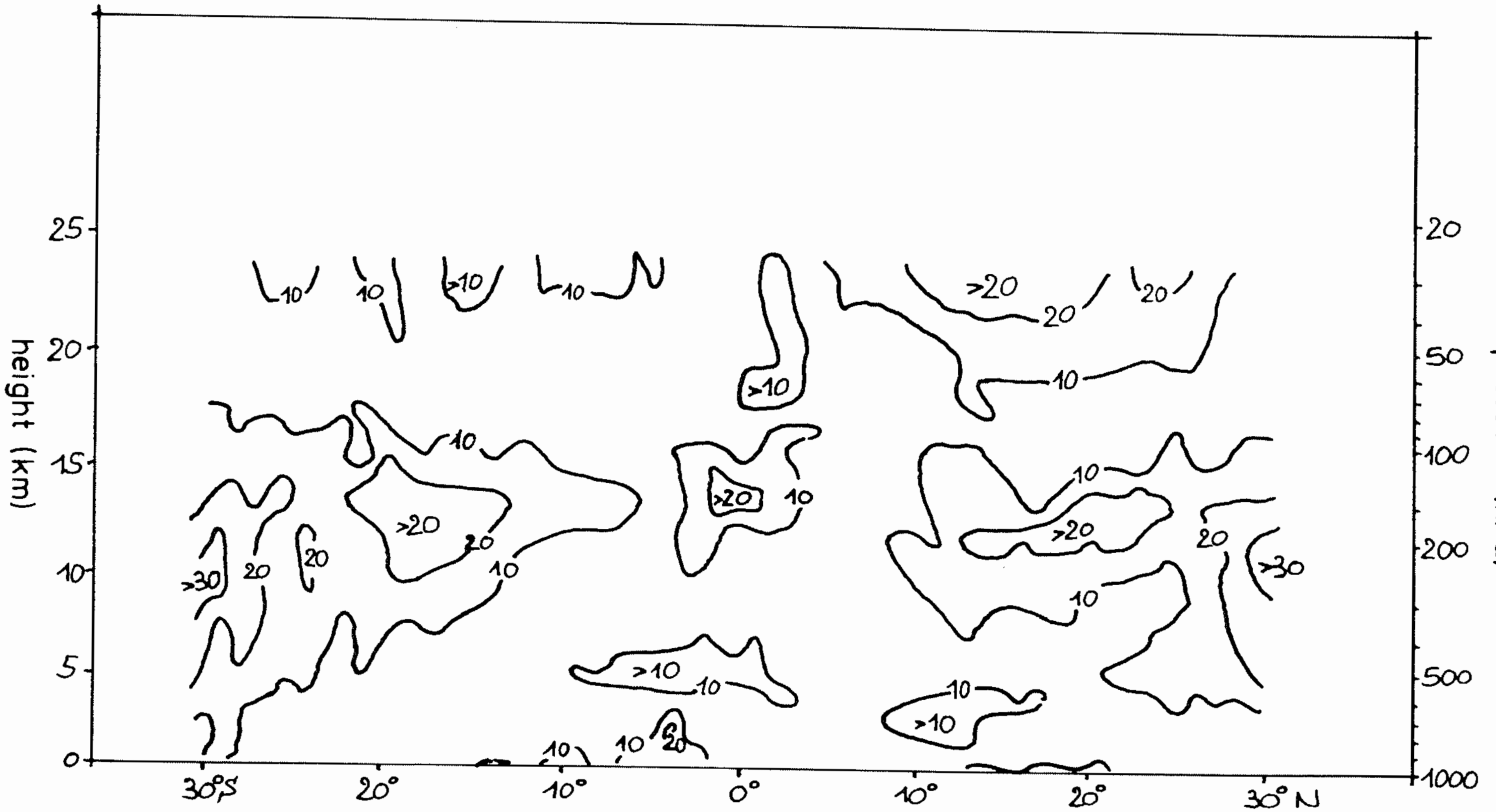


Fig. 3 Vertical cross section of wind velocity (in m/s) along 30°W, obtained during ANT VII/1

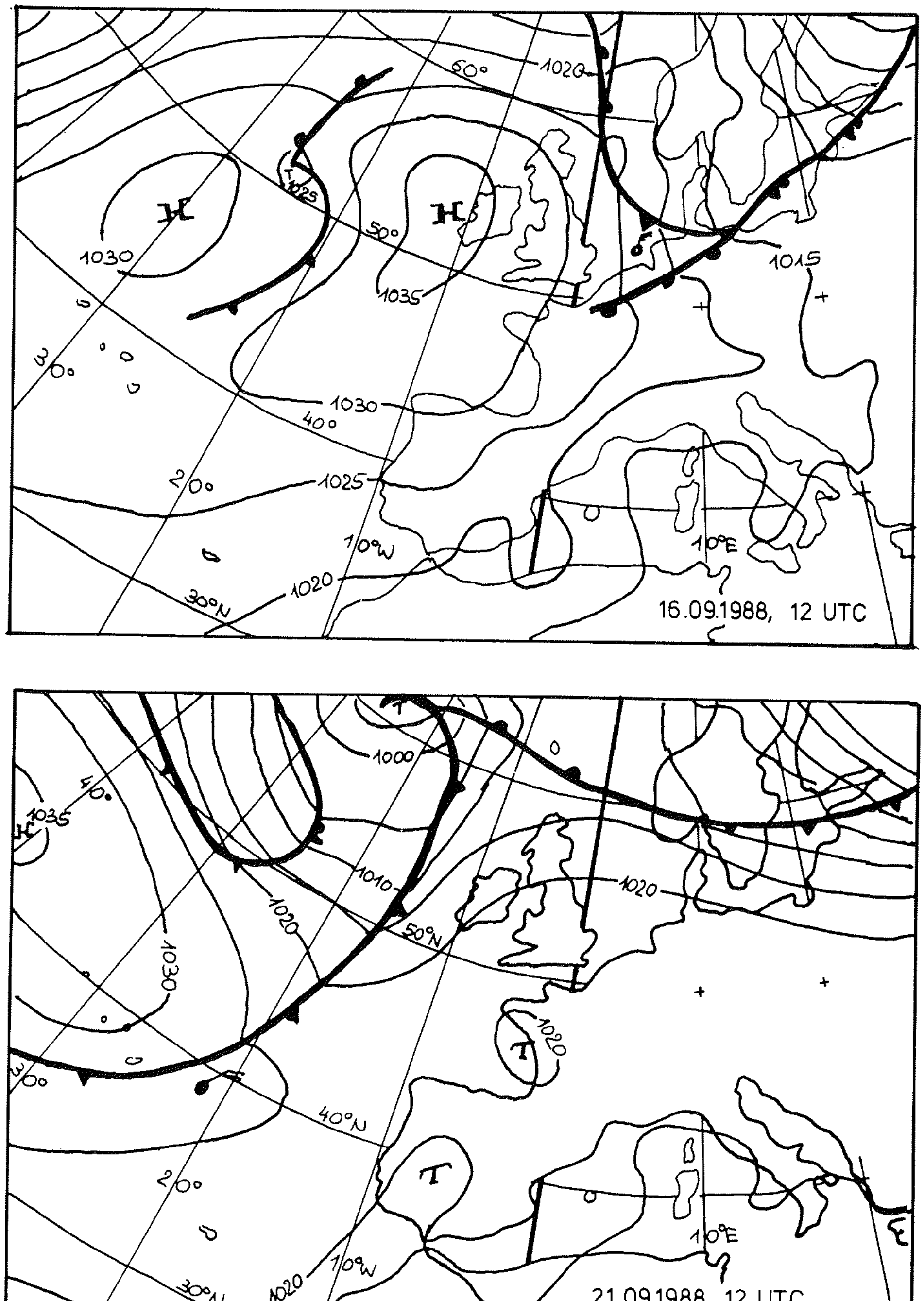
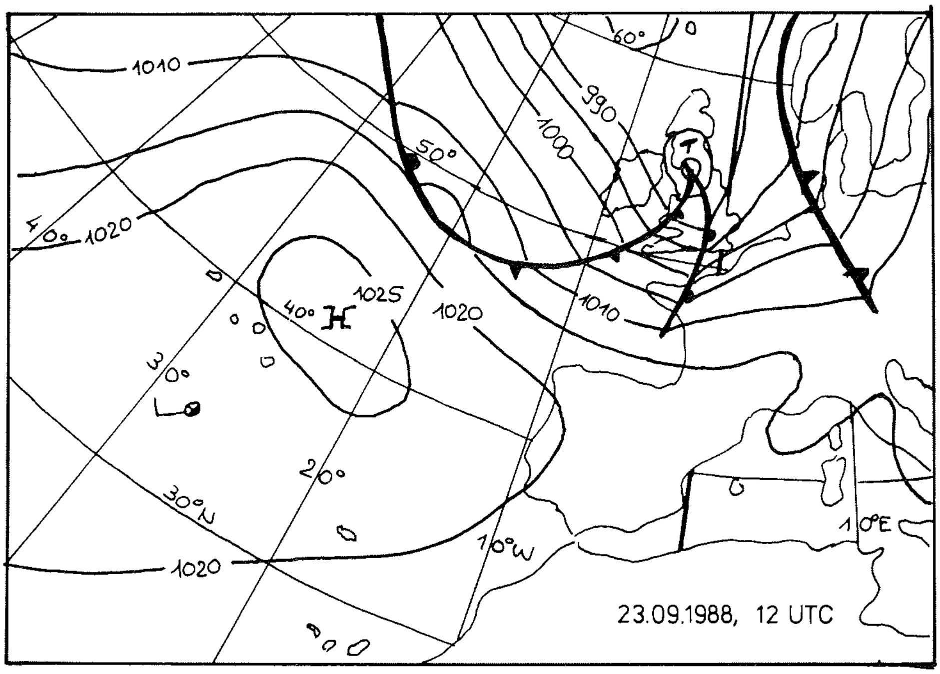


Fig. 4: Sequence of weather charts for the period 16.9.1988 to 4.10.1988 covering the transit voyage of "Polarstern" from Bremerhaven to Rio Grande



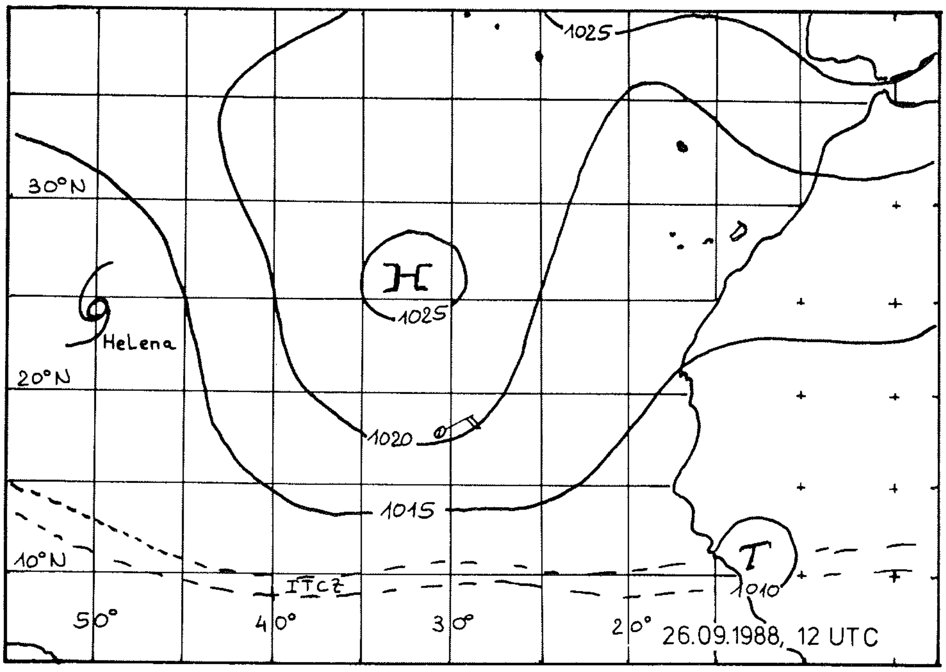


Fig. 5 : Sequence of weather charts for the period 16.9.1988 to 4.10.1988 covering the transit voyage of "Polarstern" from Bremerhaven to Rio Grande

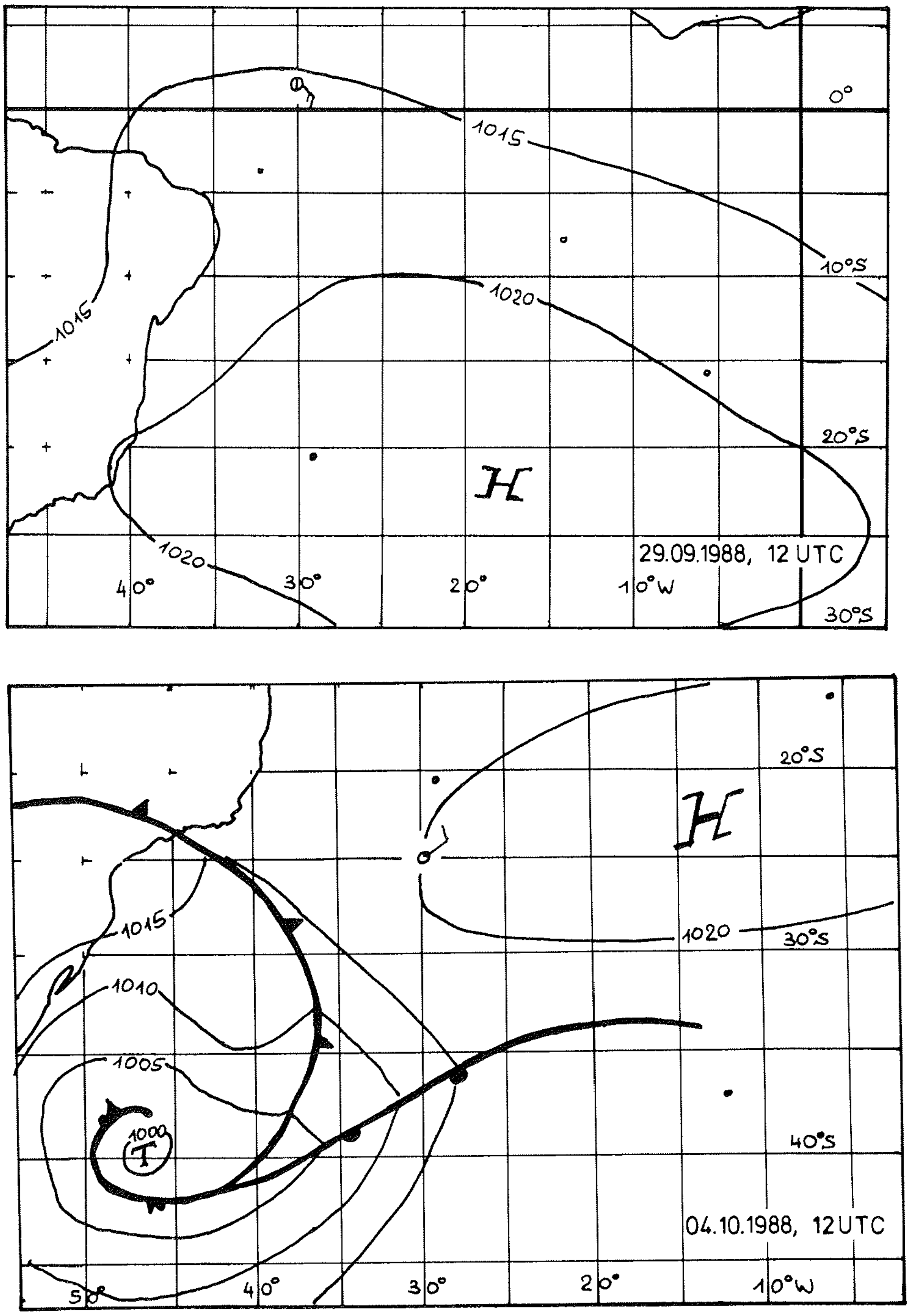


Fig. 6 : Sequence of weather charts for the period 16.9.1988 to 4.10.1988 covering the transit voyage of "Polarstern" from Bremerhaven to Rio Grande

1.2.1. OPTICAL PROPERTIES OF SEA-WATER

G. Krause, W. Baranski, W. Schneider

The aim of our participation in the large transit voyage across the Atlantic Ocean was the determination of some optical properties of sea water in relation to the water masses, particularly in the frontal zones. The data sets of temperature, salinity, chlorophyll, Mie-backscattering and Gelbstoff will be

- to study the effect of accumulation of particles in frontal zones
- to contribute to in-situ verifications of satellite remote sensing
- to make available a data base for the design of a depth profiling Lidar-system.

The respective sensors were operated from the ship under way, mounted in a depth of 11 m in the hydrographic well. In order to resolve frontal structures, a rather high sampling rate (1 second) was chosen. The data were recorded on a streamer tape together with the necessary navigational da'a of the ship. Some of the raw data were processed on the ship´s computer after writing the necessary programs during the cruise.

The optical sensors, well proven in the cold northern and southern water masses rich of plankton and particles, had to be operated at their limits of resolution in the desert regions of the Atlantic. Plankton investigations of water samples by H. Kuosa confirmed extremely low values of phytoplankton concentration. Only at the margins of the equatorial countercurrent slightly increased chlorophyll values were found.

The temperature and salinity records show many frontal regions, but it is too early to speculate on further results.

1.2.2 ATLANTIC MICROBES: ABUNDANCES AND BACTERIAL GRAZING IN SURFACE WATERS

H. Kuosa

During the expedition ANT VII/1 microbes (in Haeckelian sense - microscopical organisms) were enumerated. These data will give an indication of the importance of bacteria, protozoa and bacterial sized phytoplankton in the pelagic carbon cycle. Experiments were made to evaluate the amount of bacterial grazing i.e. how many bacteria are eaten in Atlantic surface waters. Also semiquantitative counts of larger phytoplankton were made to give background data to the other measurements made during the expedition.

Samples were taken daily from the water tunnel of the ship (6 m depth). Sampling covered a transect from 50°N to 30°S. All microbe groups were enumerated with an epifluorescence microscope, which gives an opportunity to differentiate phytoplankton from protozoa. Also bacteria can be counted with the epifluorescence microscopy. Bacterial grazing was studied by incubating natural and 1-µm filtered samples for 24 h in in situ temperature.

As a 1-µm filter separates effectively bacteria and their grazers the difference in bacterial growth rates is evidently due to the grazing pressure.

All material was analyzed during the cruise. No difficulties were met. Even the microscopy with a 100 x oil immersion objective was successful, which is rarely possible in other ships.

Four separate water masses could be identified. The first (north of 46°N) was a cold water mass with a high number of bacteria and small phytoplankton. The whole water mass between 46°N and 20°N was characterized by low bacterial and phytoplankton numbers. The water mass between 20°N and 6°S had high bacterial and small-sized phytoplankton concentrations and an elevated number of protozoa. The southernmost water mass was nearly identical to the northern water mass poor of microbes. Also the counts of larger phytoplankton revealed clear differences between the water masses.

Bacterial grazing experiments showed vivid grazing activity in Atlantic surface waters. About 50 % of water is cleared from bacteria every day. This means a bacterial generation time of two days. However, as the bacterial concentrations are low and the bacteria are small the absolute bacterial production is not necessarily high. As a mean value one protozoon clears 1.7 x 10-5 ml of water per an hour, which corresponds to 14 captured bacteria in an hour.

1.2.3 TRACE GAS MEASUREMENTS IN THE BOUNDARY LAYER USING TUNABLE DIODE LASER

G.W. Harris, D. Klemp, T. Zenker

Scientific aims

Our aims were to use our multi-laser tunable diode laser absorption spectrometer (TDLAS) to measure the latitudinal distribution of the mixing ratios of several trace gases of interest for interpreting the chemistry of the remote troposphere. We proposed to measure the following species: NO_2, HCHO, CO, H_2O_2 and HCl. The first four of these species were previously measured by our equipment on board F.S. "Meteor" in the north tropical and equatorial regions of the Atlantic from Nov. 1987 to Jan. 1988, and are species that are intimately involved in the chemical cycles resulting in the production and loss of oxidants in the troposphere. Our aim was to confirm and extend our database on these molecules. Our interest in measuring HCl, using the highly specific TDLAS method, stems from a recent suggestion that chlorine chemistry in the marine boundary layer, initiated by the liberation of Cl atoms HCl after attack by OH, could be responsible for the removal of a large fraction of the non methane hydrocarbons present in the marine atmosphere. Model calculations indicate that an HCl mixing ratio of ca. 1 ppbv would be sufficient to promote this pathway. There have been only a few (indirect) measurements of "total inorganic chlorine", presumed to be HCl, previously reported, which on balance indicate that 1 ppbv may indeed be present in the maritime boundary layer.

Methods

The method depends on monitoring changes in optical density of the order of 10^{-5} due to the absorption of specific infra red frequencies by trace molecules in air. The air sample is rapidly pumped at reduced pressure through a multiple reflection cell which provides absorption pathlengths of more than 200 meters. (Lowered pressure narrows the absorption lines leading to increased specificity and sensitivity). The light sources are Pb salt diode lasers, whose output frequencies are tunable over narrow ranges by variations in temperature or current.

Different lasers are used for each of the target molecules, but all are run simultaneously in our apparatus. Each laser is scanned rapidly and repetitively across a resolved vibration - rotation line and the signals independently accumulated for approximately five minutes - the time resolution of our measurements.

The system operates automatically under computer control and is capable of round the clock data acquisition. The instrument sensitivity is periodically calibrated by the control system. This is achieved by the automatic addition of known quantities of the target gases at the ambient air inlet, which was located ca. 2 meters above the roof of our laboratory container on the starboard side of the Peildeck. We note that whenever the relative wind direction was at 90 degrees, a condition which prevailed for much of the time in the northern hemisphere, we detected large quantities of NO_2 originating from the ship, most probably from the ventilator outlets located below the bridge on the port side. Under these conditions it was possible to smell Diesel fumes, especially on the port side of the Peildeck, even when the wind velocity was high.

We urge that consideration be given as to how best to prevent the release of contaminated air forward of the Observation Room aboard "Polarstern", since this severely perturbs air composition measurements.

Aboard "Meteor" we experienced occasional degradation of the inlet lines because of sea salt aerosol and Sahara dust, and so we employed an improved system during this campaign. The system is basically a virtual impactor mounted on a weather vane, making use of the relative wind velocity to limit the exposure of the interior surfaces to aerosols.The surface characteristics of the whole system can be investigated by activating a pneumatically operated mechanism which allows the replacement of ambient air by zero gas or by calibration mixtures while making no changes to the amount or nature of the surface exposed to the sample. The new system operated very well during this cruise.

By far the major problem we encountered was associated with telex transmissions over short wave radio, unfortunately made necessary because Polarstern`s satellite communications system was frequently not functional.

We were aware, after our "Meteor" cruise, that the control circuitry of our lasers is sensitive to high power high frequency fields and therefore requested during the present cruise that we be informed before transmissions were sent so that we could shut down the sensitive parts of our equipment. It took several days before this procedure was consistently implemented, however in retrospect it probably would have made no difference anyway.

As a result of radio transmissions three of our lasers were irreparably damaged, the third even after ample warning had been given, the equipment completely shut down and the control systems isolated from the electricity supply. The damage took place during a two to three day period when increasing distance from Europe and the non operational satellite system necessitated full power short wave transmissions, but was limited to those lasers housed in commercial Laser Source Assemblies. Two lasers housed in cryostats that we ourselves have designed and built were unaffected. It seems that the difference lies in the fact that the electrical ground for the laser current in our housings is carefully separated from the general ground to reduce common noise pickup. This is not the case in the commercial housings and we believe that the lasers were destroyed by transient reverse polarity voltages induced in the ground lines by the telex transmissions. It is not clear why this phenomenon has been so pronounced on "Polarstern" in comparison to "Meteor", but it could be that we are less well shielded in our container than we were in an interior laboratory on "Meteor".

Preliminary results

Although our original aims have been severely compromised by the events described above, we have carried out several measurements of considerable interest.

Since, by virtue of the very high spectral resolution employed, TDLAS is an extremely specific technique, it may be viewed as a reference method against which other, possibly less specific, methods can be judged. During the cruise overlapping ambient measurements of several species have been carried out using TDLAS and other methods. Although the TDLAS data sets are limited in coverage because of the loss of lasers, they will serve to provide confirmation (or otherwise!) of the specificity of the other methods.

In order to remove uncertainties in the interpretation of the joint data sets, we have cross calibrated our reference sources with those of the other investigators. Thus overlapping TDLAS and second method data exists for hydrogen peroxide, for carbon monoxide, for formaldehyde and for nitrogen dioxide. The first three intercomparison sets are rather brief, but were obtained under relatively clean northern hemisphere conditions, and so should be reasonably representative, in the sense of identifiying possible problems, of the whole. The set for NO_2 is quite extensive and includes, for example, virtually the entire time from the ITCZ to 30°S, during which period the NO_2 was very low, rarely much above our detection limit for five minute signal averaging of 10-20 pptv. Reanalysis employing more extended averaging will be carried out later.

Although our studies of HCl were also curtailed by the loss of the laser, we believe that we have succeeded in answering the question we had put, namely: is there enough HCl in the marine boundary layer to allow chlorine chemistry to play a significant role in the oxidation of non methane hydrocarbons? Our measurements provide an upper limit on the HCl mixing ratio of 0.3 ppbv, well below the level at which model calculations suggest that Cl initiated oxidation should be important.

The stating of the result as an upper limit comes in this case not from signal to noise considerations, but because of memory effects following the addition of calibration gas at the inlet system. HCl interacts very strongly with the surfaces of the inlet system, and although the signal had apparently stabilized at 0.3 ppbv several hours after the removal of the calibration spike, and this may well represent the actual HCl content of marine air, we cannot rule out that the signal would have decreased even further had we been able to measure longer. But then came the telex.

1.2.4 MEASUREMENT OF GASEOUS NITRIC ACID IN AIR

Th. Papenbrock

Our aim during the journey to Brazil was to measure the concentration of gaseous nitric as a function of day-time and acid geographical latitude.

For the measurements we used the Laser Photolysis Fragment Fluorescence (LPFF)-Method. The laser light with the wavelength of 193 nm photolyses the HNO_3-molecules and the fluorescence of the resulting OH-fragments is measured by an interference filter- photomultiplier combination.

Our system was able to measure continuously most of the time with a time resolution of 60 minutes. Because of the dominating easterly winds the air inlet was located at the port side of the ship to prevent contamination of the clean air by the ship itself. The data set of our measurements covers the track of the ship from the position 30°N, 30°W going down to the position 30°S, 30°W.

Most of the time, the mixing ratio of HNO_3 has been in the range of 30 ppt to 50 ppt during day-time. In the night often the mixing ratio was below the detection limit of 25 ppt.

At times, when the HNO_3-concentration was above those levels, it could be attributed to the wind, bringing polluted air from the ship's exhausts or from other ships passing by.

1.2.5 OXIDATION MECHANISMS AND INORGANIC TRACE ELEMENTS

P. Carlier, R. Losno, S. Pashalidis

The experiment proposed by our laboratory contributes to the study of two major problems of Tropospheric Physical Chemistry:

I. The oxidation mechanisms of organic trace compounds in remote oceanic areas.
II. The atmospheric transport of inorganics to the open Ocean.

Before examining carefully all the experimental operations, we shall note this point: In spite of all precautions and seeking of the best sampling place, a few samples were clearly disturbed by contamination from the ship (mainly the smoke and the front storage area). We must check the validity of the other samples by local wind analysis and investigation of characteristic compounds from these perturbations before our final interpretations.

I. Organic trace compounds analysis (sulphur and carbonyl compounds):

All the gas samplings were performed on the wave guard platform on the bow section of Polarstern.

1) Organic sulphur compounds:

In contrast to our previous field experiments in Britanny, the measured DMS concentrations are generally very low, of the order of the detection limit (10 ng of sulphur per cubic meter) or sometimes less. That is not very surprising since we have mainly travelled through biologically poor areas. Only a few samples show higher concentrations (maximum 120 ng m^{-3}).

We note poor agreement between our measurements and those made by the Frankfurt group which found sytematically higher values. We must now proceed to carry out further laboratory experiments to explain this disagreements.

2) Carbonyl compounds:

Once away from the influence of polluted European air masses, the aldehyde concentration in the gas phase became very low: 0.5 to 1 ppbv of formaldehyde and 0.2 to 0.3 of acetaldehyde in the north hemisphere, 0.2 to 0.3 ppbv of formaldehyde and traces of acetaldehyde (0.2 ppbv) in the south hemisphere, without significant day-night variations. This is consistent with the expected background level.

Most original are the results concerning the measurement of free and SO_2 - complexed aldehydes in rain water. Unfortunately only one rain event could be sequentially sampled.

II. Aerosol and rain sampling for inorganic trace elements analysis:

All these samples must be further analysed in our laboratory. Only pH and ionic conductivity of rain water were measured on the ship.

1) Aerosols:

The sampling was performed on the wave guard platform in clean conditions.

a. An electronic appartus was checking the direction and the velocity of the wind to prevent smoke contamination.
b. The filters are manipulated only under a laminar ultra clean air flow.

2) Rains:

We have collected twelve events, however only eight with proper conditions. It appears that we had on the 28/09 a rain which included Saharan material.

Conclusion

The results that we have already obtained are very interesting. On the other hand, the most important point is the experience obtained for resolving the problems encountered in collecting representative samples in a contaminating area, because atmospheric field experiments in oceanic remote areas should certainly grow in the future, in order to increase understanding of atmospheric physical chemistry.

1.2.6 MEASUREMENT OF FREE RADICALS BY UV - VISIBLE ABSORPTION SPECTROSCOPY

U. Platt, T. Brauers, J. Callies

Most man-made and natural trace gases are removed from the atmosphere by reaction with free radical species. Thus, research on sources, abundance, and sinks of those radicals is an important issue in atmospheric chemistry. In the marine environment hydroxyl radicals (OH), iodine oxide radicals (IO), and nitrate radicals (NO_3) are of importance. The former two radicals are a product of photochemical reactions, NO_3 radicals are formed by dark reactions between nitrogen dioxide and ozone. While a limited data base exists on the distribution of OH radicals, virtually nothing is known about the abundance of IO and NO_3. A particular problem of free radical research in the atmosphere lies in the fact that those species are only present in minute quantities, rarely exceeding a few molecules per 10^{12} air molecules.

Iodine oxide and nitrate radicals were measured by observing their characteristic absorption structure in the visible and near UV spectral ranges. A long absorption path in the open air was reached by reflecting a light beam originating from a high-pressure Xe arc about 100 times between two sets of mirrors mounted at a distance of 20 m on the compass deck of the "Polarstern". Thus a total length of the absorption path of about 2 km could be reached, resulting in detection limits of the order of one ppt (mixing ratio of 10^{-12}) for IO and NO_3.

During the cruise it was found that the operating conditions on board a ship (vibration, air turbulence, sea spray) had surprisingly little effect on the performance of the optical system. Preliminary evaluation of the data shows very low levels of both radicals, which - at least for the case of nitrate radicals - are below our expectations.

1.2.7. MEASUREMENT OF THE CONCENTRATION OF ATMOSPHERIC ^{14}CO

C. Pfleiderer

The aim of this project was to collect samples of atmospheric CO. The samples should serve for the determination of the carbon isotope ratio and further modelling of the chemistry of ^{14}CO in the atmosphere.

After installation of sampling apparatus and analytics only a few CO samples could be collected during the last part of the cruise. This was due to unexpected and not yet resolved problems concerning the extraction of the sampled CO_2 out of the absorber material.

Nevertheless these few samples may yield first isotope measurements on CO in the southern hemisphere.

1.2.8 MEASUREMENT OF NO, NO_2 AND NO_Y

F. Rohrer, D. Brüning

We have measured the mixing ratios of the nitrogen oxides NO, NO_2 and NO_y (sum of odd nitrogen compounds, not including HNO_3) with a sensitive NO-chemiluminescence detector system. NO_2 and NO_y have been converted to NO by means of a photolytic converter and by a heated gold tube. We are interested in measuring those compounds with a great distance to all continental sources to get their natural background concentrations. Our system was able to measure automatically most of the time with a time resolution of 2 minutes. The air inlet was located at the port side of the ship to prevent contamination of the clean air by the ship itself, because of the dominating easterly wind. The only difficulties have been the raising temperature in our room due to failure of the air condition at the beginning of the expedition and the daily radio transmissions.

So our data set covers more or less continuously the track of the ship starting at Wilhelmshaven going down to the position 30°S, 30°W.

Most of the time, the mixing ratios have been in the range of 10ppt for NO, 20-40ppt for NO_2 and 60-100 ppt for NO_y. At the times, when the concentrations were above those levels, they could be contributed to the wind, bringing polluted air from the ship`s exhausts or other ships passing by. It is not yet clear, if contamination by the ship can be ruled out even at the best possible wind direction, because there have been occasions, at which the NO mixing ratio was not going to zero at night time.

1.2.9 MEASUREMENT OF HYDROGEN PEROXIDE IN THE ATMOSPHERIC GAS PHASE, IN RAIN- AND SEA-WATER

P. Jacob

Scientific aims

Comparisons of H_2O_2 mixing ratios measured in Dortmund, FRG (52°N) and Salvador, Brazil (13°S) in 1988 showed about 10-fold higher values at the site in Brazil.

On the route from 30°N to 30°S along the 30°W meridian measurements should indicate a relation between UV-radiation at different latitudes and H_2O_2 mixing ratios, uninfluenced by other factors which can limit H_2O_2 generation or cause its destruction.

Simultaneous determination of the H_2O_2 concentration in the gas phase on the one hand and in rain- and seawater on the other can possibly give some data about gas-liquid equilibria.

Another aim of this project was to investigate the applicability of the cryogenic method for sampling gas phase formic and acetic acid under background conditions.

Methods

Gas phase hydrogen peroxide samples were collected by a cryogenic method about 3 m above the compass deck on the starboard side of the "Polarstern". The sampling frequency was 1 per hour, except between 1 am and 8 am. Determination of H_2O_2 in the melted sample followed immediately using peroxyoxalate chemi-luminescence.

H_2O_2 content in rain- and surface ocean water was determined by the same method after dilution.

Ion chromatographic analysis of the carboxylic acids was carried out by S. Bürgermeister.

Preliminary results

The hydrogen peroxide gas phase mixing ratio showed a decrease of ca. 45 pptv per degree latitude in both hemispheres, with a maximum of 2.6 ppbv between 0° and 10°S. Hourly maxima reached 3.3 ppbv. The diurnal variation was on average 0.4 ppbv with maxima between the late afternoon and midnight.

The H_2O_2 concentrations in rainwater varied between 100 ppbm and 4 ppmm and were sometimes far from equilibrium with the measured gas phase concentrations.

The H_2O_2 concentration in seawater was generally very low, around 3 ppbm without any significant correlation with the H_2O_2 gas phase mixing ratio.

A few measurements of gas phase formic and acetic acid indicated a wide variation both in their mixing ratios (up to a few hundred of pptv), and in their relation to each other.

1.2.10 MEASUREMENT OF THE LATITUDE/ALTITUDE DISTRIBUTION OF TROPOSPHERIC OZONE BETWEEN 52°N AND 30°S

H. Smit , St. Gilge

Due to atmospheric chemical (precursor for OH-radicals, decomposition of trace gases), climatological and toxical reasons, Ozone is one of the most important trace gases. In order to understand the chemical and transport processes which control the Ozone balance it is important to know the meridional distribution of troposheric Ozone over the Atlantic Ocean.

For this purpose there was performed an Ozone-sounding programm for measuring the Ozone-concentration in different altitudes and latitudes.

The Ozonesonde is a balloon-born instrument with an electrochemical Ozone sensor and a weather radiosonde for the additional measurement of meteorological parameters (pressure, temperature and relative humidity). During the ascent and descent the data are transferred to the groundstation aboard the RV "Polarstern" by telemetry and fed into a personal computer for further data processing.

Between 52°N and 30°S the Ozonesondes were flown twice a day (latitudinal resolution about 2-3 degrees) and measured the Ozone concentration up to 30 km altitude with a resolution of about 100-150 m.

The experiment will enable a two dimensional Ozone distribution map (latitude versus altitude) to be drawn between 52°N and 30°S for this time of the year (Sept./Oct. 1988)

Finally we will compare this meridional Ozone distribution map with earlier results between 45°N and 40°S, which we obtained on the ANT V/5 expedition in March/April 1987 in order to investigate possible seasonal effects.

1.2.11 MEASUREMENT OF THE LIGHT HYDROCARBONS IN THE SURFACE WATER OF THE ATLANTIC OCEAN

C. Plaß

In recent years unexpected high values of light hydrocarbons, especially alkenes, were found in remote ocean air and seawater. In order to estimate the importance of the ocean as a source for hydrocarbons we measured simultaneously their concentrations in air and seawater. For this purpose the same gaschromatographic analysis technique was used.

The seawater samples were taken from 11 m below the water surface and pumped through the stainless steel manifold to an outgassing device. Every three hours the dissolved hydrocarbons were stripped from 870 ml seawater with helium, cryogenic preconcentrated and analysed with a detection limit of 0,05nl gaseous hydrocarbon per l seawater. A profile was obtained from 30°N to 30°S. Some first features obtained by now were the decreasing abundance of compounds with higher carbon number and the dominance of the alkenes in each sample.

Ethene always exhibited the highest concentration, the values decreased from approx. 10nl/l around 30°N to 1nl/l at 30 degrees south. Compared to the concentrations in air, light hydrocarbons were supersaturated in seawater by about three orders of magnitude.

1.2.12 MEASUREMENTS OF THE LATITUDINAL DEPENDENCE AND THE DIURNAL CYCLES OF ATMOSPHERIC HYDROCABON

R. Koppmann

Non-methane hydrocarbons play an important role in the chemistry of the marine atmosphere. Especially the light alkenes contribute significantly to the photochemical reactions in the troposhere, and they are the precursors of a number of reaction products such as aldehydes, ketones and, in the presence of nitrogen oxide, also peroxyacetylnitrate (PAN).

During the cruise ANT VII/1 measurements of the latitudinal dependence of light hydrocarbons were carried out by in-situ gas chromatography after the preconcentration of the trace gases from about 3 -5 liter of air. The detection limits were in the range of 5-10 pptV.

Additionally whole air samples were collected in stainless steel containers (volume 2 dm^3) two times per day. These samples will be analysed in the laboratory later on.

As a first result from the in-situ measurements it was found that the mixing ratios of NMHC`s in the northern hemisphere are significantly higher than in the southern hemisphere. The mixing ratios in the northern hemisphere proved to be a factor of 2 lower than the corresponding mixing ratios measured during the cruise ANT V/ 5 in March/April 1987.

The mixing ratios of the light alkenes, ethene and propene, were found to be <30 pptv, sometimes even lower than our detection limit.

The data have to be analysed in detail in connection with the corresponding meteorological data and the results of the measurements of other trace gases which are important for the oxidation of NMHC's.

A comparison with the measurements of the cruise ANT V/5 will probaly give information on possible seasonal effects on the production and transport of NMHC`s in the marine atmosphere.

1.2.13 MEASUREMENTS OF PEROXYACETYLNITRATE AND NITRIC ACID IN THE MARINE ATMOSPHERE

K. P. Müller, G. Nohr, K. Wohlfart

Peroxyacetylnitrate (PAN) is a toxic product of photochemistry in polluted air masses. It also may act as an important reservoir for nitrogen oxides outside polluted areas, because there exist no primary sources for PAN. It only is formed during photochemical oxidation of non methane hydrocarbons in the atmosphere in the presence of NO_2.

On board of "Polarstern" during the cruise ANT VII/1 from Bremerhaven to Rio Grande do Sul the most important chemical precursors of PAN have been measured. Therefore it was possible to have the complete latitudinal variation combined with the possible air chemistry.

The equipment we used was an automated gaschromatographic system that reached under heavy conditions (up to 48°C room temperature!) a lower detection limit of about 0.5 ppt PAN. Determined by the time resolution of 90 minutes for one sample and several calibration points we were able to get about 300 PAN-measurements.

First results show, that the mixing ratio over the northern Atlantic is lower by a factor of 2 to 10 than in continental air.

South of the Azores-Islands the mixing ratio dropped below detection limits. That was in parallel to the NO_x and NO_y-measurements.

Nitric acid as a final product of the oxidation of nitrogen oxides has been sampled by absorption on filter surfaces. Due to the low concentrations of HNO_3 in the marine atmosphere, the integration time was 6 to 12 hours. The results of the although collected 60 samples will be available after analysis in our laboratory.

1.2.14 MEASUREMENTS OF BIOGENIC SULFUR COMPOUNDS AND THEIR REACTION PRODUCTS IN THE MARINE ATMOSPHERE

S. Bürgermeister, R. Staubes

On the cruise of "Polarstern" from Bremerhaven to Rio Grande (14.9. - 9.10.1988) the concentration of the gaseous sulfur compounds dimethylsulfide (DMS), carbonylsulfide (COS), and carbon disulfide (CS_2) was examined in the surface water of the ocean and in the atmosphere. These measurements should give information about maritime sources of atmospheric sulfur compounds. Oxidation products of DMS in the atmosphere are sulfur dioxide (SO_2) and methanesulfonic acid, which are converted to sulfate and methanesulfonate particles.

The concentrations of DMS, COS and CS_2 were analysed by gaschromatography and sulfur specific flamephotometric detection. 10 liters of ambient air were sampled by means of cryogenic enrichment in liquid argon. Sulfur dioxide was enriched on TCM-impregnated filters (150 liter air) and measured by a chemiluminescence technique. Aerosol was sampled on filters (air volume: 30 m^3) and analysed for methanesulfonate by ionchromatography. The pH-value and methansulfonate concentration of rainwater was determined on board. Analysis of ion concentration (esp. sulfate) in the aerosol and rainwater will be carried out in Frankfurt.

The air samples were collected at the front of the compass deck. To minimize the influence of the ship two outriggers were fixed at the rail with the location of intake being displaced about 2 meters ahead of the compass deck. Nearby a rainsampler was placed. The instruments used for sampling were located in the container AWI 11 on the compass deck. The ocean-water was taken from the ship's pumping system.

To determine possible daily variations, the measurements of the gaseous sulfur compounds were carried out in an interval of 6 hours (1:00, 7:00, 13:00, 19:00). The aerosol samples were enriched for a period of 12 hours (7:00 - 19:00 - 7:00). During this cruise rain occurred only from 21. to 23. of September and in the ITCZ (28.9.) so that only 8 samples of rainwater could be collected.

As a first result the sulfur dioxide concentrations only in the first days reached values of several µg SO_2/m^3. South of 45°N concentrations below 500 µg SO_2/m^3 prevailed. The methanesulfonate (MSA) - aerosol concentration had its maximum over the North Sea and the Channel, over the Atlantic the variation was low (15 - 30 ng MSA/m^3). The MSA-concentration was more variable in rainwater. The pH-value of the rainwater varied between 4.6 and 5.7 with the highest values being observed in the ITCZ.

1.2.15 MEASUREMENTS OF FORMALDEHYDE AND ACETALDEHYDE IN MARINE AIR

B. Mathieu, R. Bauer

Formaldehyde and acetaldehyde are important intermediates of the photochemical cycle in the unpolluted atmosphere.

Aldehydes from marine air were enriched from a constant flow for about 1 hour in a 2.4-DNPH-water solution.

The analysis of the 2.4-Dinitrophenylhydrazone solutions by HPLC with UV detector on board shows a decrease of formaldehyde from about 1ppb in the Channel to very low mixing ratios above the open ocean and some effects depending on meteorological conditions. Further analysis will probably give information on diurnal variations of aldehyde mixing ratio and their latitude dependence.

1.2.16 GASCHROMATOGRAPHY OF HYDROGEN AND CARBON-MONOXIDE

R. Bauer

The purpose was to measure the latitudinal variation of H_2 and CO in the atmosphere. During ANT VII/1 we used a special form of gaschromatography to detect H_2 and CO. The amount of mercury formed by reduction of HgO is proportional to the contentration of the two species.

The absorption of Hg at 254 nm is a sensitive detector down to 1 ppb CO.

A global analysis of the more than 1000 measurements will be done in Jülich. At last a value of 75 ppb CO was measured at 30°S and 30°W.

1.2.17 NET TOTAL RADIATION AT SEA

H.D. Behr, R. Schmidt, D. Winterkemper

The cruise of RV "Polarstern" offered a good opportunity for gaining a meridional distribution of the components of the net total radiation. The knowledge of the spatial and temporal distribution of this quantity and its components at the sea surface is important for numerous meteorological and oceanographic investigations. This work is the continuation of the measurements made during ANT V/5.

1.The following radiation components have been recorded:

- global solar radiation (G)
- reflected solar radiation (R)
- atmospheric radiation (A)
- ocean surface radiation (E)
- direct solar radiation (I)
- sunshine duration (S)
- UV-B_{er} global radiation (UV)

In the meridional distribution of the daily sums of these radiation components along the cruise of RV "Polarstern" from 40°N to 30°S, the quantities A and E increase from 40°N up to the passage of the ITCZ at 6°N, and decrease south of it. The maximum values of E in the area of the ITCZ correspond to a SST of 30°C. In both hemispheres there is a maximum of G in the areas of poor cloudiness (subtropical highs), but in the region of the ITCZ high reaching clouds cause a rapid decrease of global solar radiation and the other solar radiation exhibits a different behaviour in both hemispheres: a maximum at 28°N and a rapid decrease southwards to the ITCZ due to thin clouds. South of the ITCZ the variation with latitude of direct solar radiation is small because of low amounts of clouds. A change occurred at 28°S when a cold front reached RV "Polarstern". Ultraviolet global radiation (UV) was reduced by high reaching clouds in the area of the ITCZ.

2. Direct solar radiation has been measured at clear sky conditions by a hand-held actinometer (Linke-Feussner) and a photometer (d'Almeida). These instruments are equipped with various filters (white, red, green, ...). The instruments were used for measuring the turbidity of the atmosphere at different wave lengths.

The objectives of this project are

- to determine the net total radiation and its components in the climatic regions of the Atlantic Ocean,
- to compute the turbidity factor of the atmosphere derived from direct solar radiation I, and compare it with the data measured by the actinometer and photometer,
- to investigate the UV-B-portion of global solar radiation in the climatic regions of the Atlantic Ocean,
- to investigate the dependency on total cloud amount of global solar radiation and atmospheric radiation,
- to compare the measured global solar radiation with model values derived from Meteosat data.

Corrigendum for Berichte zur Polarforschung 62 (1989)

In the EPOS I contribution of H. D. Behr, R. Schmidt and D. Winterkemper one figure has unfortunately been omitted on page 30. Herewith a corrected version of this page is presented.

1. The following radiation components have been recorded:

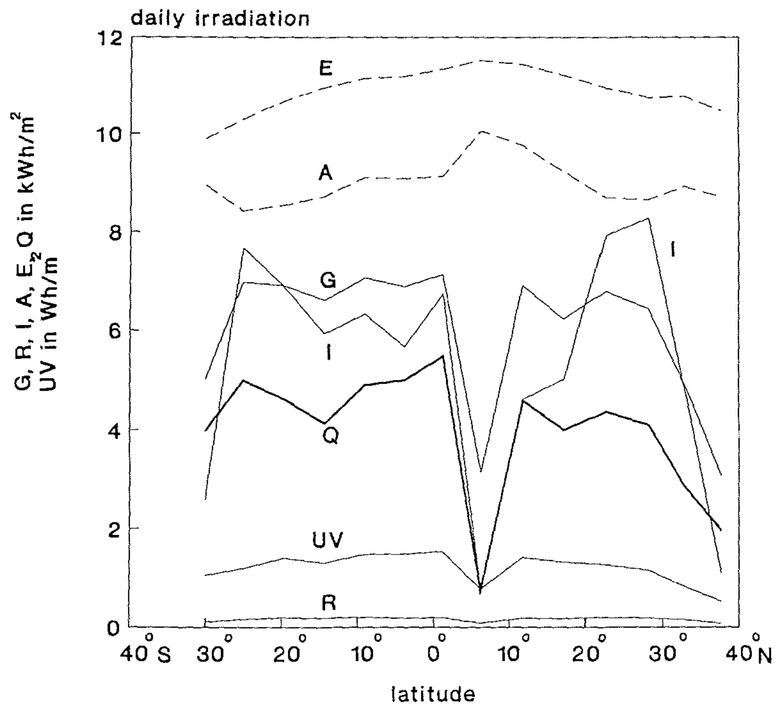
global solar radiation (G) · reflected solar radiation (R) · atmospheric radiation (A)
ocean surface radiation (E) · direct solar radiation (I) · sunshine duration (S)
UV-B_{er} global radiation (UV)

In the meridional distribution (see following figure) of the daily sums of these radiation components along the cruise of RV "Polarstern" from 40° N to 30° S, the quantities A and E increase from 40° N up to the passage of the ITCZ at 6° N, and decrease south of it. The maximum values of E in the area of the ITCZ correspond to a SST of 30° C. In both hemispheres there is a maximum of G in the areas of poor cloudiness (subtropical highs), but in the region of the ITCZ high reaching clouds cause a rapid decrease of global solar radiation and the other solar radiation components (R, I and UV), and a slight increase of A. Direct solar radiation exhibits a different behaviour in both hemispheres: a maximum at 28° N and a rapid decrease southwards to the ITCZ due to thin clouds. South of the ITCZ the variation with latitude of direct solar radiation is small because of low amounts of clouds. A change occurred at 28° S when a cold front reached RV "Polarstern". Ultraviolet global radiation (UV) was reduced by high reaching clouds in the area of the ITCZ.

2. Direct solar radiation has been measured at clear sky conditions by a hand-held actinometer (Linke-Feussner) and a photometer (d'Almeida). These instruments are equipped with different filters (e.g. white, red, green . . .). The instruments were used for measuring the turbidity of the atmosphere at different wave lengths.

The objectives of this project are

- to determine the net total radiation and its components, including statistical parameters, for the climatic regions of the Atlantic Ocean,
- to compute the turbidity factor of the atmosphere from direct solar radiation I, and to compare it with those data obtained by actinometer and photometer,
- to investigate the UV-B-portion of global solar radiation in the climatic regions of the Atlantic Ocean,
- to investigate the influence of total cloud amount on global solar radiation and atmospheric radiation,
- to compare the measured global radiation with modevalues derived from Meteosat data.



Meridional distribution of the daily sums of the radiation components obtained during ANT VII/1 (explanation see text)

1.2.18 ROUTINE XBT AND RADIOSONDE PROGRAMME

A. Walker

During the meridional atlantic transects of the RV "Polarstern", XBT-casts are done on a routine base at each full degree latitude.

In the course of the research cruise ANT VII/1 1988, temperature profiles were measured down to 800 m between 50°N and 30°S along 30°W.

The recorded temperature-profiles were stored and processed on the ship´s computer for further analysis and in order to allow a transfer to oceanographic data banks.

Due to a failure of the XBT-controller several XBT-measurements could only be recorded on an analog penwriter and were later on digitized.

Parallel to the XBT-casts radiosondes were launched to measure air temperature, humidity, pressure, windspeed and wind direction up to about 30 km height. Data were received via a Vaisala Micro Cora and stored on magnetic tape for further computation.

Preliminary analysis of both data sets was done on board of RV "Polarstern". Detailed investigations of the collected data will be carried out directly after the cruise at the Alfred Wegener Institute, Bremerhaven.

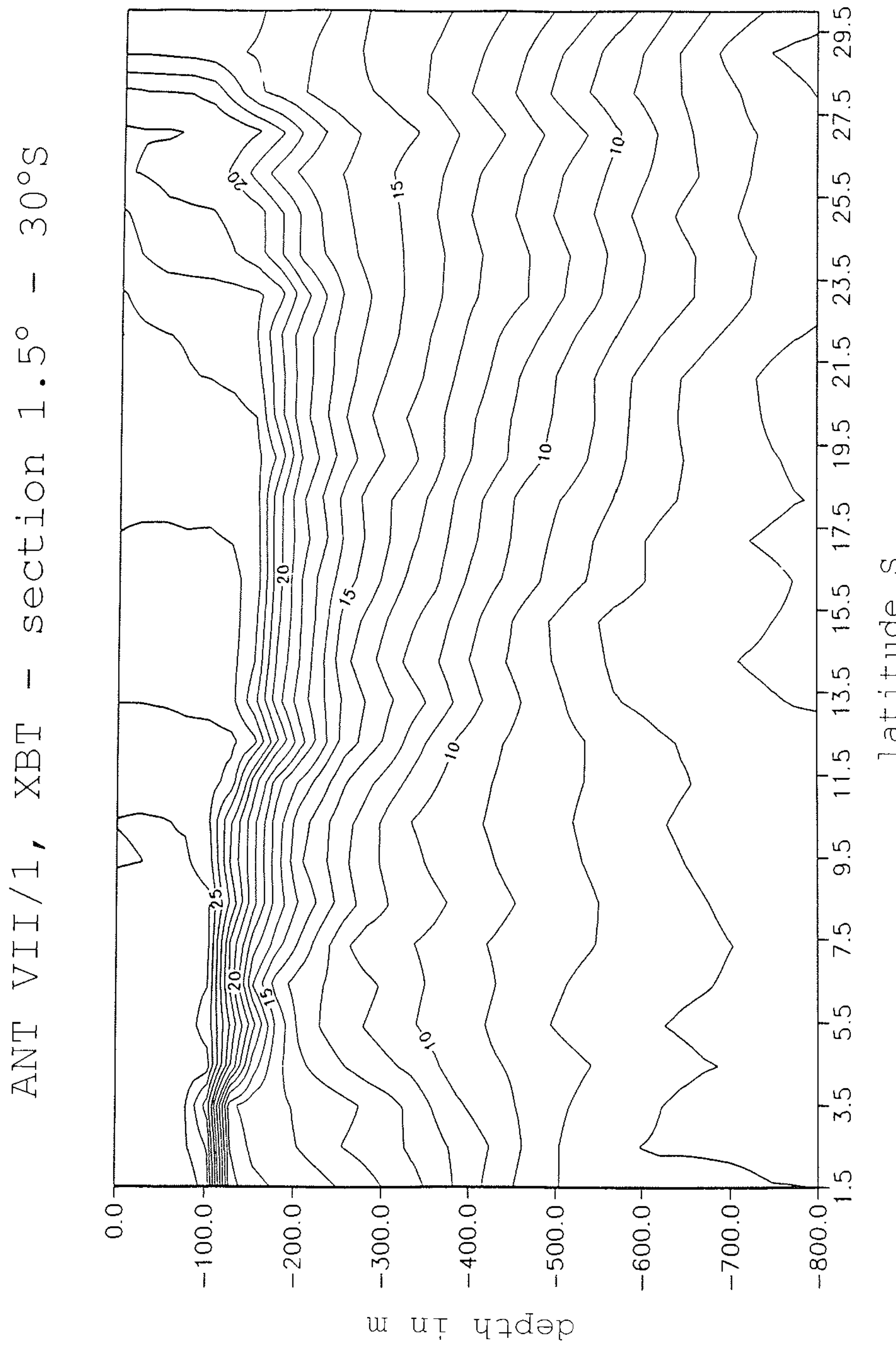


Fig. 7: XBT cast

ANT VII/2 EPOS I

RIO GRANDE/BRAZIL - PUNTA ARENAS

11.10. - 19.11.1989

FAHRTLEITER / CHIEF SCIENTIST

GOTTHILF HEMPEL

SCIENTIFIC ADVISOR

JARL-OVE STRÖMBERG

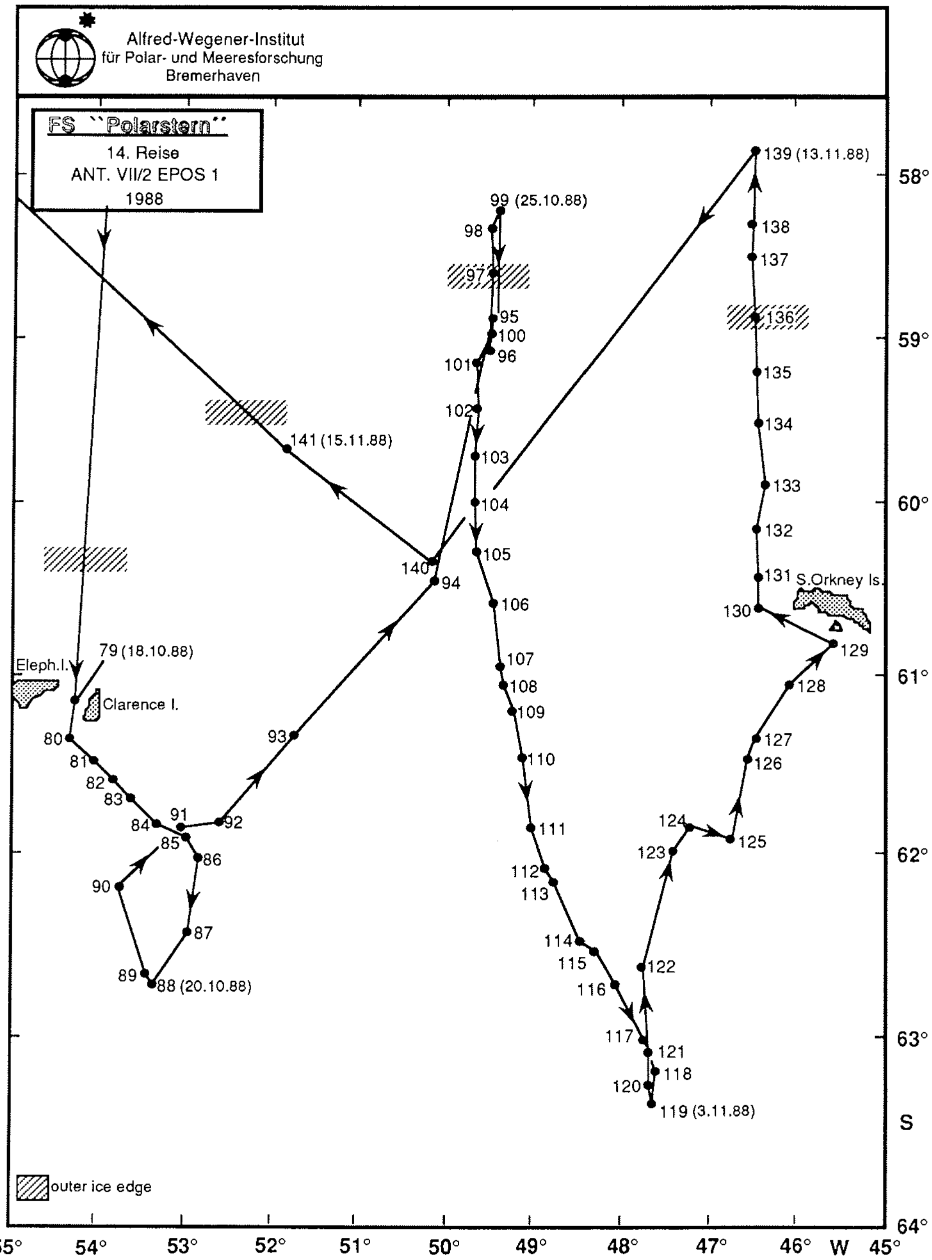


Figure 8 Itinerary of EPOS I

2. ANT VII/2 (EPOS I) RIO GRANDE (BRAZIL) - PUNTA ARENAS 11.10. - 19.11.1988

2. ANT VII/2 (EPOS I) RIO GRANDE (BRAZIL) - PUNTA ARENAS 11.10. - 19.11.1988

2.1.1 INTRODUCTION

G. Hempel

2.1.1.1 EPOS - General plans

The European Polarstern Study (EPOS) is a cooperative enterprise to study the ecology of the Weddell Sea. More than 120 scientists from 11 countries in western and northern Europe and from South-America participated in the three legs of the expedition, which was planned by an international group under the auspices of the European Science Foundation (ESF). RV "Polarstern" was provided free of charge by the German government through the Alfred Wegener Institute. Funding for travel and equipment of participants was provided by the home countries while a portion of the charter for the helicopters came from the European Community.

The international planning group (chairman J.O. Strömberg) and the technical secretariat under V. Smetacek were financed through ESF. It took almost three years to solicit and select research proposals and to transform these into a coherent cruise programme, giving each of the legs its own profile but at the same time ensuring a certain continuity in the study of seasonal changes in the pelagic communities of the ice edge and sea ice zones of the northern Weddell Sea.

Research during the first leg (EPOS I) was meant to focus on the sea ice and its northern edge during the period of early melting and retreat in October/November. The second leg (EPOS II) from late November to early January was planned as a continuation and expansion of the plankton studies of EPOS I, but work would concentrate more on meridional transects from the ice free areas of the Weddell Scotia Confluence into the ceding marginal ice zone. The main objective of EPOS III was the study of benthos, fish and macrozooplankton in the eastern Weddell Sea and off Queen Maud Land in late summer. Furthermore some of the plankton stations of the former legs in the western Weddell Sea were to be reoccupied . The reports of EPOS II and III will be published separately.

EPOS was initiated to bring together groups of marine scientists from all over Europe to provide an opportunity for many newcomers in Antarctic research to apply their experience and ideas, gained elsewhere, in this new field. Fostering the collaboration across countries and disciplines for the promotion of polar studies was the main objective of the ESF Network on Polar Research which planned EPOS as the first large scale European multinational approach to Antarctic ecology.

2.1.1.2 Scientific objectives of EPOS I

The scientific objectives of EPOS I were all related to the life within and underneath the sea ice and in the open water adjoining the marginal ice zone. Sea ice glaciology and oceanography played an important part in the expedition as disciplines in their own rights and as support to the biological studies. The western Weddell Sea is one of the few areas where the three major zones of the Southern Ocean: open ocean, seasonal sea ice zone and permanent pack-ice zone occur concomitantly and where multi-year pack-ice is in relatively easy reach for an ice breaking research vessel such as "Polarstern". The multi-year heavy pack-ice of the inner Weddell Sea resembles that of the Arctic Ocean. Neither the inner part of the seasonal ice zone nor the heavy, old pack-ice have ever been comprehensively studied during winter/early spring conditions. EPOS I provided the opportunity to study both sea ice and water column with the aim to achieve a better understanding of processes influencing the biomass and community structure of both habitats and the interaction between them.

The biological sea ice studies had to be based on a comprehensive description of the physical structure of the sea ice, its zonation and dynamics in the western Weddell Sea. Furthermore origin, development and decay of sea ice under the influence of thermo-dynamic and dynamic processes governed by atmospheric and oceanic forces had to be understood. The distribution and composition of sea ice communities was to be studied in relation to the structure and temporal variability of their habitats. Multi-year ice is expected to provide a record of successional change of the ice biota over two or three years. Coring of thick sea ice was therefore of interest to the biologists as well as to the glaciologists.

The underside of the ice offers a stable substratum for algal biomass accumulation. Honeycombing of the ice during melting greatly increases the surface area of this zone and supports rapid proliferation of algae. These outer and inner surfaces of the sea ice are the grazing grounds for heterotrophs including bacteria, flagellates, ciliates, copepods and krill. Quantitative sampling of these organisms is very difficult and becomes even more in trying to relate their occurrence, distribution, metabolism and behaviour to the environments of the ice/water interface, brine channels and melt structures. A multitude of new sampling methods and devices had to be employed, including under ice scuba diving and observations of krill by a remotely operated vehicle (ROV).

In vitro ecophysiological experiments on specific environmental properties such as light, salinity and nutrients in the ice were planned to complement the comparative field studies.

At the ice edge and in the adjacent open water of the Weddell Gyre, the study of the early development of spring blooms of phytoplankton in relation to vertical stratification and mixing of water masses and their horizontal distribution was the main objective of the northern part of the transects.

Measurements of primary and secondary production as well as respiration by autotrophic and heterotrophic microorganisms were done in both the open water and the water column of the sea ice zone. Regional and vertical distribution of nutrients, pH and alkalinity as well as the underwater light field (including UV penetration), had to be described in relation to sea ice and the abundance of phytoplankton and detritus. The cruise track for EPOS I was planned to optimize the study of the geographical distribution of zooplankton, seabirds and marine mammals in areas which have been virtually unexplored in late winter.

During summer a major part of the krill population of the Southern Ocean feeds and spawns along the Weddell/Scotia Confluence between Elephant Island and the waters around South Orkney Islands. The overwintering of the large masses of krill is little understood. For this reason the role of the sea ice of the western Weddell Sea as a habitat for feeding and shelter of krill was studied by a variety of methods in order to understand winter distribution and abundance of krill, its feeding, growth and geographical age class-stratification.

2.1.1.3 Summary review to EPOS I

The intention in the original cruise plan was to perform two pairs of zig-zag transects from the open water through the outer and inner marginal ice zones to the multiyear pack-ice of the inner Weddell Sea. A further shorter zig-zag would cover the ice edge zone only. Along the transects, stations of various duration were planned for oceanographic and phytoplankton casts as well as zooplankton and krill sampling in the water column. An extensive programme was designed for the ice stations which would combine studies in the water column with a multitude of measurements and samplings of the sea ice itself and with the direct observations by scuba divers and ROV. Two helicopters were available for ice route reconnaissance and for systematic sea ice surveys.

During the course of the expedition, certain departures from the original cruise plan were deemed more appropriate. Per saldo "Polarstern" spent more time in the ice and at open water stations than planned. The short zig-zag in the ice edge zone was omitted. Many long ice stations of 6-8 hrs were occupied. This ensured that more dives as well as ROV observations could be done. More ice cores were also obtained, than originally expected. The stronger emphasis on ice studies was mainly due to a shift in scientific interest from water biology to ice biology as it became obvious that not only winter conditions did still prevail in the water column of the sea ice zone but also that the open water between the ice edge and the Weddell/Scotia Confluence was still almost devoid of phytoplankton. Thus the melting sea ice with its vast concentrations of primary and secondary producers attracted the biologists, nutrient chemists and physical oceanographers.

Glaciological studies provided a comprehensive picture of the geographical distribution, small scale structure and the dynamics of sea ice. The predominant effect of wind on the ice cover, deformation in the broad marginal ice zone became evident. The high mobility of the ice causes considerable heterogeneity in the structure of ice fields as well as in individual floes. Analyses of thickness profiles and cores indicated that older floes are often conglomerates of ice of different age and origin. In the inner Weddell Sea with its solid pack-ice of two years or more, large leads as well as pressure ridges are brought about by the action of currents and wind. Open leads are major sources of heat loss and will quickly refreeze resulting first in grey and subsequently white nilas covered by snow. Biologists, chemists and glaciologists cooperated closely to study the melting processes during which organisms play a substantial role. Various types of sea ice at all stages of melting were encountered. Multidisciplinary groups employed mainly new instrumentation for in-situ measurements of the physical and chemical parameters of sea ice and the underlying water masses.

Light transmission through rugged pack-ice is higher than commonly expected. Tilted and upright floes as well as cracks and crevasses channel light downward. In the open water and in leads, UV penetration was also higher than expected. On the other hand the heterogeneous light field in the upper part of the water column could not be related to scarcity of plankton alone. Obviously considerable quantities of fine detrital material are released from the ice. Detailed studies of the water of the upper 10 meters and immediately underneath the ice were carried out using a CTD and specially constructed sampler deployed from ice floes or through core holes in the floes. First results suggested that the low salinity values reported in the literature were artefacts as no signs of stratification due to melting were observed. Concentrations of zooplankton - mainly copepods - were observed with the ROV in the sub ice water layer, particularly at night. These organisms are inaccessible to conventional plankton nets. The "brown water" found in the southern Weddell Sea in the vicinity of fast ice was not recorded during this expedition, i.e. virtually all primary production in the sea ice zone of the western Weddell Sea was confined to the various ice algal assemblages.

The ice algae occupy various habitats: The infiltration layer at the snow/ice interface particularly at the edges of floes had very high concentrations of algae. The algal abundance often decreases towards the center of the floe.

Patches of ice algae were observed on the underside of the ice floes particularly under white nilas. Under older ice floes, however, carpets of ice algae are less frequent and much thinner than reported from the Arctic. This might be due to the high grazing pressure of Antarctic krill as well as to ice thickness and variable snow cover.

Layers of sea ice biota of previous growing seasons were often observed within old ice floes. These may play a role as food for zooplankton or serve as an inoculum for the water column when the ice melts in spring. Brine, collected in short core holes in sea ice attracted the particular attention of the ice biologists. The brine had very rich and complex communities of diatoms, flagellates, bacteria, ciliates and other microorganisms as well as foraminifera, copepods and larger metazoan larvae. Brine channels and pockets from which the brine is derived thus have a specialized psychrophilic community, which has a different structure than the plankton in the adjacent water mass resulting partly from nutrient depletion. In spring and summer the brine channels widen and become infiltrated with water resulting in the proliferation of this community. Thus the brine channels and infiltration layers become the main habitats of krill, amphipods and even some fish larvae. The overall abundance of krill seemed to be much higher than in the eastern Weddell Sea in 1988, although a general lack of adult specimens was observed. Obviously most krill in the marginal ice zone were well fed, while abundance and state of feeding was somewhat poor in the heavy pack-ice. The combination of direct observations by ROV and divers as well as results obtained with the RMT, Bongo, divers hand net and by picking from overturned ice floes, provided a coherent, albeit non-quantitative, picture of the krill population and its life in the sea ice zone. Of particular interest was the first formation of krill swarms while moving from their melting habitat into the water column. In general the krill studies of EPOS I have confirmed the crucial importance of the seasonal sea ice zone for the Antarctic krill. It is, however, still not known to what extent krill grazing might limit the production of ice algae.

Censuses of birds and seals in the Antarctic pack-ice are scarce. The observations of EPOS I demonstrated the truly pelagic character of Adelie penguins feeding at least more than 100 miles away from land. We were lucky to observe the breeding migration of Adelie penguins from their feeding grounds over more than 100 nm to the rookeries. Families of crab eater seals with new born pubs were encountered all over the sea ice zone.

The long transects in and out of the sea ice only just brushed the Weddell Scotia Confluence at their northernmost stations. The long sections provided excellent opportunities to describe the large scale distribution of phytoplankton, microorganisms, zooplankton and birds. Except for some algal blooms between 59° and 57°S in the open water, phyto- and zooplankton occurred in very low abundance. Zooplankton showed signs of low food supply, particularly in the sea ice zone. Pelagic bacteria were more abundant in the south than in the north.

High concentrations of nutrients but strikingly low pH values (pH 7.7) were found in the inner pack-ice zone. This is of relevance for the CO_2-exchange between ocean and atmosphere. pH increased northward to pH 8.0 in the open water, with maxima of 8.2 in algal blooms.

Ecophysiological experiments on several kinds of microorganisms, ice algae, phyto- and zooplankton including krill added greatly to the success of the expedition. Potential production and respiration were measured under various regimes of temperature, light and salinity. The experiments demonstrated that for many of the organisms under study the optimum temperatures were much higher than ever met under Antarctic conditions.

2.1.2 FAHRTVERLAUF / ITINERARY OF THE CRUISE

G.Hempel

Am Abend des 11.Oktober verließ "Polarstern" termingerecht den Hafen von Rio Grande zum ersten Fahrtabschnitt der EUROPEAN POLARSTERN STUDY (EPOS). Die 47 wissenschaftlichen Fahrtteilnehmer aus 11 Ländern, sowie zwei Mitarbeiter des Deutschen Wetterdienstes und vier Mann Hubschrauberteam hatten sich am 9. und 10. Oktober eingeschifft. Sie nutzten den Hafenaufenthalt zu Kontakten mit der örtlichen Universität, die den Wissenschaftlern und der Besatzung einen sehr freundlichen Empfang bereitet hatte. Am 10.Oktober hatten interessierte Kreise der Bevölkerung sowie die Mitarbeiter des deutschen Konsulats in Porto Allegre Gelegenheit, das Schiff zu besichtigen. Vertreter der Behörden und der Universität waren am Abend Gäste an Bord.

Die relativ lange Anreise von Südbrasilien bis zum ersten Zielgebiet um Elephant Island bot Gelegenheit, in zahlreichen Gruppengesprächen und Plenardiskussionen die Pläne der einzelnen Wissenschaftler vorzustellen und die Arbeitsabläufe im einzelnen festzulegen. Vor allem wurde die Zeit zum Einrichten der Labors und Forschungscontainer und zum Aufbau der Meßeinrichtungen genutzt. Anfangs war das Wetter warm und sonnig, doch dann folgte eine Woche mit immer schlechterem Wetter, der Wind frischte stark auf und die Temperatur sank auf -10°C. Die Probestation am 15.10. verlief hinsichtlich der meisten Sonden und Fanggeräte zufriedenstellend.

Überraschend trafen wir bereits 50 sm nördlich von Elephant I. auf die ersten Eisfelder, die in Bändern angeordnet vom Südost-Sturm weit nach Norden verdriftet worden waren. Die letzten Satelliten-Bilder mit Bodensicht hatten die Eiskante südlich von Elephant Island gezeigt. So konnte der Plan, das erste Nord-Süd-Profil noch im freien Wasser zu beginnen, nicht realisiert werden.

Im Lee von Clarence Island fanden am 18.Oktober einige weitere Geräteerprobungen sowie Umstauarbeiten statt. Anschließend begann das erste Stationsprofil, das uns innerhalb von drei Tagen vom lockeren Treibeis bis ins dichte Packeis führte. Schnell wurde der Bereich großer, wahrscheinlich zweijähriger Eisschollen erreicht. Am 21./22.Oktober fand auf 62.4°S eine Dauerstation in einer Wake am Rande einer kompakten Scholle von ca. 15 sm Durchmesser statt. Erstmalig für "Polarstern" wurden dabei Taucher eingesetzt, die an der Unterseite des Meereises fotografierten, Algen, Amphipoden und Krill sammelten und in-situ Inkubationen durchführten. Das unbemannte Tauchfahrzeug lieferte gute Videoaufnahmen und Photos von der Eisunterseite. Das Eisbohrteam gewann Proben und Daten über Dicke, Struktur und mikrobielle Besiedlung des Meereises, während andere Gruppen die Wasserschicht unmittelbar unter dem Eis sowie die Wassersäule physikalisch, chemisch und biologisch untersuchten. Die großräumige Verteilung des Meereises im weiteren Umkreis des Schiffes konnte mit Hilfe systematischer Photoflüge der Hubschrauber dokumentiert werden. Sie leisteten - sofern das Wetter es zuließ - auch wertvolle Hilfe bei der Routenerkundung im Packeis und wurden im weiteren Verlauf der Expedition gelegentlich zur

Zählung von Robben und Pinguinen verwendet. Insgesamt waren die Hubschrauber 43 Stunden im Einsatz, davon zwei Drittel der Zeit für Glaziologie und Biologie und ein Drittel für Routenerkundung im Eis.

Nach der Dauerstation begann Profil 2 mit dem gleichen Nebeneinander von Arbeiten der Eisbohrer, Taucher, Untereisbeobachter, Photoflieger und der "normalen" Meeresbiologen und Ozeanographen, die mit CTD-Rosetten, Lichtsonden und Planktonnetzen verschiedener Größe vom Schiff aus arbeiteten. Wie auf dem Profil 1 fanden täglich eine große und zwei bis drei kleinere Eis/Wasserstationen statt. Ein Höhepunkt des Profils 2 war die Entdeckung der Wanderstraße der Adelie-Pinguine, die zu Tausenden über das Meereis den Brutplätzen an der Spitze der Antarktischen Halbinsel zustrebten und dabei unsere Riesenscholle umrundeten. Das nordostwärts gerichtete Profil 2 bog am 25.Oktober bei 60.0°S 49.32°W nach Norden um, wurde als Meridionalschnitt bis ins freie Wasser bei 58.2°S fortgesetzt und auf dem selben Längengrad bis 60.0°S wiederholt. Die Eisrandzone (MIZ) war hier über 100 sm breit. Das Profil erfüllte die Wünsche nach einer, allerdings noch schwachen, Frühjahrsblüte des Phytoplanktons. Daher wurde bei 59.0°S am 26./27. Oktober eine dreißigstündige Dauerstation (Stat. 100) gefahren, in deren Verlauf der Wind stark auffrischte.

Ab 60.0°S knickte der Kurs nach Südsüdost ab und führte uns über den Ostrand des Powellbeckens ins Packeis des zentralen Weddellmeeres. Am 1. November stießen wir auf eine fast geschlossene Zone mit Schollengrößen im Kilometerbereich, 1 - 3 m dick mit 50 - 100 cm Schneeauflage. Um solche Schollen zu umfahren, mußte "Polarstern" zunehmend weite Umwege machen, traf dabei aber auf bis zu 10 m mächtige Preßeisrücken an den Nahtstellen aneinander gestoßener Schollen. Dies waren Hindernisse, die nur in mehrstündigem Ramm-Eisbrechen überwunden werden konnten. Aber auch das Zerschneiden kleiner, unscheinbar wirkender Schollen erforderte sehr zeitaufwendiges Rammen. Kilometerlange Waken zwischen den großen Schollen waren zwar meist mit Neueis überzogen, hier konnte aber das RMT noch geschleppt werden. Bei 63.21°S war der Bereich fast geschlossenen mehrjährigen Packeises erreicht, in dem der Aufwand für ein weiteres Vordringen nicht mehr wissenschaftlich gerechtfertigt erschien. Mit Hilfe des Hubschraubers wurde das glaziologische Profil 30 sm nach Süden um zwei weitere Bohrstationen verlängert, während "Polarstern" eine weitere Dauerstation durchführte. Sie bildete den südlichen Abschluß des nun insgesamt 320 sm langen Nordsüd-Profils, das im freien Wasser bei 58.1°S begonnen hatte. Auf 28 Stationen war die Struktur der Wassersäule in den oberen 600 - 1000 m, sowie die vertikale Chlorophyll- und Nährstoffverteilung erfaßt worden, auf der Mehrzahl der Stationen auch das Zooplankton und das Licht- und UV-Profil. Der mittlere Stationsabstand betrug am Nord- und Südende des Meridionalschnittes etwa 7 sm, im Hauptteil ca.15 sm. Täglich hatten wir ein bis zwei Eisstationen mit diversen Bohrkern-Entnahmen, Eisdickenmessungen und Untereisbeobachtungen mit Tauchern, UWE und Sonden (CTD, "L´se") durchgeführt, parallel zu den ozeanographischen Messungen in der Wassersäule. Da das Wetter meist trüb war mit niedriger Wolkendecke, konnten auf diesem Schnitt die Hubschrauber nur selten zu Photoflügen eingesetzt werden.

In den ersten zwei Tagen nach der Südstation konnte sich "Polarstern" nur langsam ihren Weg nach NO brechen. Der Arbeitsrhythmus von zwei Stationen pro Tag wurde beibehalten, wobei eine Station in die Abend- und frühen Nachtstunden gelegt wurde, weil das Schiff wie an den Vortagen nur bei Tageslicht seinen Weg im schweren Eis suchen konnte. Am 6. November nachmittags gelangten wir früher als erwartet aus dem kompakten Eis in die Zone kleiner Schollen, die oftmals aus zusammengefrorenen Bruchstücken unterschiedlich alter Schollen bestanden. Der Frühling machte sich hier durch Abschmelzmuster an der Unterseite der Schollen und durch Aufweichung des Schnees, nicht aber in der pflanzlichen Produktion bemerkbar. Am 8. November begannen wir eine 30-stündige Dauerstation in der Zone des algenreichen Brauneises. Die dafür im zweiten Anlauf gewählte Scholle entsprach allerdings nicht den Wünschen aller Gruppen.

Knapp zwei Tage Dampfen und Stationsarbeit lagen zwischen der Dauerstation und unserem Besuch in Signy Island und der dortigen britischen Station. Wir trafen unterwegs auf sehr gutes Brauneis mit viel Krill. Als wir am 10. November morgens vor Signy ankamen, wehte und schneite es wie an den Vortagen, aber später besserte sich das Wetter, so daß alle Expeditionsteilnehmer sich gern an den Nachmittag auf der Insel erinnern werden.

Die folgenden zwei Tage waren einem Süd-Nord-Profil aus dem Meereis ins offene Wasser gewidmet. Bei 59.00°S trafen wir am Eisrand auf eine relativ reiche Diatomeenblüte, die noch einmal die Phytoplanktologen stark beschäftigte. Da dieser Schnitt auf allen drei EPOS- Teilen gefahren werden soll, standen zusätzliche Zooplanktonfänge auf dem Programm. Bei der nördlichsten Station auf 57.50°S, die wir am 13. November erreichten, waren die Chlorophyllwerte wieder abgesunken. Wir hatten die Blüte passiert.

Die nicht benötigte Schlechtwetterreserve wurde am 14./15.November für eine Wiederholung von Messungen auf Transekt 2 in der Eisrandzone zwischen 60° und 61°S verwendet. Im Vergleich zu den Verhältnissen vor drei Wochen war das Eisfeld stark aufgelockert. Eisalgen hatten sich in der Grenzschicht zwischen Eis und Schnee und in den durch Abschmelzen stark skulpturierten Schollen kräftig vermehrt, während im Phyto- und Zooplankton noch keine Anzeichen des Frühlings sichtbar waren. Auf einer 22-stündigen Dauerstation wurde das Unterwasserfahrzeug fünfmal für systematische Krillbeobachtungen eingesetzt. Als Abschluß der Forschungsarbeiten lieferten zwei RMT-Einsätze am Eisrand gute Fänge an Krill und pelagischen Tiefseetieren.

Noch am 15. November traten wir die Heimreise an, die am Mittag des 19. November nach einer schönen Fahrt durch den Beagle-Kanal in Punta Arenas endete. Bei den wissenschaftlichen Abschlußveranstaltungen wurde deutlich, welch reiches Material an Daten, Proben und Erfahrungen auf EPOS I gesammelt wurde. Die Teilnehmer waren sich einig in dem Wunsch, die gewonnenen Daten nicht nur auszutauschen, sondern auch, wenn immer möglich, gemeinsam zu bearbeiten, zu diskutieren und zu veröffentlichen. Hierzu sind Arbeitsgruppentagungen, vor allem aber ein reger Wissenschaftleraustausch einschließlich einiger längerfristiger Forschungsaufenthalte jüngerer Wissenschaftler erforderlich.

Das Konzept der Unterstützung des Fahrtleiters durch einen ausländischen Scientific Advisor (J.-O. Strömberg) hat sich sehr bewährt und könnte gelegentlich auch auf andere "Polarstern" - Expeditionen mit starker internationaler Besetzung angewendet werden.

Alle Fahrtteilnehmer waren sich einig in ihrem Dank an Schiffsführung und Besatzung der "Polarstern" für ihre ständige Bereitschaft, zum Gelingen des Forschungsprogrammes beizutragen.

The first leg of the European Polarstern Study (EPOS) commenced on October 11 with FS "Polarstern" leaving the port of Rio Grande on schedule. The 47 participating scientists, as well as two members of the German Marine Weather Service and a helicopter crew of four had arrived on board on October 9 and 10. The time before departure was well spent in establishing and deepening contacts to the local university, which had extended a warm welcome to scientists and crew. Those of the population interested, along with the staff of the German consulate in Porto Alegre, had the opportunity to be guided around the ship on October 10. In the evening representatives of the local authorities and the university were hosted on board.

The comparatively long journey from Southern Brazil to the site of our first studies at Elephant Island enabled scientists to present their cruise programs and to discuss in detail the activities planned. Above all, the time available gave everybody a chance to establish themselves in their laboratories and to assemble the scientific equipment. The initial sunshine and warm weather soon changed into a week of high winds and low temperatures, dropping to -10°C. The test station on October 15 was satisfactory with regard to the majority of the gear.

The first bands of sea ice were encountered by us as early as 50 nm north of Elephant Island, where they had been driven by persistent southeasterly winds. The last satellite images unobscured by cloud cover had shown an ice edge south of Elephant Island. The initial plan to have the first N-S transect start in the open ocean thus had to be abandoned.

In the shelter of Clarence Island further testing of instruments and stowing work in the front hold took place on October 18. Afterwards stations were conducted along the first transect that took us from the loose into the closed pack-ice within three days. The ship was finally amongst giant floes, probably of two years age. A time station was held on October 21/22 at 62°40'S in a lead at the edge of a compact floe of 15 nm diameter. For the first time, "Polarstern" was involved in work carried out by divers, who took pictures underneath the ice, sampled algae, amphipods, and krill, and conducted in-situ incubations. The remotely operated submersible UWE obtained good video coverage and photographs of the bottom of floes. The team interested in sea ice extracted cores and collected data on ice thickness and structure as well as on microbial activity within the ice. In the meantime, other groups were investigating the water column and the water layer immediately underlying the ice floes under biological, chemical, and oceanographical aspects. The large-scale distribution of sea ice was documented with the aid of systematic video-and photo-flights carried out by helicopter. The latter also functioned as valuable tools for navigation within the pack-ice; later on they were employed for occasional seal and penguin counts as well. The helicopters operated for 43 hours, two thirds of the time were used for research, the remainder for navigation.

The end of the time station marked the start of transect 2 which again was comprised of work conducted by different disciplines side by side. "Polarstern" was base for diving, ice drilling, under-ice observations, aerial photography as well as the "normal" biological oceanographical work, based on CTD-rosettes, photometers, and plankton nets lowered from the ship's side. The daily routine consisted - in accordance with transect 1 - of one extended and two or three shorter ice/water stations. A highlight of this transect was the discovery of the migration route of the Adelie penguins. Thousands of these birds flocked to their rookeries at the tip of the Antarctic Peninsula, coming past our floe along their way. Transect 2 swung round from a northeasterly to a northern heading on October 25 at 60°00'S 49°32'W. It was continued as a meridional section into open water at 58°20'S and was retraced at the same longitude to 60°00'S across a marginal ice zone of more than 100 nm width. To satisfy those in wanting a spring-time phytoplankton bloom, which had not yet fully developed, a time station (St. 100) was held at 59°00'S on October 26/27. During its 30h course winds picked up to quite a degree.

At 60°00'S the heading was set to SSE and along the eastern margin of the Powell Basin we pushed into the pack ice of the central Weddell Sea. On November 1 we reached a zone of almost complete ice coverage with floes of several kilometers width, 1-3 m thick, covered with 50-100 cm of snow. To avoid these floes "Polarstern" had to do increasingly larger detours, encountering pressure ridges up to 10 m thick along the seams of collided floes. Obstructions such as these meant several hours of ice-ramming in each case. Even cutting through smaller, seemingly thin floes could take up costly time. Leads inbetween floes were generally covered with new ice which even allowed for trawling the RMT. At 63°21'S we reached the realms beyond which further progression was not justified by the scientific merit any longer. With the aid of helicopters the glaciological sea-ice profile was extended by two stations 15 and 30 nm further to the south. Meanwhile, "Polarstern" was engaged in a time station that marked the southern end of the 320-nm-transect which had started in the open ocean at 58°10'S. At 28 stations the structure of the uppermost 600-1000 m of the water column, along with vertical chlorophyll and nutrient distributions had been determined. Zooplankton catches and measurements of visible- and ultraviolet-light penetration had been carried out on most of these stations as well. Along the northern and southern end the average distance between stations measured about 7 nm, in the central stretch approximately 15 nm. One or two ice stations per day allowed for various activities including ice coring, thickness profiles, under-ice studies by the divers, ROV, and other instruments (CTD, "L'se") as well as oceanographic studies in the water column. Because of poor visibility and a low cloud ceiling the helicopters rarely set out for video flights.

During the first two days following the southernmost station, "Polarstern" made only slow progress towards the northeast. The schedule of two stations per day was maintained, with one station set in the late evening, because the ship could only break its way through the heavy pack during daylight hours. On November 6, earlier than expected, we passed from the closed pack-ice into the more open zone of smaller floes. The latter were often composed of refrozen fragments of broken-up, older floes. Whereas spring had already produced intricate melt patterns on the bottom of the ice and softened the snow cover, it had not led to high primary production values. On November 8 we started a 30h-time-station in the brown-ice zone rich in algae, after a long but not quite successful search for a floe that suited everybody's needs.

After two days of ice-breaking and station work in brown ice with large amounts of krill we reached Signy Island on November 10. The snowfall and higher winds that had persisted during the previous days subsided in the afternoon, which allowed for a most pleasant visit to the island and the British station.

The next two days were spent on a S-N transect that led the ship out of the ice into open water. At 59°S we encountered a fairly rich algal bloom that kept the phytoplanktologists busy once more. Additional zooplankton catches were made, since this transect shall be repeated on the remaining two EPOS-legs. At our northernmost station on November 13 at 57°50'S we had passed the bloom and low chlorophyll concentrations were found again. On November 14/15 we repeated the measurements of transect 2 in the marginal ice zone between 60 and 61°S utilizing time gained because of favourable weather conditions. The pack had opened up to quite a degree compared to three weeks ago. Concentrations of ice algae had increased at the snow-ice interface and within the floes sculptured by melting processes, whereas zoo- and phytoplankton stocks were still low. During a 22h-time-station the submersible was employed five times for systematic studies of krill. The scientific operations ended with two RMT trawls, resulting in rich catches of krill and pelagic deep-sea organisms.

On November 15 we headed back towards South America, reaching Punta Arenas on November 19. The scientific conclusions reached in group discussions and plenary presentations made it clear to everyone how large and rich an amount of samples, data, and experiences had been gathered during EPOS I. The cruise participants unanimously agreed to not only exchange the data collected, but also to whenever possible cooperate closely in analyzing, evaluating, and publishing them. To these ends, scientific workshops along with an intensive exchange of scientists will be necessary, including some longer-term fellowships for younger researchers.

Having the chief scientist assisted by a foreign scientific advisor (J.-O. Strömberg) proved a very fruitful concept which might well be pursued on other "Polarstern" cruises with strong international participation. All cruise participants agreed in extending their thanks to crew and officers of "Polarstern" for their constant efforts to contribute to the success of the scientific program.

2.1.3 WEATHER CONDITIONS

B. Richter

After leaving Rio Grande a High Pressure Zone extending from Argentina over our area eastward was dominant with prevailing light and variable winds. This situation changed when "Polarstern" reached the southern frontal zone at a latitude south of 45°S. A cyclone developing north of South Georgia intensified becoming a gale cyclone of 965 hPa thus affecting us with south- easterly gales force 7 on 15 October. Due to a wedge established over the Antarctic Peninsula and then moving east, the pressure gradient increased and the south easterly gales lasted for two days and icedrift was induced, which formed some polynyas in the northwestern part of the Weddell Sea. When "Polarstern" reached Elephant-Island, the high pressure influence became dominant for our area so that stations and helicopter reconnaissance flights could be performed without interference.

On 19 October this anticyclone moved slowly northeastward to South-Georgia, but under the influence of its wedge over the Larsen Ice-shelf, light to moderate easterly wind were no problem for stations and diving activities on the first transect to the position of 62°30'S / 53°30'W. After temporary drop of pressure, this high intensified again and became dominant on the next transect until 25 October at the next vertex at 59°S / 49°30'W.

During the northern open water station easterly winds force 4 were prevailing. With a little southward track of the ship, and deepening of a low northeast of the Falklands, caused the pressure gradient to increase, so that the wind increased to force 8 on 27 October with intermittent snowfall during the passage of frontal clouds.

This low filled during the next days so that the winds weakened to force 5 from easterly direction. On 29 October, a low ceiling made reconnaissance flights impossible, but already the next day, under the influence of a wedge over the Weddell Sea, these could be performed in visual flight conditions.

Frontal clouds rotating around a stationary low over South-Georgia crossed the ship's area on 31 October to the south. Deepening due to drop of pressure in the Weddell Sea area established a circulation pattern "Low Weddell Sea" with winds reaching force 4 backing from easterly to northwesterly directions with intermittent light snowfall.

Cyclones from the Drake-Passage passed our area in the north and did not affect us until 4 November. On this day, the frontal system of a low near Adelaide-Island reached the ship's southernmost position at 63°21'S and 47°38'W. While ice-coring south of us could be performed using the helicopter, reconnaissance flights to the North could not be done due to moderate icing in snow showers and a ceiling below 500 ft. Orographic influence of the Antarctic Peninsula caused the low to slow down during its movement resulting in a retrograde motion of the frontal band. Thus flights could be performed again on 5 November and station work was done as normal.

Another low from the Drake-Passage moved under intensification to east of the Falklands on 6 November becoming a gale-cyclone and continued moving to the SSE. While the front passed by the ship's area the next day, further rotational movement of the front resulted in bad weather for the ship with temporary snowfall and southerly winds force 7. This weather situation became stationary and affected our area until 9 November, when a pressure rise indicated the filling up of this cyclone. On the next day, wind decreased to force 4 and except from temporary light white-out conditions, a visit to the British Station Signy on 10 November and a helicopter flight over the island could be done without interference.

After a period of light and variable winds, "Polarstern" sailed into the warm sector of a mesoscale low on 11 November. Warm and moist warm air was advected by light northerly winds causing formation of fog due to cooling over cold water. As the centre of this low passed by, with winds veering to easterly directions and gusting up to force 5 to 6, the fog dissolved and light intermittent snowfall started in the frontal region.

During the following days, weak pressure gradients in a cyclonic flow with light and variable winds were prevailing in our area. Due to low cloud bases, helicopter flights were only possible at altitudes below 1000 ft. After having finished the last station on 15 November, the ship set course to Punta Arenas. A gale cyclone west of the Drake-Passage moved to the Bellingshausen-Sea and its frontal system crossed the ship's track during the following night with snowfall and winds reaching force 8 from northeasterly, later northwesterly directions. The next day, large scale subsidence due to cold air advection intensified an intermediate wedge and the wind reached force 7. Another frontal band, which crossed the ship on 17 November caused no significant weather problems so that the ship could continue to Punta Arenas according to schedule.

Table 2

SMVX00 SMXX 000000 Seegebiet 00

YYMM	DDHH	Latitu/Longitud	DDD Bft	N/8 WETTER	TLTL	RF%	QNH	TwTw	See/dsvs
8810	1209	34.5 S/ 52.0 W	NNW 3	6/8 wolkig	13.5	87	1017.8	14.8	0.5m S 13kt
8810	1212	35.1 S/ 52.0 W	SSW 4+	7/8 fast bedkt	14.8	82	1018.0	19.7	0.5m S 13kt
8810	1215	35.8 S/ 52.1 W	S 3	1/8 heiter	15.6	69	1017.5	18.4	0.5m S 13kt
8810	1218	36.5 S/ 52.1 W	S 4+	1/8 heiter	15.2	67	1016.6	19.6	0.5m S 13kt
8810	1221	37.1 S/ 52.1 W	ESE 5+	7/8 fast bedkt	14.4	66	1018.3	8.4	1.5m S 13kt
8810	1306	39.1 S/ 52.3 W	E	4 4/8 wolkig	13.1	61	1022.1	19.6	.0m S 13kt
8810	1309	39.9 S/ 52.3 W	ENE 4	6/8 wolkig	13.2	61	1022.8	18.3	1.5m S 13kt
8810	1312	40.6 S/ 52.4 W	NNE 3	1/8 heiter	14.2	59	1023.7	16.3	0.5m S 13kt
8810	1315	41.3 S/ 52.5 W	NNW 4	1/8 heiter	14.2	62	1023.1	17.5	0.5m S 13kt
8810	1318	42.0 S/ 52.5 W	NNW 6-	3/8 heiter	14.6	64	1021.2	19.8	1.5m S 13kt
8810	1321	42.6 S/ 52.5 W	WNW 5+	7/8 fast bedkt	12.4	74	1019.5	13.2	1.5m S 13kt
8810	1406	44.6 S/ 52.7 W	NNW 7-	////diesig	10.0	83	1010.5	10.2	2.0m S 13kt
8810	1409	45.2 S/ 52.7 W	NW 6+	8/8 diesig	9.1	83	1007.4	9.7	2.5m S 13kt
8810	1412	45.9 S/ 52.9 W	NW 6	8/8 diesig	10.6	83	1003.4	13.3	3.0m S 13kt
8810	1415	46.5 S/ 52.8 W	WNW 6	8/8 diesig	10.3	85	1001.6	2.9	3.0m S 13kt
8810	1418	47.1 S/ 52.8 W	SW 4-	8/8 diesig	5.9	86	1000.6	9.1	2.5m S 13kt
8810	1421	47.8 S/ 52.9 W	SW 3	7/8 fast bedkt	6.8	83	1000.5	8.2	1.0m S 13kt
8810	1506	49.8 S/ 53.1 W	SSW 5+	OBSkeine Beob.	3.6	73	1000.6	5.5	3.0m S 13kt
8810	1509	50.4 S/ 53.2 W	SW 7-	7/8 fast bedkt	1.9	80	1000.4	5.5	3.0m S 13kt
8810	1512	50.6 S/ 53.2 W	SW 5	2/8 heiter	2.5	65	999.5	6.0	2.5m S 3kt
8810	1515	50.6 S/ 53.2 W	WSW 6+	7/8 Schauer	0.6	89	998.7	6.2	3.0m Station
8810	1518	50.8 S/ 53.3 W	WSW 5+	6/8 wolkig	2.6	69	997.5	6.2	3.5m S 3kt
8810	1521	51.4 S/ 53.3 W	SW 6	7/8 diesig	2.7	82	994.8	6.3	3.5m S 13kt
8810	1606	53.0 S/ 53.4 W	ESE 5+	6/8 diesig	1.4	86	996.3	6.2	2.5m S 13kt
8810	1609	53.6 S/ 53.5 W	SE 6+	7/8 fast bedkt	2.4	78	999.1	6.0	3.0m S 13kt
8810	1612	54.1 S/ 53.5 W	SE 7- 7	/8 fast bedkt	2.4	79	1002.0	6.0	3.0m S 8kt
8810	1615	54.7 S/ 53.6 W	SE 7-	7/8 fast bedkt	1.0	74	1004.4	5.7	3.0m S 13kt
8810	1618	55.3 S/ 53.6 W	SE 7	8/8 diesig	-0.6	75	1006.4	5.6	3.5m S 13kt
8810	1621	55.8 S/ 53.7 W	SE 7+	8/8 bedeckt	-3.8	75	1008.0	3.4	3.5m S 8kt
8810	1706	57.3 S/ 53.9 W	SE 7+	////keine Beob	-4.8	76	1008.0	2.6	3.5m S 8kt
8810	1709	57.8 S/ 53.9 W	SE 7+	7/8 fast bedkt	-5.6	76	1008.5	4.5	3.5m S 8kt
8810	1712	58.3 S/ 53.9 W	SE 8	7/8 diesig	-6.7	90	1007.9	4.0	4.0m S 8kt
8810	1715	58.9 S/ 53.9 W	SE 8	8/8 diesig	-8.1	84	1008.6	0.9	4.0m S 13kt
8810	1718	59.3 S/ 54.1 W	SE 8+	7/8 fast bedkt	-7.2	82	1008.9	0.4	4.0m S 8kt
8810	1721	59.7 S/ 54.1 W	SE 8+	7/8 fast bedkt	-7.8	81	1010.1	0.1	3.5m S 8kt
8810	1806	61.1 S/ 54.3 W	SW 2	////keine Beob	-7.1	69	1012.3	0.0	S 3kt
8810	1809	61.1 S/ 54.3 W	WSW 2	7/8 fast bedkt	-7.6	68	1012.9	0.3	Station
8810	1812	61.1 S/ 54.3 W	W 2	6/8 wolkig	-5.8	62	1013.9	0.2	Station
8810	1815	61.1 S/ 54.2 W	W 4-	2/8 heiter	-6.1	62	1014.5	0.4	?? 3
8810	1818	61.3 S/ 54.3 W	SE 8-	4/8 wolkig	-10.6	89	1014.7	0.5	0.5m S 3kt
8810	1821	61.4 S/ 54.3 W	ESE 7+	3/8 heiter	-10.7	87	1016.2	0.4	S 3kt
8810	1906	61.7 S/ 53.6 W	SE 4-	SKY heiter	-13.2	99	1019.7	0.1	Station
8810	1909	61.7 S/ 53.6 W	E 3	2/8 heiter	-13.1	98	1019.6	0.1	Station
8810	1912	61.8 S/ 53.3 W	E 3	1/8 heiter	-10.5	81	1019.6	0.0	SE 3kt
8810	1915	61.8 S/ 53.2 W	E 3	1/8 heiter	-7.7	73	1019.4	0.2	E 3kt
8810	1918	61.9 S/ 53.1 W	E 3	SKY heiter	-7.0	78	1018.7	0.3	SE 3kt
8810	1921	61.9 S/ 52.9 W	NE 3	1/8 heiter	-6.8	83	1018.6	0.3	E 3kt
8810	2006	62.5 S/ 53.1 W	NNE 4-	4/8 wolkig	-10.6	88	1016.0	0.1	SE 3kt
8810	2009	62.4 S/ 52.9 W	NNE 3	7/8 fast bedkt	-10.2	96	1015.2	0.8	NE 3kt
8810	2012	62.4 S/ 53.0 W	NE 3	7/8 fast bedkt	-8.1	87	1014.2	0.0	W 3kt
8810	2015	62.5 S/ 53.0 W	NNE 4-	7/8 heiter	-4.8	85	1013.0	0.1	S 3kt
8810	2018	62.5 S/ 53.0 W	NNE 3	7/8 heiter	-2.8	82	1012.5	0.2	Station
8810	2021	62.5 S/ 53.1 W	ENE 4	3/8 heiter	-2.8	77	1012.0	0.1	W 3kt
8810	2106	62.7 S/ 53.3 W	NNE 3	OBSCkeine Beob	6.3	91	1009.9	0.4	Station

8810 2109 62.7 S/ 53.4 W NNE 2	8/8 bedeckt -5.9	84 1009.5 0.4 W 3kt
8810 2112 62.6 S/ 53.5 W ENE 4-	8/8 bedeckt -5.9	86 1009.5 0.4 NW 3kt
8810 2115 62.6 S/ 53.5 W ENE 4-	8/8 bedeckt -5.9	83 1008.8 0.0 Station
8810 2118 62.6 S/ 53.5 W E 4-	7/8 fast bedkt -6.4	83 1008.5 -0.6 Station
8810 2121 62.6 S/ 53.5 W ESE 4-	7/8 fast bedkt -5.5	81 1007.9 -1.6 Station
8810 2206 62.6 S/ 53.7 W E 4	OBSCkeine Beob -6.9	88 1006.8 -1.7 Station
8810 2209 62.6 S/ 53.6 W E 4	8/8 bedeckt -7.5	91 1007.1 -1.7 E 3kt
8810 2212 62.6 S/ 53.6 W ESE 3	8/8 Schneefall -6.9	93 1007.9 -1.7 Station
8810 2215 62.5 S/ 53.7 W ESE 4-	OBSCSchneefall -5.0	92 1008.2 -1.6 NW 3kt
8810 2218 62.2 S/ 53.8 W E 4-	OBSCSchneefall -2.6	85 1008.0 -1.7 N 3kt
8810 2221 62.2 S/ 53.7 W ESE 3	8/8 bedeckt -3.7	87 1008.7 -1.6 E 3kt
8810 2306 61.9 S/ 53.2 W ESE 4-	OBSCSchneefall -8.8	92 1008.8 -1.5 NE 3kt
8810 2309 61.9 S/ 53.0 W SE 4-	8/8 bedeckt -8.8	92 1008.5 -1.5 E 3kt
8810 2312 61.8 S/ 52.6 W ESE 4-	8/8 diesig -8.6	90 1007.9 -1.5 NE 3kt
8810 2315 61.8 S/ 52.6 W E 3	8/8 diesig -8.1	91 1007.7 -1.5 Station
8810 2318 61.8 S/ 52.6 W E 3	8/8 diesig -6.8	88 1007.6 -1.3 Station
8810 2321 61.6 S/ 52.1 W E 4-	8/8 diesig -6.9	93 1007.9 -1.4 NE 8kt
8810 2406 60.9 S/ 50.9 W ESE 4-	3/8 diesig -7.8	86 1008.8 -1.3 NE 3kt
8810 2409 60.6 S/ 50.4 W ESE 4-	5/8 heiter -8.4	87 1009.2 -1.5 NE 8kt
8810 2412 60.4 S/ 50.1 W SE 4	2/8 heiter -6.4	82 1010.6 -1.6 NE 3kt
8810 2415 60.4 S/ 50.1 W ESE 4-	2/8 heiter -2.8	69 1012.0 -1.7 NE 3kt
8810 2418 60.4 S/ 50.2 W ESE 5-	2/8 heiter -3.0	66 1013.1 -1.6 ?? 3
8810 2421 60.3 S/ 50.0 W SE 4+	SKY heiter -3.5 7	4 1014.7 -1.8 NE 3kt
8810 2506 58.9 S/ 49.5 W E 4-	8/8 bedeckt -5.4	83 1019.4 -1.8 N 13kt
8810 2509 59.1 S/ 49.5 W E 4-	7/8 fast bedkt -5.4	84 1021.2 -1.8 0.5m S 3kt
8810 2512 59.1 S/ 49.5 W E 4-	7/8 fast bedkt -5.7	86 1023.4 -1.8 0.5m Station
8810 2515 59.1 S/ 49.5 W E 4	7/8 fast bedkt -4.8	84 1025.4 -1.7 0.5m Station
8810 2518 58.6 S/ 49.5 W E 4-	7/8 fast bedkt -4.5	81 1025.9 -1.3 0.5m N 8kt
8810 2521 58.3 S/ 49.5 W ESE 5-	7/8 fast bedkt -4.3	82 1025.2 -1.2 1.5m N 3kt
8810 2606 58.7 S/ 49.5 W E 6	3/8 heiter -2.9	78 1023.5 -1.7 1.0m S 8kt
8810 2609 59.0 S/ 49.5 W E 6-	4/8 heiter -2.7	76 1023.3 -1.6 0.5m S 3kt
8810 2612 59.0 S/ 49.6 W E 6+	7/8 heiter -2.3	73 1020.8 -1.7 0.5m W 3kt
8810 2615 58.9 S/ 49.6 W E 7-	8/8 heiter -1.9	71 1018.1 -1.6 1.0m N 3kt
8810 2618 58.9 S/ 49.5 W E 8	7/8 heiter -1.7	72 1014.3 -1.6 1.5m ?? 3
8810 2621 58.9 S/ 49.6 W E 8-	8/8 Schneefall -2.3	82 1010.8 -1.6 1.0m W 3kt
8810 2706 58.9 S/ 49.6 W E 8-	OBSCSchneefall -1.5	89 1000.9 -1.6 1.5m Station
8810 2709 58.9 S/ 49.6 W E 8	OBSCSchneefall -1.2	89 998.3 -1.6 1.5m Station
8810 2712 58.9 S/ 49.6 W E 8-	8/8 Schneefall -1.1	93 996.8 -1.6 1.5m Station
8810 2715 58.9 S/ 49.6 W E 7+	8/8 Schneefall -1.3	96 993.6 -1.6 1.5m Station
8810 2718 59.2 S/ 49.6 W E 7-	8/8 Schneefall -0.9	92 992.6 -1.4 1.5m S 3kt
8810 2721 59.4 S/ 49.6 W E 7	8/8 Schneefall -1.0	89 991.5 -1.6 1.0m S 3kt
8810 2806 59.7 S/ 49.7 W E 6	8/8 diesig -1.6	89 98 76 -1.5 0.5m W 3kt
8810 2809 59.7 S/ 49.7 W E 6+	8/8 Schneefall -1	93 987.6 -1.7 S 3kt
8810 2815 60.0 S/ 49.7 W E 5	8/8 Schneefall -1.9	91 986.9 -1.6 S 3kt
8810 2818 60.0 S/ 49.9 W E 6-	8/8 Schneefall -1.6	85 986.9 -1.5 W 3kt
8810 2821 60.3 S/ 49.7 W E 5+	8/8 Schneefall -1.5	91 986.6 -1.6 S 8kt
8810 2906 60.9 S/ 49.4 W ENE 4	8/8 Schneefall -1.1	90 992.2 -1.7 S 3kt
8810 2909 61.1 S/ 49.4 W NE 4-	8/8 Schneefall -1.7	93 993.2 -1.7 S 3kt
8810 2912 61.2 S/ 49.3 W E 5-	8/8 bedeckt -1.5	90 994.2 -1.7 SE 3kt
8810 2915 61.2 S/ 49.2 W E 2 8	/8 diesig -0.4	87 995.0 -1.4 ?? 3
8810 2918 61.2 S/ 49.2 W E 3	8/8 bedeckt -0.7	87 995.5 -1.2 S 3kt
8810 3006 61.8 S/ 49.0 W E 5-	8/8 bedeckt -5.0	87 996.2 -1.2 S 3kt
8810 3009 61.9 S/ 49.0 W E 4	8/8 bedeckt -6.5	90 996.6 -1.2 S 3kt
8810 3012 61.9 S/ 49.0 W E 4	6/8 heiter -5.9	86 996.3 -1.1 Station
8810 3015 61.9 S/ 49.1 W ESE 5-	6/8 heiter -4.6	78 996.0 -1.0 W 3kt
8810 3018 61.9 S/ 49.0 W ESE 5-	3/8 heiter -3.1	76 996.6 -0.9 E 3kt
8810 3021 62.1 S/ 49.0 W ESE 5	2/8 heiter -3.8 7	7 997.0 -0.8 S 3kt
8810 3106 62.2 S/ 48.8 W E 4-	8/8 bedeckt -5.6	86 997.7 -0.8 S 3kt
8810 3109 62.2 S/ 48.8 W E 3	8/8 Schneefall -4.9	88 997.7 -0.8 Station
8810 3112 62.2 S/ 48.8 W E 3	8/8 diesig -3.5	86 997.2 -0.7 Station
8810 3115 62.2 S/ 48.8 W NE 3	8/8 diesig -2.5	85 996.7 -0.7 Station

8810	3118	62.3 S/	48.5 W	NE 3	8/8	Schneefall	-1.4	84	996.0	-0.6	SE	3kt
8810	3121	62.5 S/	48.5 W	NE 3	8/8	Schneefall	-1.1	89	994.5	-0.6	S	3kt
8811	0106	62.5 S/	48.5 W	WNW 4-	8/8	Schneefall	-2.7	91	988.4	-0.6	Station	
8811	0109	62.5 S/	48.3 W	NW 4-	8/8	Schneefall	-2.9	88	987.7	-0.6	E	3kt
8811	0112	62.5 S/	48.3 W	NW 4	8/8	diesig	-2.8	91	986.5	-0.6	Station	
8811	0115	62.6 S/	48.2 W	NNW 4	8/8	bedeckt	-1.4	76	985.7	-0.5	S	3kt
8811	0118	62.7 S/	48.1 W	NNW 4-	8/8	bedeckt	-1.7	84	984.7	-0.5	SE	3kt
8811	0121	62.8 S/	48.0 W	NE 2	8/8	diesig	-1.6	81	983.9	-0.4	SE	3kt
8811	0206	62.8 S/	48.0 W	S 2	OBSC	Schneefall	-4.2	91	982.4	-0.5	Station	
8811	0209	62.9 S/	47.8 W	uml 2	8/8	bedeckt	-4.8	91	982.9	-0.5	SE	3kt
8811	0212	63.0 S/	47.8 W	S 2	8/8	bedeckt	-4.2	93	983.7	-0.5	S	3kt
8811	0215	63.0 S/	47.8 W	WSW 3	8/8	bedeckt	-4.1	86	984.4	-0.5	Station	
8811	0218	63.1 S/	47.8 W	WSW 3	8/8	bedeckt	-2.8	93	985.4	-0.4	S	3kt
8811	0221	63.2 S/	47.6 W	WSW 3	8/8	bedeckt	-3.2	83	987.1	-0.4	SE	3kt
8811	0306	63.1 S/	47.6 W	SSW 4	8/8	diesig	-2.4	89	992.4	-0.5	Station	
8811	0309	63.1 S/	47.5 W	S 4-	8/8	Schneefall	-3.2	91	993.7	-0.5	E	3kt
8811	0312	63.2 S/	47.6 W	S 4-	8/8	diesig	-4.8	86	994.9	-0.6	S	3kt
8811	0315	63.4 S/	47.6 W	S 3	8/8	diesig	-4.2	81	995.6	-0.5	S	3kt
8811	0318	63.4 S/	47.6 W	SE 2	8/8	diesig	-2.7	83	994.9	-0.4	Station	
8811	0321	63.3 S/	47.6 W	uml 1	8/8	bedeckt	-5.0	84	994.8	-0.6	N	3kt
8811	0406	63.3 S/	47.6 W	ENE 3	OBSC	Nebel	-4.1	89	990.4	-0.6	Station	
8811	0409	63.3 S/	47.6 W	NE 3	OBSC	Nebel	-3.7	92	989.9	-0.6	Station	
8811	0412	63.3 S/	47.6 W	ENE 3	8/8	bedeckt	-2.9	91	989.0	-0.6	Station	
8811	0415	63.3 S/	47.6 W	NE 4	8/8	bedeckt	-2.2	94	987.6	-0.5	Station	
8811	0418	63.3 S/	47.6 W	NE 4+	8/8	bedeckt	-1.8	76	986.5	-0.5	Station	
8811	0421	63.3 S/	47.6 W	NE 4	8/8	bedeckt	-2.9	87	985.2	-0.5	Station	
8811	0506	63.4 S/	47.7 W	E 5	8/8	bedeckt	-3.4	82	982.2	-0.5	Station	
8811	0509	63.3 S/	47.7 W	E 5	8/8	Schneefall	-3.7	83	982.4	-0.6	N	3kt
8811	0512	63.2 S/	47.7 W	E 5-	8/8	Schneefall	-3.1	83	983.1	-0.6	N	3kt
8811	0515	63.2 S/	47.7 W	E 5-	8/8	Schneefall	-2.0	82	983.9	-0.6	Station	
8811	0518	63.1 S/	47.6 W	ENE 4-	8/8	bedeckt	-1.8	80	985.2	-0.5	NE	3kt
8811	0521	63.1 S/	47.6 W	NNE 2	8/8	bedeckt	-1.6	77	986.4	-0.6	Station	
8811	0606	63.0 S/	47.7 W	WNW 4	8/8	bedeckt	-2.8	85	987.1	-0.7	Station	
8811	0609	63.0 S/	47.7 W	WNW 4+	8/8	bedeckt	-3.8	78	987.7	-0.7	Station	
8811	0612	62.7 S/	47.7 W	NNW 5-	8/8	Schneefall	-2.7	93	987.8	-0.8	N	3kt
8811	0615	62.6 S/	47.7 W	NNW 5+	8/8	Schneefall	-1.1	92	986.0	-0.7	N	3kt
8811	0618	62.6 S/	47.7 W	NNW 6-	8/8	diesig	-0.2	84	984.2	-0.7	Station	
8811	0621	62.3 S/	47.7 W	NNW 5	8/8	Schneefall	-1.0	89	983.6	-0.7	N	8kt
8811	0706	62.0 S/	47.4 W	S 5	8/8	bedeckt	-4.9	88	975.6	-1.0	Station	
8811	0709	61.9 S/	47.2 W	S 5+	8/8	bedeckt	-4.9	86	973.5	-1.3	NE	3kt
8811	0712	61.8 S/	47.2 W	S 6-	7/8	fast bedkt	-5.7	82	972.2	-1.1	N	3kt
8811	0715	61.8 S/	47.2 W	SSW 7	5/8	wolkig	-5.1	81	971.1	-0.8	Station	
8811	0718	61.6 S/	47.3 W	SSW 7	8/8	Schneefall	-4.5	91	970.0	-1.1	SE	8kt
8811	0806	61.9 S/	46.9 W	S 6	8/8	diesig	-4.5	85	972.2	-0.8	W	3kt
8811	0809	61.8 S/	46.9 W	S 6+	8/8	Schneefall	-5.0	87	973.6	-0.9	N	3kt
8811	0812	61.8 S/	46.9 W	S 7	8/8	Schneefall	-5.1	91	975.5	-0.8	Station	
8811	0815	61.8 S/	46.9 W	S 7	8/8	Schneefall	-3.7	88	976.9	-0.8	Station	
8811	0818	61.8 S/	46.9 W	S 7-	8/8	Schneefall	-2.9	83	978.9	-0.6	Station	
8811	0821	61.8 S/	46.9 W	S 6	8/8	Schneefall	-2.9	91	980.8	-0.7	Station	
8811	0906	61.5 S/	46.6 W	S 5	8/8	Schneefall	-5.3	89	980.5	-1.1	Station	
8811	0909	61.5 S/	46.6 W	S 5-	8/8	bedeckt	-5.2	89	980.0	-1.1	Station	
8811	0912	61.4 S/	46.5 W	S 5+	8/8	Schneefall	-5.1	91	979.0	-1.1	NE	3kt
8811	0915	61.3 S/	46.5 W	S 6-	8/8	Schneefall	-5.7	86	978.3	-1.1	N	3kt
8811	0918	61.3 S/	46.5 W	S 7	8/8	Schneefall	-5.5	86	978.0	-1.1	1.0m	Station
8811	0921	61.1 S/	46.0 W	S 7	8/8	Schneefall	-4.7	88	977.6	-1.4	NE	8kt
8811	1006	60.8 S/	45.6 W	S 5+	8/8	Schneefall	-4.4	88	981.5	-1.3	NE	3kt
8811	1009	60.8 S/	45.6 W	SSW 6	8/8	Schneefall	-5.0	86	983.0	-1.3	Station	
8811	1012	60.8 S/	45.6 W	SW 4	8/8	Schneefall	-5.0	84	985.0	-1.1	Station	
8811	1106	60.6 S/	46.5 W	WSW 2	8/8	bedeckt	-6.7	84	987.0	-1.5	NW	3kt
8811	1109	60.6 S/	46.5 W	NNW 1	8/8	bedeckt	-6.1	82	986.6	-1.3	Station	
8811	1112	60.5 S/	46.5 W	NNW 3	8/8	Schneefall	-4.6	81	985.9	-1.6	N	3kt

8811	1115	60.4 S/	46.6 W	ENE 3	8/8 bedeckt	-3.2	93	985.3	-1.6	NW 3kt
8811	1118	60.4 S/	46.6 W	NE 5-	8/8 bedeckt	-2.3	93	984.6	-1.6	Station
8811	1121	60.1 S/	46.5 W	WNW 2	OBSCNebel	-0.8	92	985.3	-1.5	N 8kt
8811	1206	59.6 S/	46.5 W	E 4	////Nebel	-1.6	89	981.9	-1.5	N 8kt
8811	1209	59.5 S/	46.5 W	E 5	OBSCSchneefall	-1.3	89	979.1	-1.2	N 3kt
8811	1212	59.2 S/	46.6 W	ESE 6-	OBSCSchneefall	-1.3	96	975.1	-1.1	N 8kt
8811	1215	59.2 S/	46.5 W	ESE 6-	OBSCSchneefall	-1.3	96	971.4	-1.0	0.5m W 3kt
8811	1218	58.9 S/	46.5 W	S 5-	OBSCSchneefall	-1.2	96	969.1	-0.9	1.5m N 3kt
8811	1221	58.8 S/	46.5 W	SSW 6+	8/8 Schneefall	-1.8	96	969.5	-0.7	2.0m N 3kt
8811	1306	58.0 S/	46.5 W	SW 6-	8/8 bedeckt	-2.3	87	979.8	-0.5	2.0m N 8kt
8811	1309	57.8 S/	46.5 W	SW 5	8/8 bedeckt	-2.6	88	982.1	0.0	2.0m N 3kt
8811	1312	57.8 S/	46.5 W	SW 4	8/8 bedeckt	-2.1	85	983.5	0.1	1.5m Station
8811	1315	58.0 S/	46.7 W	SSW 4-	8/8 bedeckt	-2.0	84	984.1	0.0	1.0m SE 3kt
8811	1318	58.3 S/	47.2 W	SW 4-	8/8 bedeckt	-2.0	83	984.8	-0.3	1.0m SE 8kt
8811	1321	58.8 S/	47.8 W	SSW 4+	8/8 bedeckt	-3.1	75	985.3	-0.2	0.5m SE 13kt
8811	1406	59.9 S/	49.6 W	S 4+	8/8 bedeckt	-6.5	82	986.4	-1.2	SE 8kt
8811	1409	60.1 S/	49.9 W	SSW 5-	8/8 bedeckt	-6.0	86	987.1	-1.6	SE 3kt
8811	1412	60.4 S/	50.1 W	SSW 4+	8/8 Schneefall	-5.3	81	987.6	-1.5	S 3kt
8811	1415	60.3 S/	50.2 W	S 4+	8/8 Schneefall	-4.2	74	988.2	-1.2	NW 3kt
8811	1418	60.3 S/	50.1 W	SSW 4	8/8 bedeckt	-3.4	78	989.9	-1.4	E 3kt
8811	1421	60.3 S/	50.1 W	SSW 5-	8/8 bedeckt	-4.2	78	991.6	-1.3	Station
8811	1506	60.3 S/	50.1 W	SW 4-	8/8 bedeckt	-6.3	84	996.8	-1.4	Station
8811	1509	60.3 S/	50.0 W	SSW 2	8/8 bedeckt	-5.5	82	997.9	-1.4	E 3kt
8811	1512	60.2 S/	50.4 W	WNW 4-	8/8 bedeckt	-4.9	81	998.9	-1.4	NW 3kt
8811	1515	59.9 S/	50.9 W	NE 3	8/8 bedeckt	-3.7	81	998.9	-1.4	NW 8kt
8811	1518	59.7 S/	51.6 W	NNE 4+	8/8 bedeckt	-2.0	73	997.6	-1.2	NW 8kt
8811	1521	59.6 S/	51.9 W	NNE 7	8/8 bedeckt	-1.2	77	993.5	-0.3	1.5m NW 3kt
8811	1606	59.0 S/	53.5 W	W 6+	3/8 bedeckt	1.9	86	984.5	0.0	2.0m NW 8kt
8811	1609	58.8 S/	54.3 W	WNW 7-	7/8 diesig	2.5	85	986.4	1.9	2.5m NW 8kt
8811	1612	58.5 S/	55.2 W	W 7	8/8 diesig	2.4	81	989.0	1.4	2.5m NW 8kt
8811	1615	58.4 S/	56.0 W	W 7	7/8 diesig	2.4	80	991.8	0.3	2.5m W 8kt
8811	1618	58.1 S/	56.8 W	W 7	4/8 diesig	3.0	78	995.3	0.4	3.5m NW 8kt
8811	1621	57.9 S/	57.4 W	WNW 6	2/8 heiter	3.1	80	998.5	0.4	3.5m NW 8kt
8811	1706	57.4 S/	59.5 W	WNW 6	8/8 heiter	5.4	74	996.0	3.9	2.5m NW 8kt
8811	1709	57.2 S/	60.2 W	WNW 6-	8/8 bedeckt	6.0	7 1	993.5	4.0	2.5m NW 8kt
8811	1712	56.9 S/	61.0 W	WNW 6	7/8 fast bedkt	6.5	76	988.4	5.5	2.5m NW 8kt
8811	1715	56.8 S/	61.8 W	WNW 5-	2/8 heiter	5.6	83	987.1	6.1	1.5m W 8kt
8811	1718	56.6 S/	62.5 W	NNW 4-	6/8 wolkig	5.6	81	986.4	4.1	1.0m NW 8kt
8811	1721	56.3 S/	63.3 W							

2.1.4 SEA ICE CONDITIONS

H. Eicken and M.A. Lange

1. The large scale sea ice distribution in the western Weddell Sea

The western part of the Weddell Sea is one of the few regions of the Circumantarctic Ocean, which remains ice covered during the entire seasonal cycle of growth and decay of Antarctic sea ice. Within the oceanic Weddell Gyre south of approx. 62°S (i.e., the northern tip of the Antarctic Peninsula) this is a region of strong convergence, which inhibits the dispersal of much of the ice during summer months and leads to a perennial sea ice cover.

Because most of the ice formed in the Weddell Sea passes through this area and being partly trapped one can expect to find the oldest sea ice within the Weddell Sea in this region. This makes it an interesting place to study sea ice properties, because young and old ice can be observed in close proximity to each other. Most of the old ice is expected to have survived one summer, because transport rates of the Weddell Gyre amount to approximately one year for ice originating in the south-eastern part of the Weddell Sea and ending up in the western Weddell Sea. Young ice (i.e., of less than one year in age) is expected to be found here during winter and early spring. This is the season covered by the first leg of the EPOS-project.

On our approach to the ice edge, satellite pictures allowed for a first glance at the overall sea ice distribution in the western Weddell Sea (Fig. 9). This large scale distribution had changed little until the end of the cruise and can best be described in terms of three zones. In proceeding from the south northwards, these are the pack-ice zone of the inner Weddell Sea, the inner marginal ice zone (IMIZ) and the outer marginal ice zone (OMIZ).

The distinction made between an outer and inner marginal ice zone is a special feature of the western Weddell Sea. It can be explained in terms of two opposing forcings. On the one hand, persistent winds result in northward divergence of the ice field, while on the other hand the local geography, i.e., the location of the Antarctic Peninsula in combination with the prevailing oceanic currents lead to convergence. The IMIZ is the region, which represents the area that is primarily influenced by these two mechanisms, whereas the OMIZ belongs to the divergent regime. In the following the zonation of sea ice is described as observed in late October and early November.

1.1 The closed pack-ice of the inner Weddell Sea

In the inner Weddell Sea, i.e. south of approx. 62°S, closed pack-ice is the dominant form of sea ice during the winter months. The ice consists of giant floes measuring several kilometres to tens of kilometers. The floes themselves consist of smaller units, which become apparent by internal ridges that mark their old edges. However, in most cases a thick snow cover of 0.4-0.6 m obscures these ridges and the giant floes appear as relatively homogeneous units (Fig. 10). Their sizes are primarily determined by a system of leads, which can be observed on satellite pictures to cover the inner Weddell Sea (c.f. Fig. 9). These leads are an expression of the overall deformational regime the ice cover is undergoing while being forced by the circulation of the Weddell Gyre. They probably represent large shear cracks. They are places of intensive energy losses of the ocean to the atmosphere and are mostly covered by new ice and/or grey nilas. While the lead system appears almost stationary when observed over a period of a few days, the freshly formed cracks as frequently seen in the new ice cover indicate their on-going changes.

1.2 The inner marginal ice zone

To the north of the sea ice of the inner Weddell Sea lies a zone approx. covering 2 degrees in latitude, i.e. between approx. 62 to 60°S. We call this the inner marginal ice zone, because it consists of dense pack reaching 10/10 in concentration. However, what becomes evident when entering this zone from the south is a significant decrease in floe size from the kilometre sized floes of the inner Weddell Sea to less than 100 m. The floes in this zone have well defined polygonal shapes and mostly fall into a fairly narrow size range. Because they are not yet subjected to a divergent flow regime, there is little open water between individual floes. In most cases, the fragments of a previously much larger floe lie still in close proximity to each other and often form a giant "puzzle" (Fig. 11).

These features can best be explained by assuming that the smaller floes as found in this region are a result of breakage by ocean waves that penetrated the ice pack. It is well known that the further the swell penetrates the pack-ice the more it is reduced in intensity. While the small wavelength components of the swell are rapidly damped out in the outer part of the pack-ice field, the longer wavelength components can travel further into the pack. Here they lead to bending movements of the closed ice cover, which eventually fails under tension. Since highest tensile stresses occur at the crests of the swell, a regularly spaced crack system should be expected closely adhering to the dominant wavelength of the swell. This explains the narrow size spectrum of the observed floes. Once the energy of the wave has been expended, little or no further damage will be done to the pack-ice and its floes remain intact, except they are moved further north where they are affected by shorter waves.

1.3 The outer marginal ice zone

North of approx. 60°S, the pack-ice undergoes extensive divergent movements. This leads to decreasing ice concentration until towards the outer edge of this zone at approx. 58°30'S the ice remains only as stripes of some hundred meters width and concentrations below 3/10 in open water (Fig. 12). North of this position only patches of sea ice and scattered floes remain. This zone appears much more diverse in ice conditions than the zones to the south of it. Here one finds a surprisingly large number of old floes. However, they are apparent only because they preferentially survive wave induced breakage in contrast to younger and thinner floes. The latter remain only as brash ice whose concentration is much higher in this zone than anywhere else. It is also in this zone, where floes are largely disintegrated by bottom melting.

2. Sea ice conditions along the cruise track

While moving through the ice covered waters of the western Weddell Sea, continuous ship-based ice observations were carried out. They followed a standardized scheme and consist of estimates of ice concentration, mean floe size, snow cover thickness and the amount of rafting and ridging. In addition, photographs on the port and the starboard side of the ship were taken. These observations were supplemented by aerial photography and aerial video footage acquired with the use of a helicopter.

Our cruise track consisted of two tracks that led into the inner pack and two going out from here into the open ocean. In the following, we will describe major properties of the sea ice cover along each of the tracks; they are also depicted in Fig. 13.

2.1 First southbound track (Oct. 17-21)

We encountered the first ice bands of the outer marginal ice zone (in the following abbreviated as OMIZ) on Oct. 17 at 60°05'S. For the next 80 nm, little changes were observed and only scattered floes were encountered. Between 61°21'S and 61°45, ice concentrations gradually increased from 3/10 to 9/10, with floe sizes not exceeding 10 m. South of 61°45'S to 61°57'S typical floes of the inner marginal ice zone (in the following abbreviated as IMIZ) with sizes slightly above 10 m were passed. From here to the southernmost point of this transect (62°42'S) we entered the closed pack-ice of the inner Weddell Sea. Here, floe sizes exceeded 1km and frequent leads were noticed along our track. The leads extended for some kilometres having widths of several hundreds of meters. They were partly covered by grey and white nilas. Thus, the local ice coverage decreased to 6/10 in the vicinity of the large leads. We used one of the large leads for our first time station, while lying alongside a giant floe of old ice.

2.2 First northbound track (Oct. 22-27)

After travelling to the west, we started our way north on Oct. 22, leaving the closed pack ice zone at approx. 61°46'S. From here to 60°S, we traversed the IMIZ where we found variable concentrations from 10/10 to as low as 5/10, floe sizes not exceeding 100 m. In the northern part of this traverse, we passed through two stripes of high concentration some 10 to 15 nm wide. They consisted mainly of older, reworked floes with highly ridged edges. The amount of brash ice increased, reaching about 50% of the ice present at 60°18'S. Also, clear signs of melting along the sides and the bottom of floes were seen. North of the dense ice bands, the OMIZ was traversed, again being characterized mainly by bands of rotten white ice and brash consisting of floes < 10 m and showing increasing melting.

2.3 Second southbound track (Oct. 27-Nov. 4)

For about 100 nm, we followed the same track as going out of the ice in the OMIZ. At 59°50'S, we entered the IMIZ, where ice concentrations increased again to 9/10. To about 62°20'S, ice conditions changed little, with angular floes of up to 100 m in size dominating the pack. Between these floes, remnants of older floes were observed and identified mainly by the higher amount of ridging they exhibited. South of 62°40'S, we travelled through the closed pack again. We observed a fairly high concentration of young ice (20%) covering previously open leads. Both old floes of 1.5-2m in thickness and younger floes of < 1m were seen in varying proportions but in both thickness classes exceeding 100m in size. We reached our southernmost point on Nov. 4 at 63°11'S in closed pack of two- and multi-year ice, using the leads as a manageable way of making progress in a navigationally difficult region.

2.4 Second northbound track (Nov. 4-13)

On our way out of the ice again, we had to pass first the closed inner pack to approx. 62°18'S. Conditions were very similar to what we had observed on the southbound track. North of this position, we entered the IMIZ with floe sizes decreasing to 100 m or less. Compared to the first southbound and northbound tracks, the IMIZ appeared to be more extensive covering about two degrees in latitude compared to about 60 nm in the earlier traverses. North of 61°38'S, although still in the IMIZ with 10/10 ice concentration, floe sizes decreased to several tens of meters. Using thicknesses as estimates for floe age, most of the ice encountered in this region consisted of two-year ice. At approx. 60°30'S, we left the IMIZ and went to a region of about 50% open water and with ice consisting to equal parts of brash and old floes of white ice of up to 100 m in size. The OMIZ extended to 59°30'S, north of which only scattered bands and patches of ice were encountered. However, between 59°59'S and 59°43'S, another zone of high ice concentration (8/10) was observed, consisting mainly of brash ice and old white ice in equal amounts. This was followed by the typical bands and patches of sea ice of the OMIZ. North of 58°30'S, only occasional bits of brash ice were encountered.

2.5 Third southbound track (Nov. 13-15)

On a last shorter traverse into the ice we reached the position of Oct. 24 again, at the edge of the IMIZ and the OMIZ. Compared to the earlier ice condition, little had changed (c.f. Fig. 9), particularly south of 60°S. The only noticable difference was an extension of the ice edge to ~59°S. Also we encountered a zone of somewhat higher ice concentration between 59° and 59°30', which was not observed in the earlier, more westerly tracks. Similar to our earlier observations, we observed primarily bands and patches of old white ice and brash between 59° and 60°S. Here, ice concentrations as well as floe sizes increased to 6/10 and < 100m, respectively. Both angular and rounded floes as well as brash ice prevailed in this part of the IMIZ. We left the ice again, going north through the OMIZ. It was in this zone (Oct. 15) that first significant signs of surface ablation were observed. In addition bottom melting was prominently displayed on most floes observed.

Figure 9 Photograph of a satellite picture in the visible obtained from the Soviet Meteor-weather satellite on Oct. 26 1988. The picture covers the region from appr. 40 to 65°W and 60 to 73°S. Dark pixels represent open water and light pixels ice covered water or clouds.

Figure 10 Photograph of a typical situation in the central pack-ice, taken from the helicopter. The prominent feature in the center of the photograph is a partly refrozen lead. In the upper right-hand corner, "Polarstern" can be seen for scale.

Figure 11 The inner marginal ice zone as seen from the helicopter. The larger floes in the foreground measure appr. 20 - 30 m in their smallest dimension.

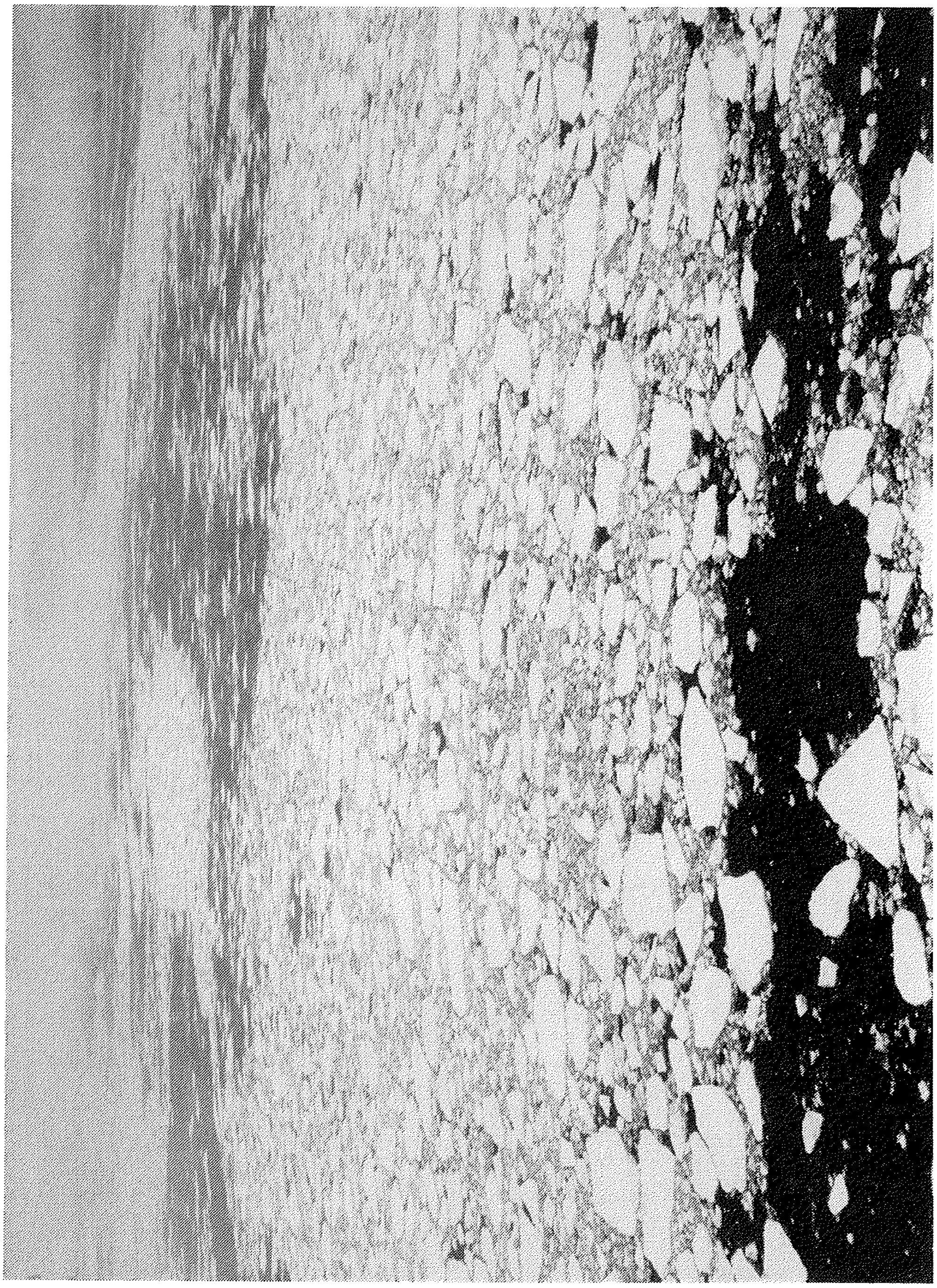


Figure 12 Photograph of the outer marginal ice zone from the helicopter. The triangular floe in the foreground has a sidelength of appr. 20 m.

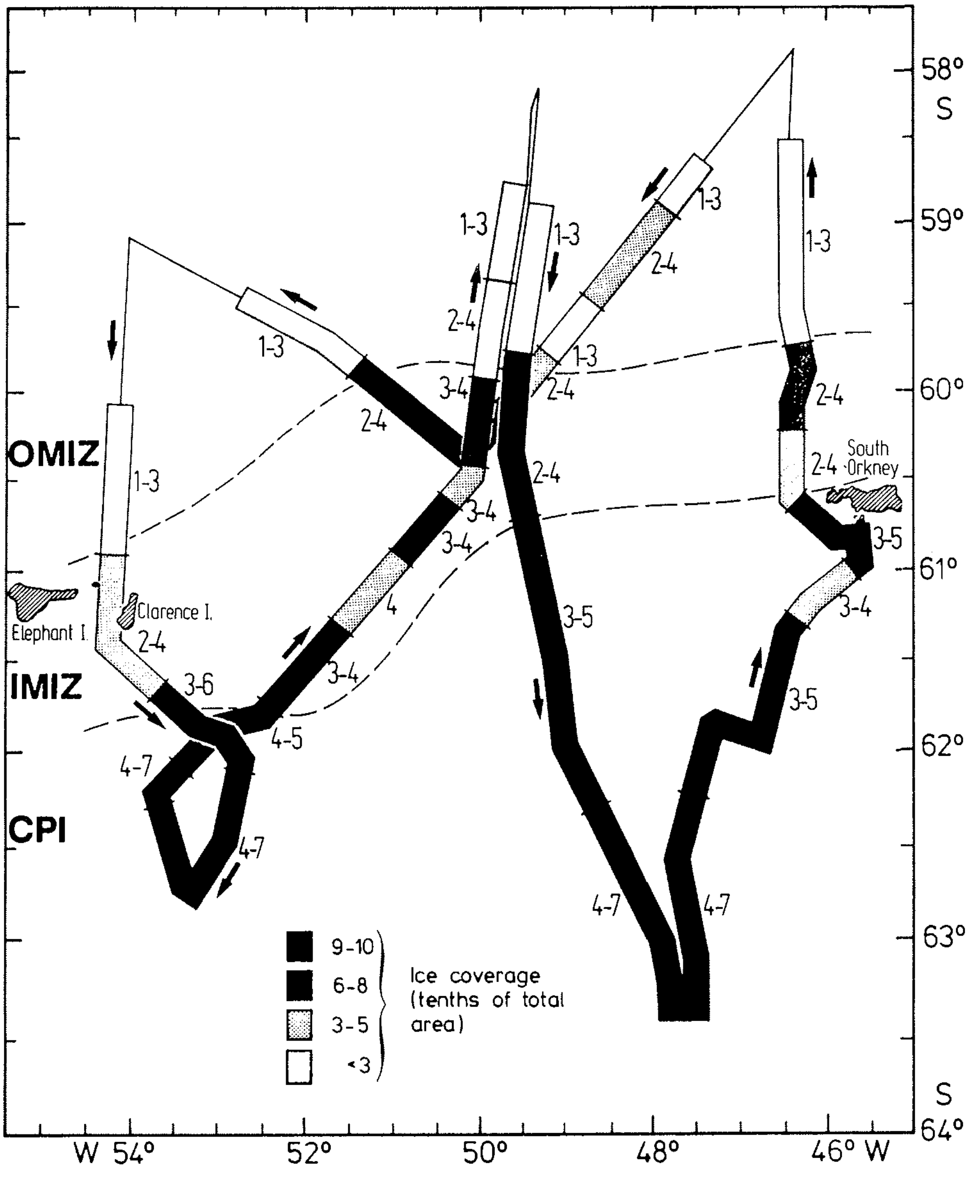


Figure 13 Sea ice conditions along the cruise track. Given are the ice coverage in tenths of total area (shown as different signatures as explained in the figure) and the mean floe sizes for specific parts of the track. Floe sizes are indicated by numbers next to the track line; we use the following floe size classes, 1:<1 m; 2:1 to 3 m; 3:3 to 10 m; 4:10 to 100 m; 5:100 to 1000 m; 6:>1000 m; 7:vast. The dashed lines indicate the boundaries between the closed pack (=CPI) and the inner marginal ice zone (=IMIZ) and the IMIZ and the outer marginal ice zone (=OMIZ).

2.1.5 SCIENTIFIC DIVING

B. Bergström, A. North, B. Seim and E.E. Syvertsen

Introduction

Diving from "Polarstern" was necessary to undertake sampling and performing *in situ* experiments in the sea ice of the Inner Marginal Ice Zone (IMIZ) and the pack-ice of the inner Weddell Sea, which cannot be done using conventional methods from above the ice surface, or, by the use of a remotely operated vehicle. Diving was restricted by rules to make it as safe as possible. These rules worked well in practice, yet allowed the scientific work to be done. Generally four divers, one support person and the ships doctor formed the ice-based diving team with a look-out in radio contact on the ships bridge. Besides the four regular divers G. Dieckmann had one test dive.

Diving Logistics

To carry out the diving in the safest possible way the following rules were adopted:

1. All diving equipment used was constructed to withstand the most rigorous polar conditions, and consisted of drysuits, full-face masks with telephone, and environmentally protected demand valves.

2. Diving was restricted to within 500 m from the ship and in easy view of the ships bridge, and usually at least 50 m away from the ship to avoid the ship's thrusters and propellers.

3. There was always one person on the bridge, in radio contact with the dive team, on the lookout for leopard seals, closing leads or other potential hazards to the divers.

4. There were usually two divers in the water simultaneously, on separate lines tended by trained dive tenders communicating to the divers by line signals. At least one diver and tender were in contact by underwater telephone (normally both). At least one of the dive tenders was a fully equipped diver able to go into the water at short notice if necessary.

5. At each dive a further person was present to maintain radio contact with the ship's bridge. He also carried a signal pistol and flares to be used to scare off large predators such as leopard seals which were considered a threat.

6. The ship's doctor was present at the dive site with oxygen breathing equipment and an extensive medical kit.

7. Diving was restricted to less than 10 m depth and less than 30 m distance under the ice-edge.

Following these regulations all diving was undertaken without accidents or technical problems.

Preliminary results

Diving was performed on a total of 25 different occasions. These, and the work performed, are summarized in Tab. 2 which also shows that there was considerable cooperation between the divers and other research groups. More than 100 samples were collected, three *in situ* experiments were performed and extensive photgraphic documentation was obtained. Scientific work, with the number of sampled sites in parentheses, included: samples of algae (15), amphipods (23), bacteria (11), krill (19), fish (8), nutrients (11), salinity (8); still photography (14), stereo photography (11), and video (5); and others including light measurements. Further details of the results should be obtained in the relevant section of the report e.g. preliminary results from diver collected samples in the chapters on "Ice-algae", "Krill" etc..

Evaluation of diving as a scientific method

As previously mentioned the great asset of diving is the ability to undertake sampling, *in situ* experiments and observations where no other method can be utilized. This is partly due to the inaccessibility of the under-side of the ice to conventional sampling methods. However, there is a great advantage in the divers ability to perceive the total picture of the under ice habitat and choose an appropriate area for sampling and experiments; This cannot easily be done by lowering instruments through holes in the ice. Similarly the picture obtained through the camera lens of an ROV is considerably restricted compared to that perceived by the human eye. Diving in the pack-ice in winter benefits from the enormous transparency of the sea water with vision ranges of 40 m or more.

Scientific diving as undertaken during EPOS Leg 1 kept the risks to an absolute minimum. Risks were lowered by self-imposed restrictions in depth and radius of underwater action. As a result the diving operations have had safety margins almost unheard of in any other kind of diving. However, the limited area of operation has also been the single scientific drawback of the diving. In this respect the considerably larger underwater radius of action of the ROV, and the possibilty to drill holes anywhere from the floe surface are methods superior to diving in covering a larger area. Thus the best use of diving is not by replacing it for other methods, but by utilising it in cooperation with them.

Table 3. Dive activities during EPOS I, 1988

#	DATE	STATION	ALGAE	AMPHIPODS	BACTERIA	KRILL	FISH	NUTRIENTS	‰	IN SITU INCUBATION	SIMULATED IN SITU INC.	LIGHT MEASUREMENTS	STEREO	STILLS	VIDEO	NOTES
1	2010	87	X	X								X	X	X		TEST DIVE
2	2110	89	X	X		X		X	X	X		X	X	X		
3	2110	89	X	X		X				X						
4	2210	89		X				X								
5	2310	92	X	X	X	X	X	X	X		X	X	X	X		
6	2910	109	X	X		X	X	X	X				X	X		
7	3010	111	X	X		X	X	X	X	X	X	X	X	X		
8	3110	113	X	X	X	X	X	X	X			X	X	X	X	
9	111	115	X	X	X	X	X	X	X				X	X	X	
10	111	116														ROV SALVAGE
11	211	118	X	X	X	X		X	X							
12	311	119	X	X	X	X		X					X	X		
13	411	119		X	X	X								X	X	EYE AND UV
14	411	119		X		X										
15	511	120		X	X	X							X			
16	611	122	X	X	X	X	X	X	X		X	X	X	X	X	
17	711	124		X	X									X		
18	711	125		X			X							X		
19	811	125	X	X	X	X	X	X					X	X		SED TRAP
20	811	125		X		X										
21	911	127	X	X	X	X										
22	1011	SIGNY	X	X										X		ROCKY BOTTOM
23	1111	131		X		X										
24	1411	140	X	X		X									X	
25	1411	141				X										CO DIVE ROV

2.2 REPORTS OF WORKING GROUPS

2.2.1 PHYSICAL AND CHEMICAL OCEANOGRAPHY

2.2.1.1 Physical oceanography

A.M. Larsson, P.-I. Sehlstedt, G. Ljungek, A. Paviglione

Objectives

The objectives for the physical oceanography group during the EPOS I cruise was

- to work in close conjunction with the biologists, to support them with the necessary physical enviromental framework for the ecological studies,
- to study fluxes of nutrients in the water column in different types of Antarctic areas; the open water zone, the marginal ice zone and the pack-ice zone,
- to study if and how the stability of the water column, or the mixed layer depth, is related to the depth of the euphotic zone and biological activity,
- to study the physical and chemical properties of the water immediately underneath large ice floes (see 2.25).

Work at sea

CTD measurements with a Neill Brown Mark III sonde were carried out at 63 stations in four sections. Temperature and salinity were usually recorded down to 600 meters at more shallow stations and to 1000 meters at deeper ones. At two occasions the CTD-profile was recorded down to 3000 m. Water samples were collected at standard depths (2, 10, 20, 30, 40, 60, 80, 100, 120, 150, 200, 300 m) with a Rosette-sampler, containing 12 Niskin-bottles of 12 litres each. Attached to the Rosette was a Neill Brown Smart CTD, a light-meter and a fluorescence-meter. Deeper water-sampling was performed at two occasions by single Niskin-bottles attached on the wire and closed with messenger.

From each station selected samples for salinity and oxygen were taken. Salinities were measured by a Guildline Autosal laboratory salinometer. Oxygen titrations, according to the Winkler method, were kindly performed by Mr G. Kraay. The endpoint for the titration was recorded by photometer. Furtheron, samples for ammonia and phosphate from nine Rosette depths have been analyzed at all time-stations and at those long-stations, where also CTD from the ice was performed (see 2.25)).

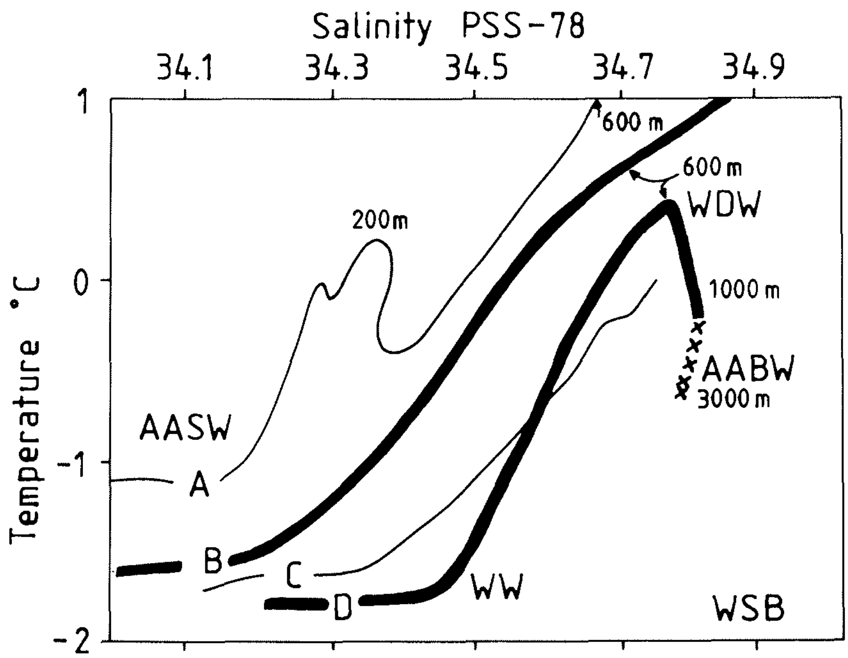
Preliminary results.

A TS-diagram for some stations shows the different main watermasses along the four transects in figure 14. The Weddell Sea Winter Water (WW) was found south of stn 105 in the surface layer, extending down to 100-150 m. This is a cold watermass with salinities between 34.2 and 34.5 PSS. The lowest temperature recorded under this cruise was -1.86°C, which is just above the freezing point. North of stn 105 the Antarctic Surface Water was found. This watermass has higher temperature and lower salinity than WW. Deeper, at about 600 m, extends the Warm Deep Water with temperatures above 0°C. At the deep cast on stn 114 the cold Antarctic Bottom Water was found below 2500 m depth.

Variations in temperature during the third transect, which ended at Lat. 63:20 and included stations 99-119, is drafted by computer as a section diagram in figure 215 This shows, that the northernmost station was located on the southern part of the Weddell-Scotia Confluence Zone, with -0.6°C in the surface water. In the Marginal Ice Zone and in water covered with ice a thermocline is established on depths between 100-300 m.

The fluctuation of the thermocline and halocline was recorded during 4 timestations with CTD and nutrient measurements every six or four hours. The preliminary analysis of data from station 125 gives that the thermocline-depth moves up and down 25 meter during 24 hours.

Oxygen measurements in the four sections show higher values in the open water than in water covered with ice. In open areas the surface waters are saturated with oxygen, with maximum values of about 380 µM at stations 135-138. In the ice covered areas the saturation is only 80% even in the surface water. Interesting is also that an oxygen maximum was found at 20-40 meters depth for many stations.



Watermass: AASW - Antarctic Surface Water
WW - Weddell Sea Winter Water
WDW - Warm Deep Water
AABW - Antarctic Bottom Water
WSB - Weddell Sea Bottom Water

TS-station: A - station 137
B - stations 100-104
C - station 105
D - stations 106-114

Figure 14. TS-diagram for some stations in two transects including stations 99-119 and 119-140.

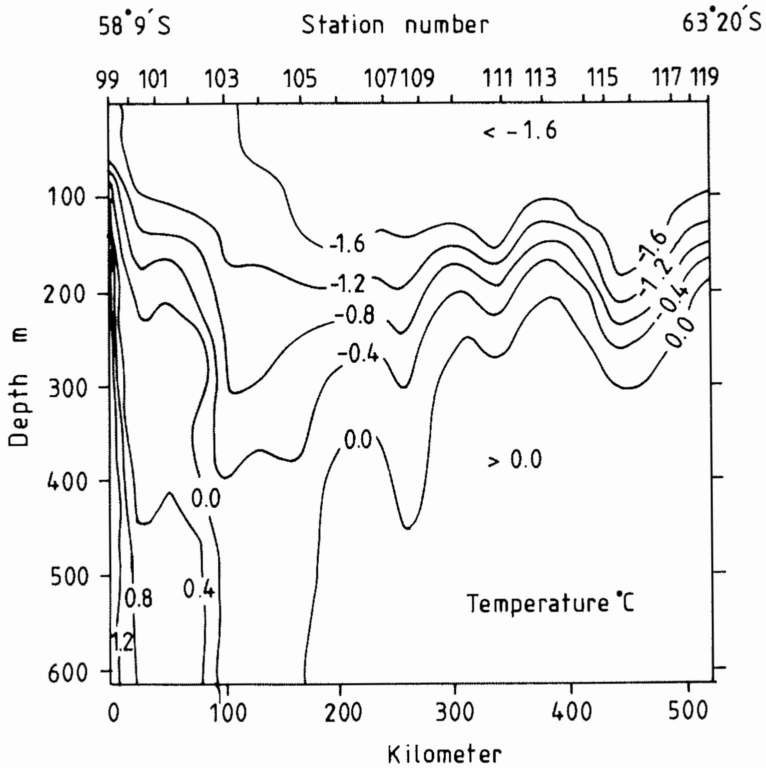


Figure 15. Temperature section diagram for stations 99-119.

2.2.1.2 Seawater CO_2 System.

JM. Bouquegneau, C. Joiris , W. Overloop

Objectives

In the framework of the well known problem resulting from the release in the atmosphere of fossil fuel CO_2, the study of the seawater CO_2 system of the Antarctic ocean is of particular interest due to the scarcity of available data and because the Antarctic convergence is one of the main sinks of the anthropogenic CO_2 for the deep ocean. The whole CO_2 system will be described after calculations from pH and alkalinity determinations. When the alkalinity is remaining constant, the pH variations may reflect changes in local temperature or dissolved CO_2 level (such as the one induced by photosynthesis and respiration). On the contrary, the alkalinity, which is not affected by such changes, can be considered as a conservative parameter allowing to characterize the water masses and their movements.

Work at sea.

Water samples have been taken at most of the stations, at different depths for later determination of alkalinity by electrotitration in the laboratory. pH has been electrochemically measured either directly in situ or from Niskin bottles immediately after sampling.

Preliminary results.

The emf developed by the pH cell is shown in figure 16. pH values will be calculated by taking into account salinity, temperature and standardization data. Nevertheless, due to the low temperature gradient between 58°S and 64°S, the emf pattern allows a preliminary discussion in term of acidity. So, it appears that emf (pH) is particulatly low in the water completely covered by ice. In open water, the values are higher and close to normal values for the ocean. A clear maximum was noted close to the surface between stations 14/134 and 14/138, where a maximum of chlorohpyll was also detected (cf data by Dieckmann).

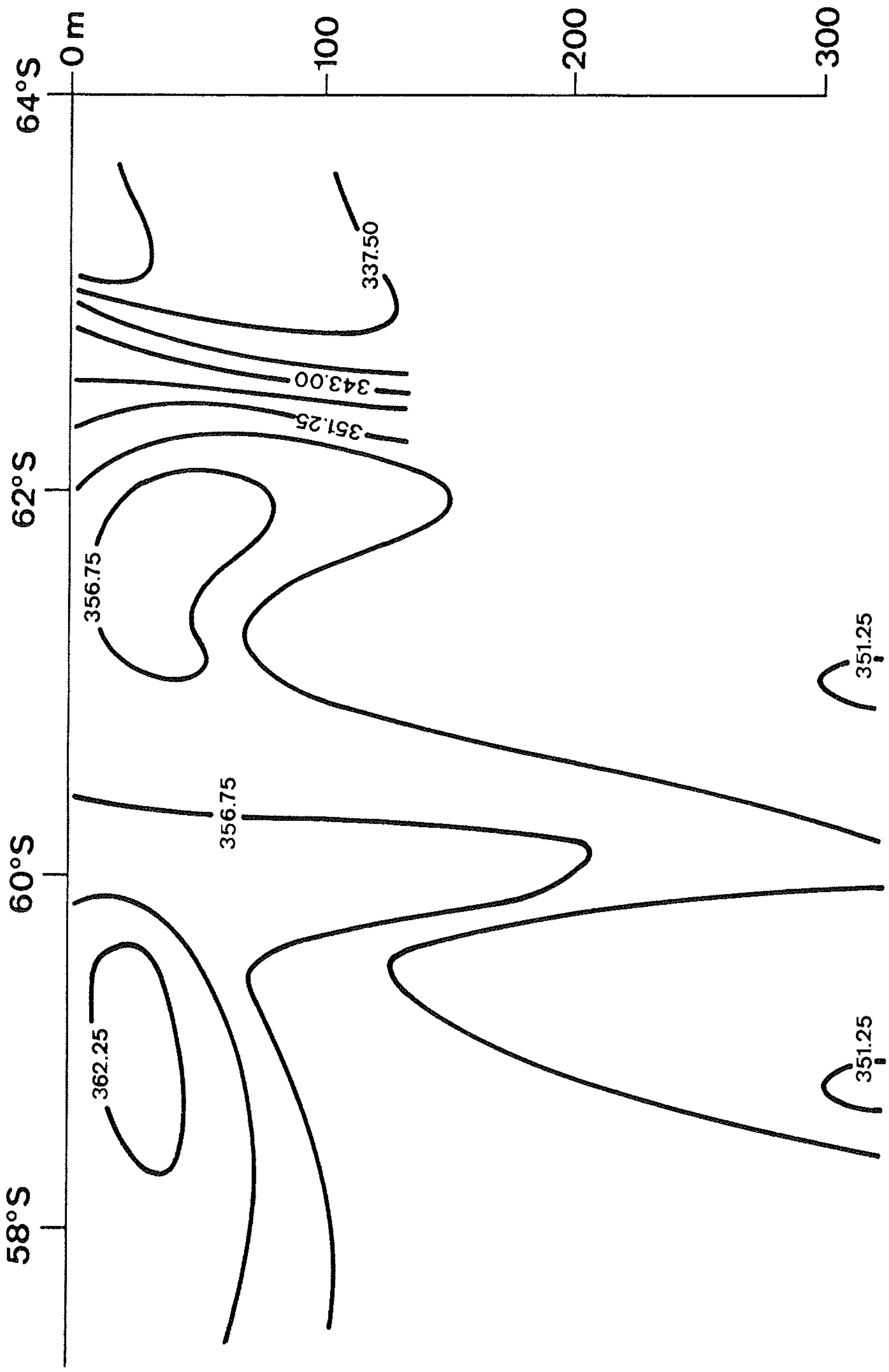


Fig. 16. Emf values recorded along the transect from station 14/117 to 14/139.

2.2.2 THE UNDERWATER LIGHT CLIMATE

W. W. Gieskes, R. Heusel, G. Kraay, M. M. Tilzer

The water of the Southern Ocean is only to a minimal extent influenced by terrestrial inputs and consequently has an extremely low content of allochthonous seston and gilvin ("Gelbstoff"). Phytoplankton and other suspended particles, therefore, should play a greater role in influencing the optical properties of the water than in other water bodies. We believe that these optical characteristics also have important consequences for the energetics of the production process of phytoplankton.

Objectives

i) To describe the optical properties of Antarctic Ocean water both in the visible and in the ultraviolet spectral ranges.
ii) To examine and quantify the impact of phytoplankton and detritus on water transparency.

Work at sea

Our work included measurements both in situ during station work and in the laboratory on collected samples.

i) Underwater spectroradiometry: On 26 stations a total of 32 underwater light profiles were assessed to a maximum depth of 75 m. A Model MER 1010 underwater spectro-radiometer (Biospherical Instruments, San Diego,U.S.A.) was used. This instrument is equipped with a cosine receptor. Underwater irradiance spectra were automatically recorded at 12 wavelengths between 410 and 694 nm every 10 milli-seconds. Ten scans were averaged and stored on-line by computer. At the same time, incident irradiance was measured by a spherical sensor for integral photosynthetically active radiation (PAR) on deck as a reference for the underwater measurements.

   The assessment of each light profile consisted of two casts: downwelling irradiance was recorded with the light sensor facing upwards, and upwelling radiance by turning the instrument by 180 degrees.

   Both data acquisition and reduction were performed by using a software package provided by the manufacturer. In addition, calculation programmes were developed on board by one of us.

ii) Underwater UV measurements: Immediately following the spectro-radiometer casts, UV was recorded at 30 stations down to a depth of 27 m by an underwater ultraviolet sensor developed by N.I.O.Z.,Texel, The Netherlands. This instrument records UV radiation at 4 wavelengths between 340 to 405 nm. The data were stored on a LiCor data logger and thereafter printed and evaluated.

iii) Secchi-depth readings: During a total of 20 stations Secchi-disk readings were performed by using a Secchi disk of 35 cm diameter.

iv) In vivo light absorption spectra of suspended matter filtered onto Whatman GF/C filters were registered by using a LKB Ultraspec spectrophotometer. The spectra were plotted on a printer.

Preliminary results

i) Underwater spectra of photosynthetically available radiation (PAR) and phytoplankton abundance:

At most stations, downwelling underwater radiation was chararacterized by maximum water transparency in the blue spectral range (488 nm). Chlorophyll a concentrations at these stations roughly ranged from 0.1 to 1.0 mg m^{-3} (chlorophyll measurements by G. Dieckmann and E.-M. Nöthig). Only at the stations with chlorophyll concentrations well above 1 mg m^{-3} (Stations 135 - 139) maximum water transparency shifted somewhat towards the green with a rather broad waveband of maximum transparency (488-540 nm).

This shift in the spectral properties of the underwater light can be explained by the spectral absorption and scattering properties of algal suspensions which absorb most of the light in the blue spectral range (see iii, Fig. 19). Overall transparency then was greatly reduced. Red light, by contrast, is rapidly absorbed by the water molecules themselves and showed considerably smaller sensitivity to chlorophyll concentration (Fig 17).

The vertical light attenuation coefficient (Kd) was evaluated for each of the 12 wavelengths where underwater irradiance had been measured and will be used to quantify the impact of phytoplankton on water transparency as a function of wavelength and chlorophyll concentration. Vertical differences in chlorophyll concentrations led to corresponding variations of vertical light attenuation coefficients (Fig. 18).

Upwelling irradiance comprised less than 1 % of downwelling light (Fig. 17). It is caused by scattering of light by both water molecules and suspended particles. The spectral composition of upwelling radiance was very similar to that of downwelling light. This indicates that scattering from particles (which is largely wavelength-independent) is the major source of upwelling light. However, it remains to be examined to which extent the ratio of upwelling to downwelling irradiance depends on seston concentration or phytoplankton biomass.

ii) Vertical gradients of underwater PAR and Secchi disk transparency:
By integrating over the spectrum, overall gradients of PAR were determined. The penetration depth of 1 % of surface PAR ("euphotic depth", Z_{eu}) is frequently considered to be in a constant proportion to the Secchi depth (Z_s), and conversion factors of 2-3 are applied to predict euphotic depth from Secchi readings. We examined this relationship during this cruise. We found that the euphotic depth in fact was non-linearly related to the Secchi depth by

$$Z_{eu} = 16.9\ Z_s^{0.4} \qquad (1)$$

By using this equation, euphotic depths can be predicted from Secchi readings with reasonable accuracy (maximum error 17 %). The ratio of euphotic to Secchi depth increases with rising turbidity from values below 2 in very clear water to over 4 at the maximum phytoplankton biomass observed during our cruise (Table 4).
This non-linear relationship is explained by the fact that Secchi depth is more dependent on light scattering by particles than is vertical light attenuation. Our findings are in agreement with current theory but the non-linear relationship has only rarely been demonstrated empirically.

iii) Absorption of light by particulate matter:
At most stations suspended matter absorbing light clearly did not consist of phytoplankton alone: cultures of Antarctic diatoms dominant in the survey area grown on board absorbed less in the green, blue and ultraviolet part of the spectrum than filtered suspended matter in seawater samples; the additional absorption was due to detrital particles (Fig. 19). These particles could not be identified under the microscope; they were amorphous, in a size range between 1 and 50 µm.

iv) The contribution of phytoplankton and detritus to light absorption cannot be quantified precisely until the concentration of the algal pigments has been measured. This will be done at home in the laboratory by using HPLC (high performance liquid chromatography). However, comparison with absorption spectra of samples free of detritus (judged by microscopic observation) suggests a low but significant contribution of the detrital particles to overall light absorption, especially at wavelengths below 500 nm, all the way down to 200 nm.

The absorption of particulate matter on the filters at 16 wavelengths between 340 and 693 nm was closely related to the attenuation of light in the water at these wavelengths. This suggests that autochthonous particulate matter, both phytoplankton and detritus, has a greater influence on underwater light penetration in the Weddell Sea than has dissolved organic matter.

iv) The penetration of near-ultraviolet light into the water column:
At the stations with very clear water (Secchi disk visibility over 40 m), 10% and more of ultraviolet radiation (340 nm wavelength) measured above the water surface penetrated to 25 m; extrapolations indicate that

1% of surface UV is present at depths of up to 57 m. At these stations, all of which were located in the Southern part of the study area, attenuation of UV was usually highest in the upper part of the water column (Fig. 20). Here the vertical attenuation coefficient Kd was often twice as high as Kd at greater depths.

The higher absorption at 340, 365, 380, and 405 nm in the near-surface water layer was correlated with the presence of relatively high concentrations of particulate matter absorbing light effectively at these wavelengths (see section iii). Difference spectra of absorption by particulate matter on filters sampled at less than 0.5 m and 10 m depth are typical of detritus (cf. Fig. 19). The near-surface detritus layer was not only found near the vessel but also at the edge of ice floes distant from the ship (samples taken by Niskin samplers by Larsson, Sehlstedt and Ljungek and at one occasion by one of the divers).

The origin of the surface detrital layer, which was encountered in the study area wherever sea-ice was present, may have been heterotrophs consuming ice algae, the degradation products being flushed into the open water from underneath the ice. The enhanced levels of ammonia often observed at the very surface in leads and polynyas supports this view. Another possibility is that the surface detritus is older refractory material that accumulated at the surface over prolonged periods of time.

Attenuation of ultraviolet light by sea-ice was highest under ice with a snow cover. The clear ice of nilas, however, obstructed UV penetration much less.

Table 4: Euphotic depths (depth of 1 % of surface irradiance), Secchi depths,where measured, and ratios of euphotic depth to Secchi depth. Also given are predictions of euphotic depth from Secchi depth by using eq. 1 and errors of these predictions.

Station	Z_{eu}	Z_s	Z_{eu}/Z_s	Z_{eu} pred	error %
080	44.3	--	--	---	---
084	83.2	--	---	---	---
085	71.5	29	2.5	67.5	- 5.6
087	76.6	54	1.3	87.2	+13.8
089	93.0	50	1.8	85.8	- 7.7
089i	93.3	52	1.9	84.5	- 9.18
090	54.8	--	---	----	----
100f	62.0	15	4.1	51.5	-16.9
101	59.0	--	---	---	----
104	63.0	18	3.5	55.5	-11.9
109	98.4	34	2.9	111.7	+13.5
111	78.8	46	1.7	81.6	+ 3.6
113	49.5	--	---	----	---
115	72.0	38	1.9	75.5	+ 4.9
117	94.4	49	2.5	83.7	-11.3
119	92.9	49	1.98	83.7	- 9.8
120	83.1	48	1.7	83.1	0.0
122	67.0	28	2.4	66.5	- 0.7
124a	73.3	22	3.3	60.2	-17.9
125a	73.1	25	2.9	63.5	-13.1
125b	76.0	--	---	----	---
125c	77.0	--	---	----	---
126	58.1	28	2.3	66.5	-14.7
127	71.3	--	---	---	----
128	41.1	--	---	----	----
131	63.9	28	2.3	66.5	+ 4.1
135	35.1	11	3.2	45.8	+29.0
136	34.8	--	---	---	----
139	45.7	11	4.2	45.2	- 1.1

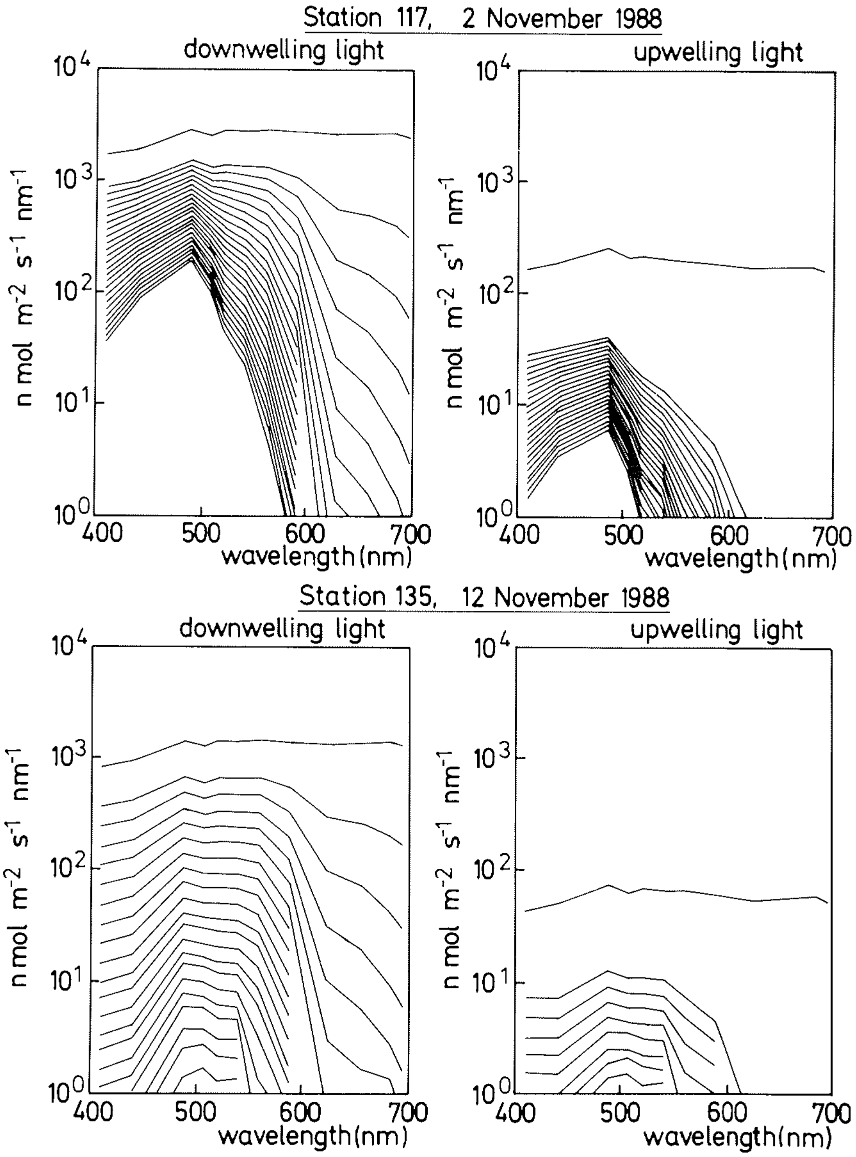


Fig.17. Underwater spectra at 2.5-meter depth intervals at the station with the highest (top panels) and with the lowest water transparency observed during the cruise (bottom panels). Left panels: downwelling, right panels: upwelling radiance. The spacing between the spectra reflects the degree of vertical light attenuation. The topmost spectral curves represent values recorded above the water surface. The spectral scans of Station 117 show typical properties of very pure water and are almost solely controlled by the optical properties of the water molecules. By contrast, the spectra of Station 135 are strongly influenced by phytoplankton and detritus both of which absorb blue light more efficiently than light of greater wavelengths.

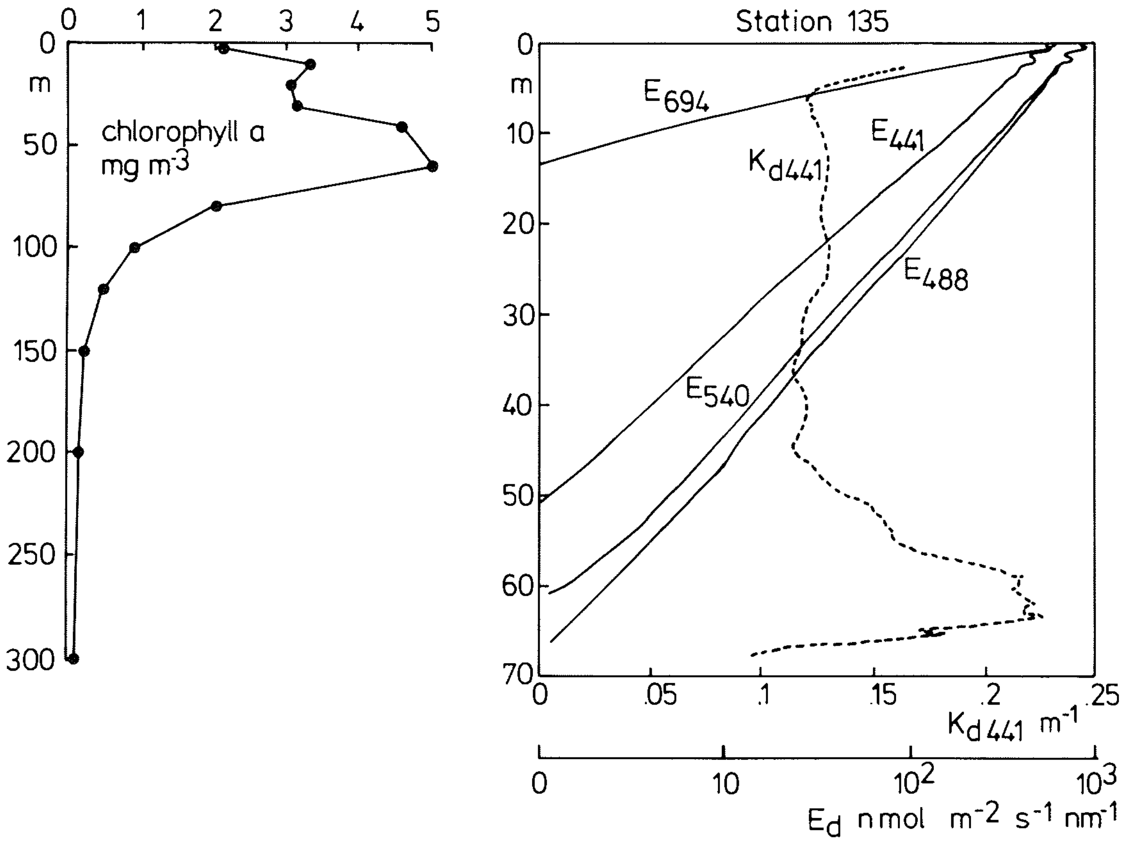


Fig. 18. Profiles of chlorophyll concentration (left panel) and semi-logarithmic plots of downwelling radiance at the 4 wavelengths indicated, as well as the vertical attenuation coefficient of light at 441 nm which corresponds with the blue in situ absorption maximum of chlorophyll. Note the difference in depth-scales in both panels. The chlorophyll concentration maximum at a depth of 60 m is clearly reflected in the corresponding maximum in the attenuation coefficient for blue light. Chlorophyll analyses by G.Dieckmann and E.-M. Nöthig.

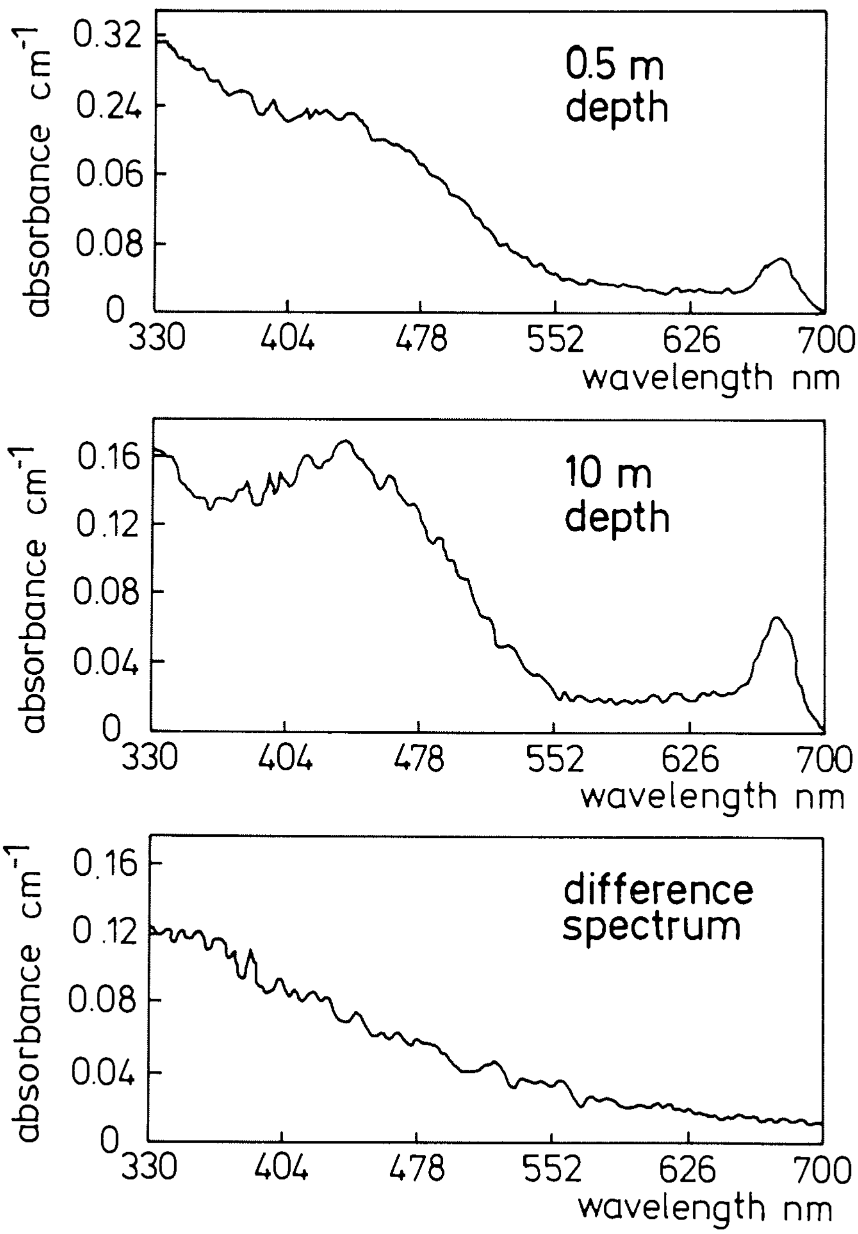


Fig 19.In vitro absorption spectra of suspended matter collected onto glass-fiber filters at 0.5 m and 10 m at Station 126. Dominance of diatoms at 10 m is reflected in the absorption spectrum. The difference spectrum is similar to the spectrum of detrital material alone which implies that at 0.5 m depth more detritus was present than at 10 m depth. Station 126 is representative for most stations in the survey area.

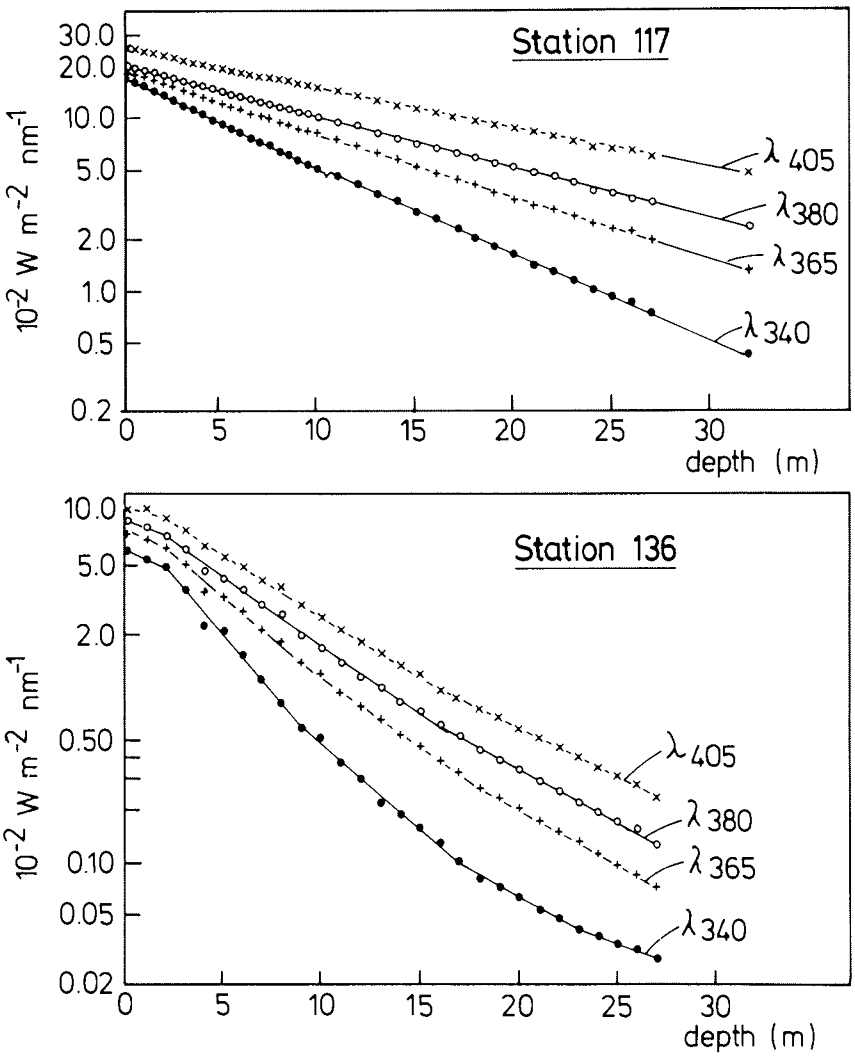


Fig 20. Penetration of ultraviolet light into the water at a station with very clear water (Secchi depth nearly 50 m, Station 117, see Fig. 17), and at open-water Station 136, located at the northern edge of the survey area (Secchi depth: 12 m).

2.2.3 SEA ICE PROPERTIES

M.A. Lange

Sea ice influences the transfer of energy, momentum and matter between ocean and atmosphere and plays a major role in the marine ecosystem of Antarctic waters. EPOS I led to an area of the Weddell Sea (appr. 59 - 63°S and 45 - 52°W), which uniquely provided an opportunity to assess the properties of two- and multi-year sea ice during late winter and spring. Here, sea ice can be found that has been transported primarily by the oceanic Weddell Gyre through the eastern and southern Weddell Sea. Because of the relatively slow transport rates, it is in this region, where sea ice might survive the summer season to become two-year ice. At the same time, former landfast ice that has broken loose will also be transported with the Gyre and will be found here. Thus, along with the one- and two-year ice, ice of even older age can be sampled.

With this in mind, we set the following goals:
(i) to assess the physical, chemical and biological properties of sea ice;
(ii) to determine the surface characteristics of the sea ice, both on a small (i.e., 20-30 m) scale and a regional scale (i.e., over some 10 - 30 nm);
(iii) to investigate the thickness distribution of ice and snow on a local to regional scale;
(iv) to evaluate the overall properties of the sea ice cover along the transect through the western Weddell Sea and
(v) to investigate the chemical and biological properties of brine in sea ice.

In order to achieve these goals, two basic approaches were followed. We performed in-situ measurements and took samples at 35 ice stations distributed along the cruise track (Fig. 21). Secondly, we have continuously monitored the ice conditions during a ship-based "ice watch" and have performed video- and standard photography along predefined patterns by using a helicopter at times during our track through the ice (Fig. 21).

In the following, we will give an account of the sea ice investigations performed during this expedition following the list of major goals as given above. The overall ice conditions have been described in 2.1.5 of this report.

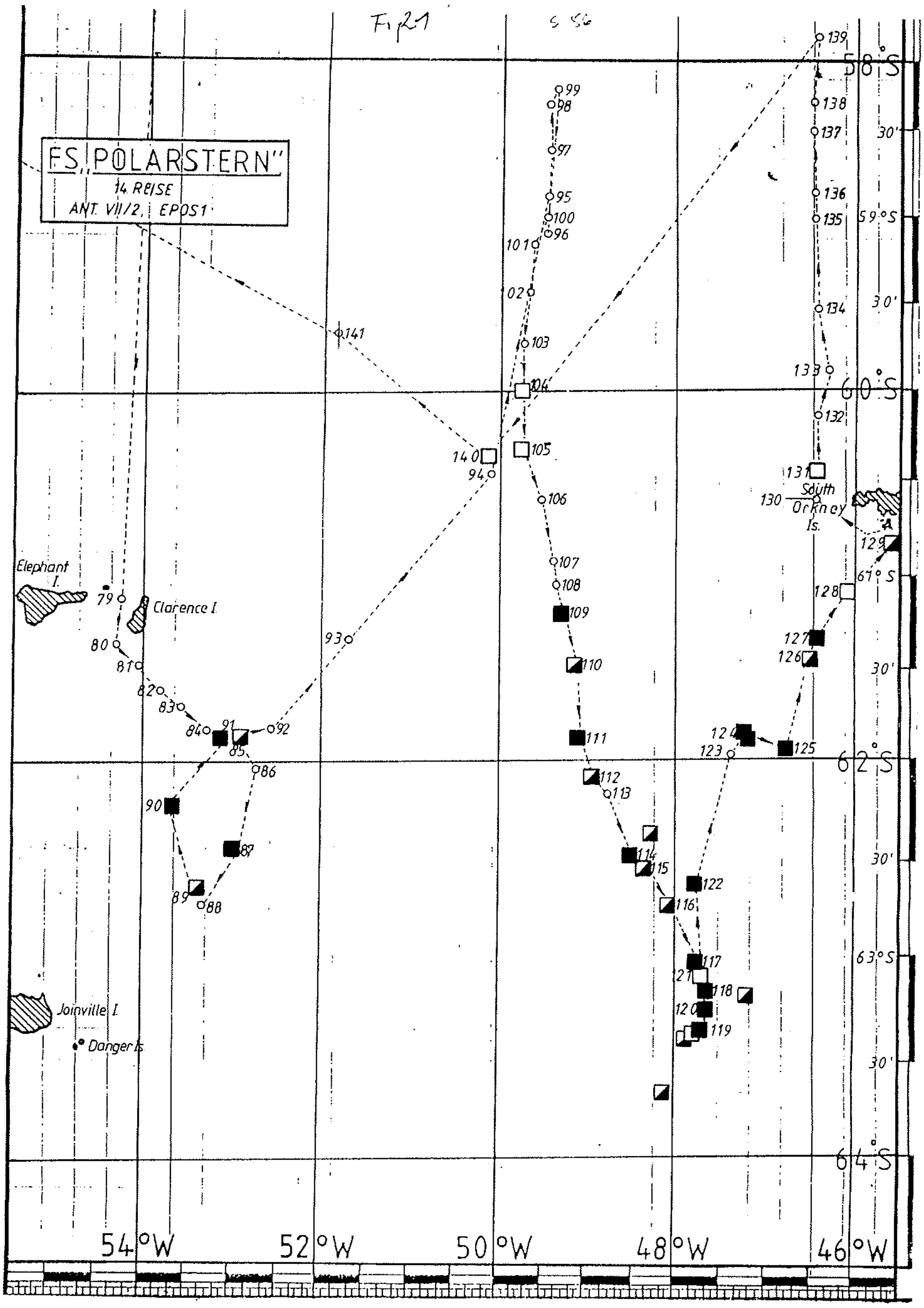


Fig. 21 Cruise track with positions of ice stations during EPOS I. Closed symbols denote full ice stations (coring, ice thicknesses, surface charcteristics, half-filled symbols denote reduced ice station work (coring, surface characteristics) and open symbols denote places at which only coring and a reduced surface characterization was performed.

2.2.3.1 Physical, chemical and biological properties of sea ice

G.S. Dieckmann, H. Eicken, M.A. Lange , P. Mursch, E.-M. Nöthig, R. Steinmetz

Objectives

Sea ice undergoes a variety of changes during its development, which are primarily driven by atmospheric and/or oceanic processes. In particular, the texture of the ice gives an account of these various processes, which can be deciphered by means of the stratigraphy of a sea ice core. The major objective of this project is the assessment of sea ice properties on ice cores and the determination of relationships amongst the physical, chemical and biological properties. Secondly, we want to determine the distribution of genetic ice classes among the floes sampled. Thirdly, we will compare the properties of one-year ice with those of two- and multi-year ice.

Work at sea

We performed in-situ measurements and sampled sea ice cores at 35 stations during our transect through the ice. The majority of stations was located between 60° and 61°21'S and 45°35' and 50°W. At each station, we collected at least two ice cores (yielding a total of 87 cores) and measured the temperature distribution in the ice on one core. One of the cores was subsequently analysed for texture, salinity and chlorophyll a content on board "Polarstern". A subsample for foraminifera counts was preserved for later analysis. The textural analysis preceded following work in order to allow assessment of sea ice properties according to ice texture. Additional, land-based work will include the measurement of density and nutrient content on one core of each station, species enumeration on selected samples, additional detailed structural studies on selected parts of ice cores employing digital image processing techniques and the determination of ^{18}O-concentrations on individual samples of selected cores.

Preliminary results

Presently, we have analyzed 29 cores for texture, 19 for salinity and chlorophyll a content and have measured temperatures on 35 cores. Ice temperatures range from -4.5 to -1.5°C, thus indicating relatively mild temperature conditions in the ice. The textural composition of the cores categorized according to 5 length classes is given in the following table . The selection of these classes, though somewhat arbitrary, follows our results from the ice thickness distribution (see below). Here we found that annual layer thicknesses lie at approx. 0.7 m. Thus thickness classes can roughly be regarded as age classes as well, starting with one-year or younger ice and ending at three or multi-year ice.

Table 5. Textural composition of sea ice

Thickness (m)	Number	Total length (m)	Polygon gran. (%)	Orbicul gran. (%)	Column (%)	Mixed gr./co. (%)	Interm. gr./co. (%)
0.00-0.75	5	2.395	4.0	77.7	13.8	1.2	3.3
0.75-1.50	7	8.755	11.1	45.2	35.4	2.3	5.9
1.50-2.25	10	18.760	8.5	45.6	34.6	5.8	5.5
2.25-3.00	2	4.715	8.7	49.2	30.1	5.7	6.3
>3.00	3	9.725	7.4	70.4	10.4	7.5	4.6
total	27	44.350	8.5	53.1	27.9	5.2	5.4

There is an obvious dominance of orbicular granular ice in all length classes. This is particularly evident for the thinnest and the thickest floes sampled, while in ice of intermediate thickness columnar ice attains fractions almost approaching those of granular ice. The amount of polygonal granular ice is relatively high, reaching more than 7% in ice thicker than 0.75m. However, it is often difficult to clearly distinguish orbicular granular from polygonal granular ice in thick sections. Since most of the polygonal granular ice represents meteoric ice, which became metamorphosed in the presence of sea water, there is an independent way of assessing the total amount of polygonal granular ice in a core. Because the negative signature in ^{18}O-concentrations as seen in meteoric precipitation is not lost when forming polygonal granular ice, measurements of ^{18}O along an ice core will help to better define the exact amount of polygonal granular versus orbicular granular ice.

We interprete the large fraction of granular ice as being a consequence of dynamic processes during ice growth. In the case of the younger ice (i.e., with thicknesses below 0.75m), the repeated formation of pancake ice and its rafting into increasingly thicker floes ("pancake cycle") contributes most to the large fraction of granular ice in these cores. Older floes (i.e., those with thicknesses above 3m) acquire their share of granular ice mostly during spring and fall, when ice concentrations become smaller and allow increased movement of floes within a pack ice field. This gives rise to increased rafting and ridging activities, both of which might increase the amount of granular ice in a given floe. In addition, the increased mobility of individual floes might create sub-ice oceanic conditions, which will enhance frazil rather than congelation growth.

Based on the proportions of orbicular granular to columnar ice, genetic ice classes are assigned to each of the floes sampled. The overall distribution of genetic ice classes is given as:

60 - 80 % frazil	37%
< 60 % frazil	7%
mixed frazil/congelation	22%
60 - 80% congelation	15%
<60% congelation	19%

The larger fraction of frazil (55%, when splitting the mixed fraction into equal parts) versus congelation ice (45%) also indicates that dynamic processes rather than steady thermodynamically driven growth dominates the overall development of ice in the Weddell Sea

The chlorophyll a concentrations in older ice cores (i.e., with thicknesses > 1.5 m) analyzed so far show local maxima at depth corresponding to summer conditions. The positions of these maxima roughly adhere to the annual growth rate as inferred from our thickness data and are separated by approximately 0.7 m. This gives the ice floes their characteristic banded appearance that was observed during our ice watches. In addition, a pronounced maximum close to the top of the cores indicates algal growth in an infiltration layer. Younger floes (i.e. with thicknesses < 1 m) show a maximum in their upper parts, also corresponding to an infiltration layer. In addition, a local maximum towards the bottom of the floe indicates increased biological activities at the onset of summer growth in the observation area.

Salinities are fairly well correlated with chlorophyll a concentrations in younger floes. In older floes, this applies only to the upper half of the cores, while in the bottom parts these quantities are less well related.

2.2.3.2 Surface properties of sea ice floes

H. Eicken and M.A. Lange

Objectives

Microwave brightness temperatures, as an important means of remotely assessing sea ice coverage and sea ice properties on a large scale, depend on:

- physical and chemical characteristics of the snow cover and of near-surface ice,
- distribution of floes belonging to different ice classes and
- the relative proportions of ice versus open water.

In order to determine these properties, a two-fold approach was taken in this project, having the following objectives in mind:

(i) assessment of the local surface properties of snow and the uppermost ice layers by means of standardized analyses at ice stations and

(ii) evaluation of distribution and relative amount of different ice surface classes and open water by use of helicopter-based video- and standard photography.

Work at sea

At most of the 35 ice stations during our traverse through the ice, we sampled the ice surface following either a fairly extensive standardized scheme or in a reduced way, where station time was limited. The standard scheme consisted of snow thickness measurements at 1m interval along three 1 m lines arranged around a central point at an angle of 120° to each other. At the central point and at the ends of each thickness line, snow pits were dug. They were utilized to determine the snow stratigraphy, a temperature profile to the snow-ice interface and snow densities at selected depths within the snow pack. At a limited number of stations, we also took ice cores of some 0.2-0.3 m at these points, in order to assess the near-surface stratigraphy and small scale salinity structure of the ice surface. In our reduced samplings, snow pit work was performed only at the central point of the grid. Most of the data and samples were analyzed on board "Polarstern". However, a detailed interpretation of the data will follow after the expedition.

Helicopter-video flights were performed 15 times during this expedition yielding a total of 15 hours video footage as well as some 400 still photographs. During these flights, a video camera was mounted outside the cabin in such a way as to enable a near vertical look at the ice surface. In most of the flights, we followed a standard pattern, which consisted of two quadratic boxes with 10 and 5 nm in size, where both boxes were centred around the current position of "Polarstern", the smaller box lying within the larger one. At three instances, instead of the standard box, we flew along a single rectangular box of 30 by 5 nm. While most of the photographs and some of the video footage has been inspected during the expedition, the major part of the analysis will be performed later. This will include visual definition of ice surface classes and their spatial and temporal distribution. Selected scenes of the video footage will be analyzed by means of digital image processing techniques allowing a more quantitative assessment of surface class distributions.

Both, the small scale as well as the regional scale surface characteristics obtained through our measurements will be compared to passive microwave data that have been acquired for the same time and region. Thus, we will try to relate the different data sets in order to gain insight into multi-spectral microwave signatures of specific ice surface classes as encountered during the expedition.

Preliminary results

Preliminary results will only be given for our small scale ice surface characterizations. Here, the snow stratigraphy and its small scale spatial variability is of particular interest. Stratigraphic data provide the clue for determining the development of the snow cover and allow estimates of properties likely influencing the emission of microwaves from the snow and the underlying ice floe. Of particular importance is the presence of refrozen melt layers and/or melt lenses and of depth hoar layers in the snow pack. On the one hand they indicate spring and summer conditions and can be used as stratigraphic markers, which help estimate snow layer ages. On the other hand, it is known that these layers influence microwave emissivities and are thus of particular importance in interpreting remote sensing data. In almost all of our stations, which were situated on one-year or older floes (i.e., with thicknesses > 1 m), we find melt layers at intermediate depths, mostly underlain by depth hoar. Depth hoar is also found on these floes close to the bottom indicating that the floe is probably of more than one year age. When looking at the small-scale variability, we find that most stratigraphic units occur at fairly constant relative (normalized to total snow thickness) positions and with approximately equal relative thicknesses, thus indicating that surface properties on a local scale can be characterized by means of our sampling technique. The same is true for snow thicknesses, which are usually found to have fairly low standard deviations and comparable mean thicknesses along each transect. This does not apply though at places with mean snow thicknesses < 0.2 m, which are found on young floes or on floes that have undergone extensive wind induced ablation of the surface snow. Here, the snow thicknesses vary to a greater extent and the stratigraphies are less uniform at the four sampling sites. On young floes and on older floes with thick snow covers, bottom layers of wet snow have been found. These layers are strongly modifying the microwave emissivity and are thus important features with regard to remote sensing data.

2.2.3.3 Ice thickness distribution

H. Eicken, M.A. Lange, P. Mursch and R. Steinmetz

Objectives

Snow and sea ice thicknesses largely influence the energy transfer between ocean and atmosphere. The ice thickness distribution in the western Weddell Sea , both when considering individual floes as well as when looking at floes on a regional scale reflect the overall mass flow in the Weddell Gyre as well as deformational processes the ice has undergone on its drift trajectory. Both, the surface and the bottom topography are a measure of surface roughness, which largely influences the drag coefficient of these surfaces to flow of the adjacent air and water masses. The snow thicknesses provide a measure for the atmospheric contribution to the overall ice thickness. Snow layer thickness in relation to ice thickness determines the position of the snow-ice interface and thus the amount of snow metamorphism into polygonal granular ice as well as the potential for the development of an infiltration layer community.

In order to address these questions, our objectives in this project are:

- to determine snow and ice thicknesses and freeboard heights along linear transetcs of up to 100 m, with a spacing between measurements of 2 or 1m at as many ice stations as possible;
- to derive thickness distributions on a regional scale in the western Weddell Sea and
- to interprete the ice thickness data in terms of deformational processes and overall ice development of the sampled floes in the observational area.

Work at sea

We measured ice and snow thicknesses on 17 floes along 19 profiles. The measurements were performed by direct readings in a total of 1300 drilled holes. At two sites we also measured thicknesses along profiles running perpendicular to each other. The data were subsequently input into a computer and statistically analyzed. Major results include the mean thicknesses of snow and their standard deviations, the probability density function (in the following abbreviated as PDF) and regression analysis of different thickness data (e.g., snow versus ice thickness) of profile data acquired on individual floes.

Preliminary results

The following table gives the major statistical results of our measurements. PDF's are shown in Fig. 22. As can be seen, we have classified our thickness data into four different categories (i.e., class I to IV). The differentiation was motivated by the overall PDF of our data. Fig. 22a-e, which shows a pronounced bimodal distribution with peaks at 0.4-0.6 m and 1.2-1.4 m and a weaker local maximum at around 2-2.2 m. Thus, the class II floes with a clear thickness maximum in the PDF at 0.4-0.6 (Fig. 22c) correspond to the first maximum in the overall PDF and probably represent one year and younger ice. The high standard deviation indicates large thickness variations due to rafting and ridging of ice in this class. Class III floes with a maximum in the PDF at 1.2-1.6 m (Fig. 22d) represent two year old floes that have undergone some, but significantly less ridging than seen in the class II floes. Floes of class I with a fairly diffuse PDF (Fig. 22b) probably consist of ridged portions of one- and two year old ice. The oldest ice found (i.e. more than two year in age), constitutes class IV of our thickness distribution and is characterized by a broad maximum between 1.4 and 3.2 m (Fig. 22e). Here the thickest ice with more than 4 m encountered during our expedition has been found. The extreme thicknesses of more than 2.5 m are due to ridges.

Snow thickness distributions can be even better categorized for each of the four floe classes, with the exception of class I floes. They appear to be covered by a snow layer of highly variable thicknesses. This is mainly due to snow drift induced thickening or thinning of the snow cover along ridges. Class II to IV floes show well defined maxima in their snow-PDFs that reach from 0.1 over 0.35 to 0.6 m, respectively

Table 6. Statistical results of snow and íce thickness measurements

Class	No of points	Mean value (m) Snow	Ice	Freeb.	Draft	Standard deviation (m) Snow	Ice	Freeb.	Draft
I	333	0.37	1.36	0.41	1.32	0.20	0.53	0.19	0.65
II	404	0.14	0.72	0.18	0.68	0.11	0.41	0.12	0.39
III	482	0.35	1.51	0.40	1.46	0.10	0.39	0.10	0.36
IV	85	0.58	2.53	0.66	2.46	0.09	0.58	0.12	0.53
all	1304	0.30	1.30	0.35	1.25	0.18	0.67	0.19	0.66

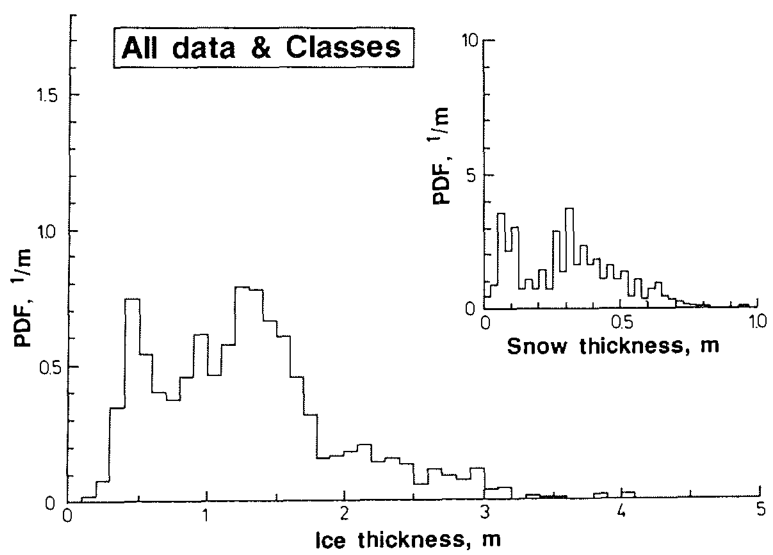


Figure 22 a for legend see next page

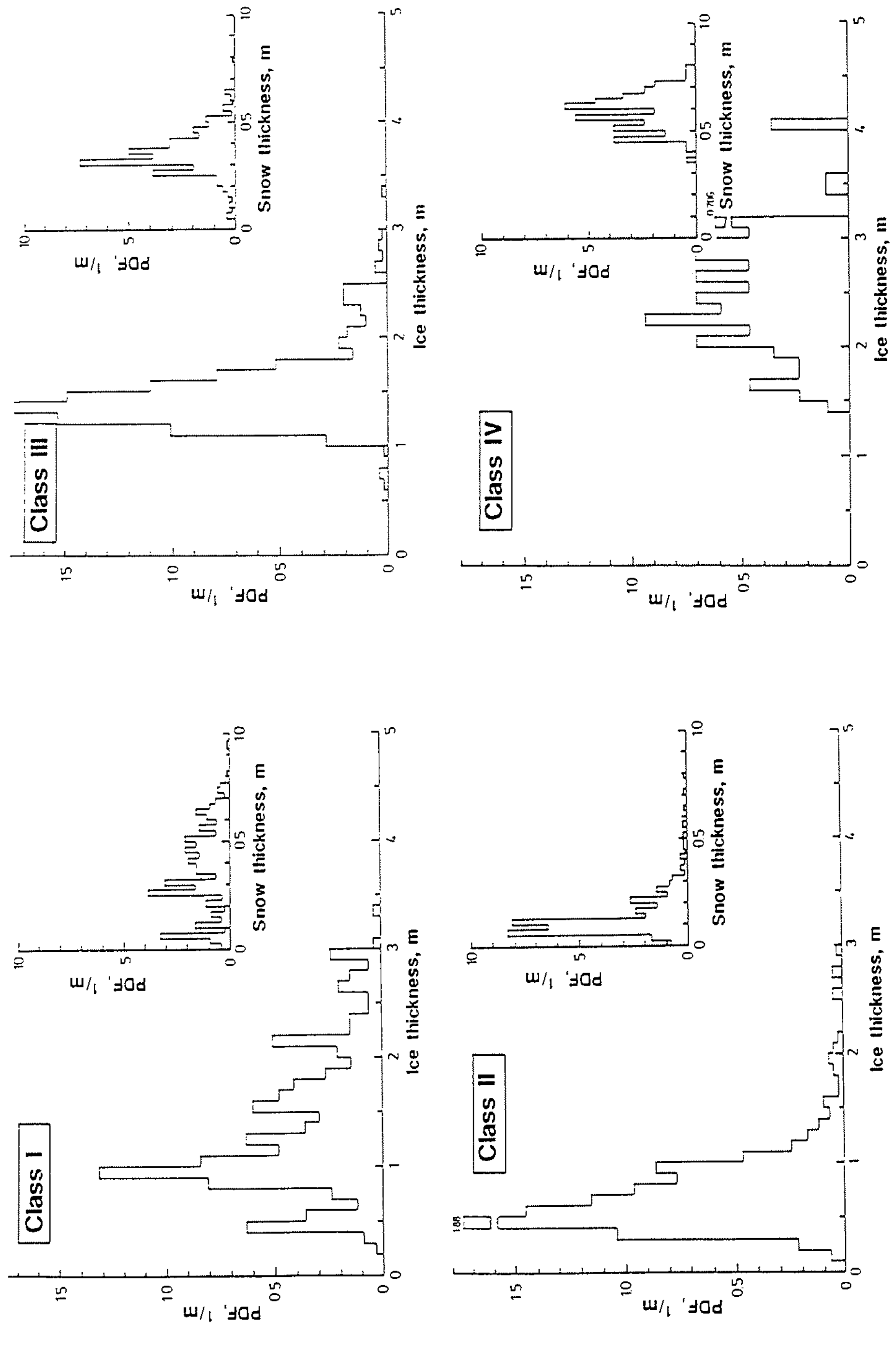


Fig. 22 b-e Probability density functions of ice- and snow thicknesses as obtained by measurements in coreholes. 22a gives the overall distribution and 22 b-e represent PDF's of parts of the data (see text for further details).

2.2.3.4 Brine investigations

F. Bianchi; J.-M.Bouquegneau, F.Cioce, D.Delille, G. Dieckmann, G. Kirst, K. Kivi, S. Kristiansen, H. Kuosa, M.A. Lange, A.M. Larsson, B. Norrman, E.M. Nöthig, G. Socal, E. Syvertsen

Introduction

Living within sea ice is a wide spectrum of microorganisms ranging from bacteria to smaller metazoans such as copepods. These organisms form assemblages which occupy different niches or zones in the sea ice system. Here the organisms live in brine pockets and/or channels resulting from physical processes during ice formation in the autumn or winter. The organism are subjected to large temperature and salinity fluctuations. They may become completely isolated from the sea water surrounding the ice.

A conventional method to study these internal ice communities is the analysis of melted ice cores since the brine from the frozen sea ice is difficult to isolate . This method has several disadvantages:

a) The organisms are subjected to severe osmotic stress as the ice melts so that sensitive organisms are destroyed.
b) The sea ice is melted at temperatures too high for the organisms.
c) Melted ice cores cannot be used for physiological experiments.
d) Chemical analyses of the ice melt are difficult to interpret.

Some of the algae in the various assemblages are initially isolated from the surrounding sea water in winter and early spring. Later in the year, however, as the ice is broken up and begins to melt, these assemblages become gradually exposed to the water where they proliferate and become available to the major consumer, *Euphausia superba*

Objectives

Brine was collected from various different ice floes to:

a) Determine the composition of the different assemblages.
b) To obtain estimates of organism numbers and biomass.
c) To study the chemical composition of the brine.
d) To investigate the activity of sea ice organisms i.e. ^{14}C uptake, nitrogen regeneration and O_2 production.

Work at sea

Brine was collected at 10 stations. After removing the snow cover, holes of 15 to 60 cm depth were drilled into the ice using an ice corer. The cores removed from the ice were used for species enumeration and chlorophyll a analyses. The brine which had accumulated in the core holes was extracted using a hand pump. On several occasions samples from more than one hole were combined. Subsamples were taken for the following analyses:

1. Chlorophyll a
2. Species enumeration;
   a) Bacteria and flagellates
   b) Other organisms
3. Salinity (Refractometer and Salinometer)
4. Nutrients;
   a) Ammonia and phoxphate
   b) Other nutrients
5. Alkalinity and pH
6. C/N analyses
7. Isotopes (^{18}O)
8. Other chemical analyses e.g. macromolecules

Uptake rates of nitrate and ammonia using ^{15}N, were studied on parallel samples collected at stations 14/115, 14/125 and 14/127. While regeneration of ammonia by zooplankton in the brine was measured at stations 14/115 and 14/125 only.

Preliminary results

Depending on the sea ice temperatures which ranged from -1.7 to -2.5 °C the salinities of the brine varied between 32 and 66 ‰.

A comparison of some brine properties with those of the sea water is shown below

	Salinity ‰	Chl a µg/l	pH	NO3 µmol	NH3 µmol	PO4 µmol	SiO4 µmol
Brine	32-66	3-60	8,5-8.7	0-14	0-1,5	0,2-0,7	20-60
Sea Water	34	0,3	7,8-8,2	30	0,2	2,0	100

The brine community consists of a high number of heterotrophic microbes, especially bacteria and flagellates including choanoflagellates, of diatoms, ciliates, foraminifers and several species of copepods and many as yet unidentified taxa. Concentrations of these organisms per unit volume are up to several orders of magnitude higher than in the surrounding water column. Nutrient values obtained from brine revealed completely different concentrations and ratios than those of sea water: While ammonia is higher than in the water column, nitrate has in some cases been exhausted and phosphate and silicate show strong signs of depletion. Further analyses of samples are required before the nutrient data can be interpreted.

For some floes investigated, the high biomass in the brine could be attributed to the infiltration layer near the snow/ice interface. This may mean that brine collected from this layer actually represents infiltrated sea water which has undergone changes due to high biological activity. On the other hand brine was also sampled from clearly visible bands or interstitial assemblage layers.

Our results indicate that biological activity within the ice is already very high long before the ice melts or breaks up. This activity is even more enhanced when the assemblages mentioned above are exposed to the surrounding sea water or when infiltration of sea water occurs more freely. In this way the sea ice becomes the most important substratum for primary production during the antarctic winter and spring.

2.2.4 ICE ALGAE

2.2.4.1 Distribution, biomass, communities and uptake rates.

G. Dieckmann, S. Kristiansen, E. Nöthig, E.E. Syvertsen

Introduction

"Ice algae" are microalgae which at some stage of their life cycles are associated with sea ice. Various general terms may be used to indicate where in the ice column they are found. These terms apply regardless of geographical location and type of ice.

"Surface assemblages" may be "pool assemblages" resulting from melting or flooding of the ice, or "infiltration assemblages" formed when the snow cover is submerged.

"Interior assemblages" may be termed "brine assemblages", when constituted by layers of algae frozen into the ice.

"Bottom assemblages" may consist of "interstitial assemblages" found between ice crystals and platelets at the ice under-surface, or "sub-ice assemblages" accurring as loosely attached mats and strands on the ice under surface.

During the present investigation various kinds of algal assemblages were observed, but the infiltration assemblage dominated the investigated area. It was found both as a developing system in its typical state and as crushed and refrozen "brown ice".

Objectives

To study the spatial distribution of ice algae, the types of assemblages and communities, the species composition, and the uptake rates of ^{14}C and ^{15}N and remineralization by *in situ* and simulated *in situ* experiments. Furthermore, to compare the findings during the EPOS I cruise in the Weddell Sea with the results from the Norwegian Research Program for Marine Arctic Ecology (PRO MARE) in the Barents Sea.

Work at sea

Sampling was either done by diving under the ice (see 2.1.6 for list of dive stations and samples), or by digging holes or taking cores from the top of the floes. A total of 50 ice algal samples were collected at 15 stations and an additional 30 samples were collected for under-ice and infiltration layer nutrient and salinity determinations. *In situ* and simulated *in situ* uptake experiments were performed 3 and 10 times respectively. Quantitative samples were obtained by using cylindrical plexiglass incubation chambers (88 or 900 cm^3) which could be pressed or hammered into the ice and then capped off. Qualitative samples were obtained in the same way, or by utilizing a small under-water "vacuum cleaner" which sieves the ice/water through a coarse grid and subsequently through a plankton net (10 or 20 µm mesh width). Ice samples for chlorophyll a determinations were melted in a large volume of water (88 : 912 ml) at low temperature. *In situ* uptake experiments with sub-ice algae were either done in capped plexiglass incubation chambers suspended in a plexiglass rack floating under the ice, or in polycarbonate bottles attached to the ice under surface.

Preliminary results

Fig. 23 shows the different kinds of ice algal assemblages encountered during the cruise. Of these the infiltration layer was the only one present at every station, and it also appeared to be the main food source for the krill in the ice.

The infiltration assemblage consists of algae in the porewater between the snow/ice crystals in the submerged part of the snow cover of the ice floes. Sometimes algae may also be found above the water level. The heterogeneity of the ice in the investigated area was reflected in the distribution and biomass of the infiltration algae. Thus, the differences between two floes lying side by side were often considerable.

The highest chlorophyll a values measured on a sample from this assemblage (st. 14/125) was 848 µg chl a l^{-1} (volume of snow/pore water). Typical values in a section from the ice edge towards the middle of the floe are given in Table 7, which also shows a typical pattern of the variation in nutrients and salinity. A few comments on these values are made below.

Some speculations on the origin and development of the infiltration assemblage may be made at this point. First it is evident that there is a concentric pattern in terms of biomass, nutrients, salinity and partly species composition. Thus, the higher values of biomass and nutrients are found towards the edges of the floes, while the salinity increases inwards from the edge.

Looking at the species composition, one feature is striking: the abrupt decrease in the number of species from the water-exposed part of the infiltration layer at the ice edge towards the middle of the floe. While at the outer edge there is an assemblage consisting mainly of planktonic algae, with a heavy bias towards ribbon-forming *Nitzschia* species, further in, there is a relatively low number of solitary motile species only, notably flagellates and raphiid pennate diatoms. With one exception: *Phaeocystis pouchetii* whose colonial stage was often found in large numbers deep into the infiltration layer. This allows for some speculation and some questions to be raised.

The observed decrease in biomass from the edge towards the middle may be explained as the result of a migration process from the open water and into the infiltration layer. If this is the case, one would expect only motile forms to be able to penetrate deeper than just a few centimetres. This may explain the dominance of flagellates and motile diatoms. For *Phaeocystis* the explanation may be the same: its mobile, flagellated stages move into the infiltration layer, whereafter colonies develop. This model could also explain the observed differences in biomass as it takes time to penetrate into the ice. However, Table 1 shows depletion of nutrients away from the ice edge, and this may account for a decrease in biomass with an increase in distance from the ice edge. A combination of the two factors, however, is probably closer to the answer.

It may be discussed whether the algae really invade the infiltration layer from the ice edge. It seems to be the intuitively obvious explanation, but it might equally well be that the bloom in this layer is innoculated from algae that are already present in the ice when it freezes. Then the nutrient conditions might account for the concentric distribution. Another possibility is that motile algae penetrate through brine channels and cracks from the water below the ice and into the infiltration layer.

Ice assemblages other than the infiltration assemblage were present on a few stations only, and they will be briefly commented here.

A band assemblage was found on three stations (st. 14/118, 14/119, 14/140) and consisted of remnants from a sub-ice algal bloom the previous year frozen in between the first and second year layer in two years old ice. These assemblages consisted of a few centric diatoms (*Porosira*, *Corethron*) and a majority of typical ice algae from the genera *Nitzschia* and *Tropidoneis*.

A sub-ice assemblage was present on three stations (st. 14/111, 14/122, 14/127) where the ice under surface had not started melting. It consisted of a thin (2-3 mm) layer of algae covering the under surface of flat floes. The dominating genera were *Gyrosigma/Pleurosigma* and *Nitzschia*.

A frazil ice assemblage was present on one station (st. 14/089) within a 1-10 cm layer of frazil ice on the under surface of the ice floes. Chlorophyll a content in this layer was 1.2 µg Chl a l^{-1} versus 0.15 µg l-1 in the water. Thus, there had been a growth or a concentration in this layer.

Table 7. Infiltration layer. Chlorophyll a, nutrients and salinity. st. 14/111.

Distance from ice edge	Chl a	NO_3	PO_4	$SI(OH)_4$	S ‰
water	0.5	30.1	2.1	74.5	34.4
0.25	106.0	16.3	0.5	36.5	34.4
1.5	69.8	1.3	0.0	32.3	34.7
4.0	27.4	13.8	0.4	42.2	34.1
20.0	4.1	0.0	0.1	1.8	36.5

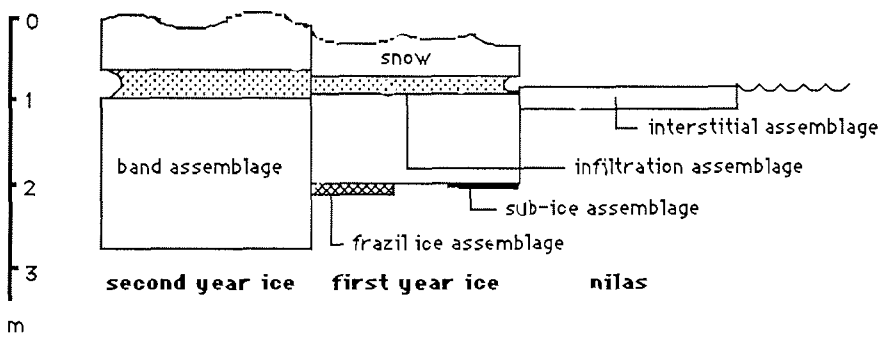


Fig.23. Schematical drawing of the ice algal assemblages encountered during EPOS I, leg 1.

2.2.5 THE UNDER-ICE WATER LAYER

G.Dieckmann, H. Kuosa, A.-M. Larsson, G. Ljungek,
K. Meyer, E.-M. Nöthig, P.-I. Sehlstedt

Objectives

The sea ice which forms annually in the polar regions influences many physical, chemical and biological processes in the underlying water column. We wanted to study the influence of the ice cover on the underlying water masses in the Weddell Sea during early spring on both a small scale (0-about 3m under the ice) and a larger scale, down to 300m water depth. Special emphasis was to be placed on physical, chemical and biological properties of the underlying water masses such as the reduction of turbulence, attenuation of light needed for algal growth, and the stratification of surface water caused by melting ice and concomittant release of algae into the water.
Work on ice floes at a 50 m distance from the ship allowed us to measure the undisturbed water masses of the upper ten meters rather than from the ship. During Epos I the following aspects were studied in the under-ice water layer
- physical properties (light, temperature, salinity)
  chemical properties (nutrients, oxygen)
- biological properties (biomass concentration and species composition of bacteria, phytoplankton and protozooplankton)

Work at sea

All the studies were carried out on thick ice floes (> 50 cm thick) south of 61°S. A Smart CTD with internal registration (Neill Brown) was used to study the physical and chemical properties of the under-ice water. It was lowered down from a hole surrounded by ice to avoid ice-edge effects. The CTD was attached to a transportable motor winch and lowered down to a depth of 300 m. Whereas temperature and salinity were recorded down to 300 m, samples for nutrient analyses and oxygen were only taken from 1,2 and 10 m depth of the water column with a Niskin bottle. To avoid too much disturbance only one bottle was used and the 1m sample was taken first.

For the small scale studies in the upper two to three meters under the ice a L-shaped sampling instrument (L´se) of a total length of 4 m was inserted under the ice through a 10 cm hole drilled into the ice. After lowering the instrument down to a depth of 2.5 m (including the ice thickness) the 1m long arm of the L´se was brought into a right angle by pumping air into an inner tube of a bicycle attached to the movable arm. The arm was thus extended parallel to the ice surface. A total of 4-8 depths, beginning from 2.5m to the immediate undersurface of the ice were sampled. Altogether, 14 profiles were obtained at different stations (see Tab. 9). Pictures of the under-ice-surface were taken at some stations using a video camera attached to the the end of the arm. Light was measured with a photo-sensor under the ice and later calibrated with a Liquor 2π sensor, which was also used to measure the incident light, 20 cm above the snow.

Five to ten litres of seawater per depth were pumped by a vacuum pump through perforations at the end of a silicon tube in the arm of the L´se. This water was used for the following measurements:

- -salinity
- -nutrients
- -particulate organic carbon and nitrogen
- -enumeration and biomass estimates of the organisms
- -chlorophyll a

Salinity, chlorophyll a, and some nutrient samples were measured and few flagellates and bacteria enumerated on bord. The remaining samples were preserved or deep frozen for later analyses on land.

Preliminary results

The results of the physical, chemical, biological samples analysed so far on both the small (L´se) and large scale studies (Smart CTD and Niskin bottles) showed that there were no remarkable differences between the CTD casts run from the ship and the investigations some distance from the ship. This leads to the conclusion that the upper part of the water column in ice covered areas represented an uniform mass still showing winter characteristics. Any stratification under the ice probably breaks down again due to the movements of the big ice floes which are very rough underneath. Tab.8 shows CTD and nutrient data (large scale studies) from station 115, these profiles are also representative for most of the ice stations, where no measureable stratification under the ice between 1 and 10 meters was found.

A closer look at the chlorophyll a values obtained with the L´se (small scale studies) showed that the under-ice-investigation area could be roughly divided into two zones. One is situated south of approximately 62.30°S and the other between 61.00 to 62.30°S. The first area was characterized by more consolidated ice with large ice floes, whereas in the other zone the individual ice floes were smaller (see chapter 2.1.5.). In the first zone, chlorophyll a values were less than 0.15 $\mu g\ l^{-1}$ and the salinity values higher than 34.40 PSS (Tab. 9). In the more northern zone the values for chlorophyll a were higher reaching values up to 0.5 $\mu g\ l^{-1}$ while the salinity was lower between 34.39 and 34.25 PSS. The higher phytoplankton biomass in the northern zone may have been the result of leads and ice free areas between floes rather than the overall thickness of the individual floes. One possible explanation for this is, that more light penetrates the water at the edges of the smaller floes.

The vertical distribution of the chlorophyll a values showed in some cases sightly higher values directly under the ice (Fig.24). This could be due to ice algae being released out of the brine pockets and channels. The enumeration of species should cast more light on this question, as they will be compared with the other water column samples and with ice core samples.

Flagellates and bacteria communities from the uppermost sample of the L´se have already been counted. Evidence of different microbial communities comparing the water column samples with the samples taken with L´se were found at some stations. At station 119 the under ice sample consisted of many rod-shaped bacteria not present in the water column. The sample from station 120 had a high number of heterotrophic flagellates (about 10 x the water column values) probably orginating from the ice, an increase in bacterial number was also observed at station 122.

Tab. 8. CTD and nutrient data from station 115, 01.11.88

Depth m	Salinity PSS-78	Temperature °C	Phospate µM	Ammonium µM	Oxygen µM
1	34.380	- 1.858	2.11	0.02	304.8
2	34.382	- 1.861	2.08	0.02	305.0
3	34.382	- 1.861			
4	34.382	- 1.860			
5	34.385	- 1.860			
6	34.386	- 1.860			
7	34.388	- 1.862			
8	34.389	- 1.864			
9	34.390	- 1.860			
10	34.390	- 1.859	2.10	0.02	305.8

Tab.9. Locations of L´se samples (L) at stations (stn), snow + ice cover over the sampling sites, chlorophyll a (chl a) and salinity ranges from the various sampling depth at each station

L	stn	position °S	snow+ice cover (cm)	chl a ($\mu g\ l^{-1}$)	S PSS-78
L1	87	62 27	75	0.02-0.07	34.392-34.449
L2	89	62 40	180	0.03-0.06	34.391-34.402
L3	90	62 12	70	0.37-0.41	34.298-34.304
L4	92	61 48	70	0.34-0.37	34.310-34.319
L5	111	61 51	175	0.02-0.15	34.398-34.402
L6	113	62 10	180	0.21-0.26	34.391-34.400
L7	115	62 32	20	0.13-0.16	34.403-34.410
L8	117	63 01	185	0.08-0.13	34.400-34.406
L9	119	63 20	155	0.10-0.12	34.429-34.434
L10	120	63 14	145	0.09-0.10	34.434-34.435
L11	122	62 36	50	0.14-0.36	34.426-34.432
L12	124	61 51	150	0.12-0.34	34.357-34.368
L13	125	61 55	70	0.28-0.37	34.251-34.252
L14	127	61 20	190	0.47-0.55	34.081-34.088

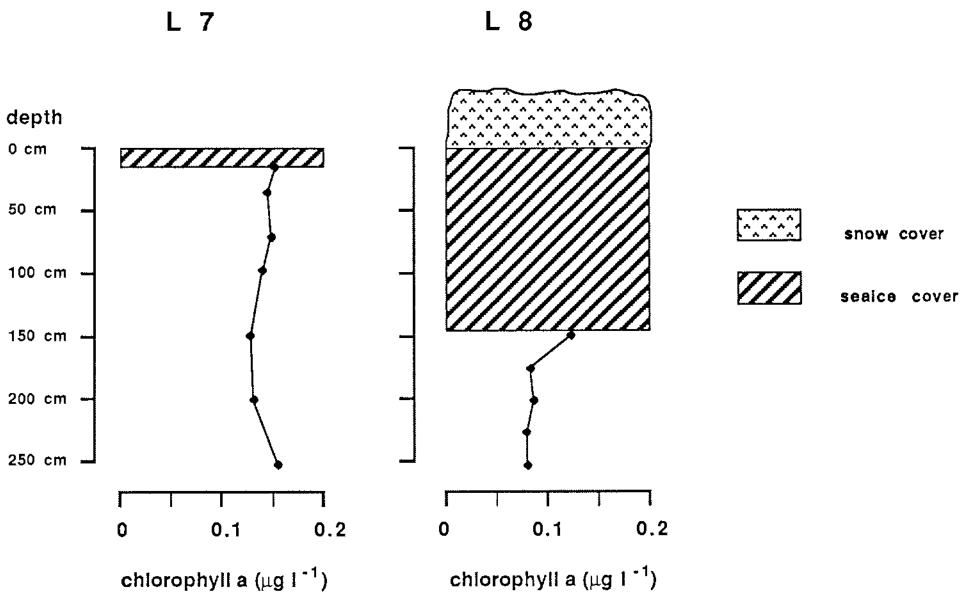


Fig. 24. Vertical profiles of biomass distribution expressed as chlorophyll a at two different L'se stations (stns 115 + 117)

2.2.5.1 Comparative ecophysiology of ice-algal assemblages

G.O. Kirst, J. Nothnagel, M. Wanzek

Objectives:

EPOS I provided a unique opportunity to study the ecophysiology of algal samples deriving from surface assemblages (infiltration layer), from interior assemblages (brine channel and band assemblages), and from the bottom assemblages (interstitial algae in ice cores).

The investigations were focussed on:

a) Photosynthesis and respiration as a function of light intensity, salinity and temperature;
b) Capacity for heterotrophy under light (stimulation) and dark conditions;
c) Estimation of the contents of sulphur-organic compounds (dimethyl-sulphonium-propionate : DMSP) in the ice-algae and the phytoplankton, to assess the production of dimethylsulfide (DMS) in Antarctic waters;
d) In addition: Samples of living algae were prepared to be used as sources for unialgal cultures in the laboratory.

Work at sea

Basic data such as salinity, temperature, chlorophyll, cell numbers and species composition were obtained in cooperation with other scientists (G. Dieckmann, E.M. Noethig, E. Syvertsen, S. Kristiansen, and A.M. Larsson).

Sampling of algal material: Phytoplankton samples and pieces of "brown ice" were collected for comparison and calibration purposes. The algae were enriched by filtration onto membrane filters or by centrifugation. Collection and cleaning by density centrifugation (discontinuous density gradient on a sucrose-seawater basis, up to 1.3 g/ml density) was not successful: The diatoms passed through the layers; the method was not further improved because of the very low yield of cells per batch. Samples dense enough for experimental purposes were obtained directly from the algal rich infiltration layers or from the brown bands of algae in the ice-cores.

Infiltration assemblage: After removing the top layers of snow the brownish to dark brown coloured snow-ice mixture was collected. Shortly after collection the liquid containing most of the algae was separated from the ice by sieving, thus avoiding too much a dilution of the salinity by the thawing ice. The salinity was usually in the range of 28 - 32ppt. These solutions were used immediately for most of the experiments or stored at 0°C until use.

Interior assemblage and interstitial (bottom) algae: Ice-coring was done together with M. Lange and G. Dieckmann. Whole ice-cores were dissected into 10 cm pieces, which were thawed in the laboratory and used for DMSP-estimation. For experiments, only brown coloured bands were cut out of the cores, and carefully partially thawed at 4°C until the brine and some melting water from the ice had washed out most of the algae. This solution (salinity in the range of 15 - 25 ppt) was used as band assemblage. Algal samples separated out of the bottom 10 cm of ice-cores were considered to be the interstitial assemblage.

Snow and brine samples: Upper layers of snow were collected and thawed immediately (at 12°C). "Brine" from the brine pockets in the ice was pumped out of drill holes in the ice (15 to 60 cm deep, depending on the ice thickness) according to the method of G. Dieckmann. Both, the snow and the brine samples, were used for DMSP-estimates only.

Experiments: It was intended to do most of the work on photosynthesis by a combined O_2-Probe and fluorescence measurement. However, the oxygen probe did not provide reasonable results at low temperatures (especially below 3°C) with natural (thin!) algal suspensions. This may be due to a change of the oxygen permeability of the teflon membrane at temperatures around 0°C. Reliable results could be produced only after stretching the membrane before assembling the oxygen probe, applying long incubation times (40 to 90 min. per measurement at a given light intensity), and the use of high algal densities.

DCMU-enhanced fluorescence was used to assess the photosynthetic activity of phytoplankton and ice algae. Chlorophyll fluorescence is low in photosynthetically active plants. If the photosynthesis is blocked by the herbicide DCMU, the light energy is converted into a maximal fluorescence. Algal samples were filtered onto GF/C filters the fluorescence of which was then measured before and after the addition of DCMU. The difference represented the maximal photosynthetic capacity of the sample. Aliquots treated with various salinities (9 to 62ppt; according to the range of salinity which they encounter in their natural habitat) exhibited different fluorescence levels indicating partial inhibition of photosynthesis.

^{14}C-fixation in various light intensities at -1°C was used in addition to the oxygen probe to compare rates of photosynthesis of the algal assemblages. After incubation with $H^{14}CO_3$- the algae were collected on a membrane filter and methanol was added to kill the algae and preserve the sample. The samples, stored at -27°C , will be extracted and the labelled compounds separated and identified by thinlayer chromatography in the laboratory at home. Especially low molecular weight compounds (osmolytes) such as proline, glycerol, several polyols are expected to be labelled preferably in samples subjected to high salinity.

The heterotrophy was investigated by incubation of samples with ^{14}C-labelled serine, glycine and glucose. Only freshly collected algal samples were used which had little bacterial contamination compared to the algal cell number (microscopical control). The number of bacteria increased remarkably after one day storage at 0°C.

DMSP: From stations in the open water, the Marginal Ice Zone and in the pack-ice zone more than 340 samples were collected, filtered and stored, sealed in Alufoil, at -62°C to be estimated for DMSP-content at home. Usually bucket samples from surface waters were taken. Samples from -10 and -80 m depth were collected by Rosette samplers as additional information to experiments conducted by M. Tilzer, W. Gieskes and R. Heusel. During time stations every two hours sampling was done to possibly prove a diurnal rhythm predicted for DMSP production. The DMSP content, the chlorophyll concentration and the species composition will be compared to see, if there is a similar patchiness of the correlations as observed in temperate ocean waters.

Preliminary results

DMSP-data and the ^{14}C-experiments will be evaluated after further preparations for measurement in the laboratory at home.

Oxygen probe: The rate of photosynthesis increased with increasing temperatures (Fig.25). At the average temperature of the ice-algal habitat the rate was lowest, only about 3% of the rate at 14°C. Several ice microorganisms, especially flagellates are known not to survive exposures to temperatures above 5 - 10°C. However, most algae exhibit a much broader physiological tolerance range than ecological (local) conditions demand.

The photosynthesis - light correlations (P-I curves) are presented in Fig. 26. The ice algae in these experiments typically show a high respiration rate, irrespective of various temperatures and the types of assemblages. The respiration rate of a phytoplankton sample was only about 1/3 of that of the ice algae. Contamination by bacteria has to be considered (the samples were filtered through a 200 μm net before experiments, hence, most of the zooplankton was excluded). According to microscopic controls and assessment of the number of cells we concluded that the bulk of the metabolic activity derived from the ice algae. A comparison with the ^{14}C experiments and quantitative cell counting will give more information. The fairly high compensation points in the range of 20 to 50 $\mu E\ m^{-2}s^{-1}$ may be explained by an inevitable overestimation of the irradiance, which was measured on the ship at the light source. A correction will be made with more precision at home. This would reduce the compensation point. However, even after this correction and considering the relatively high saturation irradiance (around 200 μE/m s) the ice algae as well as the phytoplankton show the typical features of high light adapted algae. Under the snow cover irradiances of about 200 μE/m s were observed (S. Kristiansen).

The ability to tolerate changes in salinity - as it may occur during freezing and thawing in the ice - is demonstrated by the response of the DCMU enhanced fluorescence which reflects the photosynthetic activity (Fig. 27). The photosynthesis was inhibited in samples subjected to osmotic stresses. In experiments with approximately twice the salinity (63ppt) of normal seawater the rates decreased to about 45% instantly, very likely due to plasmolysis and blocking the electron transport between PS II and PS I (photosystem PS II is the main source of the fluorescence after being cut off from the electron transport chain). The immediate response after dilution was less severe. During the duration of the experiment (150 min), the inhibition of the photosynthesis under increased salinity was always more pronounced.

However, after two days, the algae under hyper-osmotic treatement had fully recovered, exhibiting even a stimulation of photosynthesis.In contrast the photosynthesis of the samples in the dilute medium still was reduced. Since a number of flagellates (Dinoflagellates), which are sensitive to osmotic down shocks due to their flagella pits, were present, the low rates may be accounted for by the decrease of active cells.

In conclusion, the observed salinity tolerance meets the expectations and is a prerequisite to survive in the forming and melting sea ice.

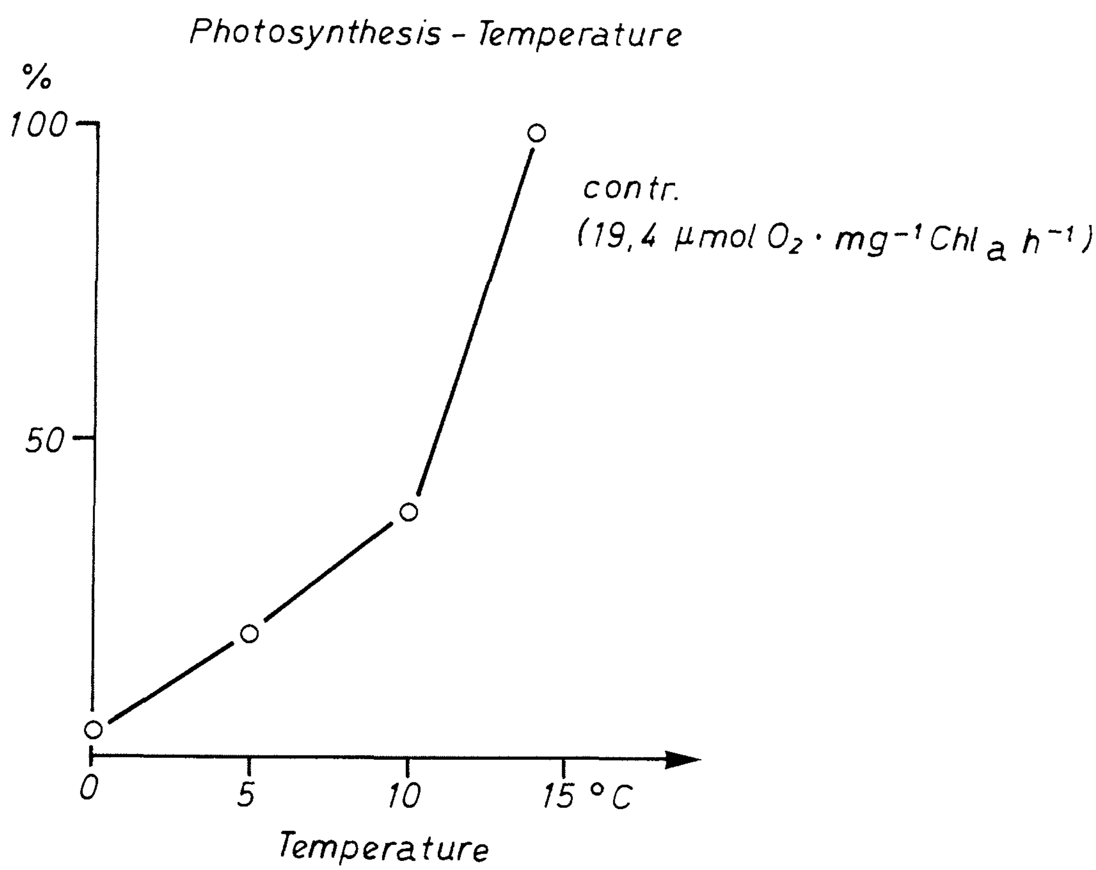


Fig. 25 Photosynthetic rates as a function of temperature. Rate at 14°C = 100% (19.4 µmol O_2 mg Chl a h), algal sample collected from the infiltration layer.

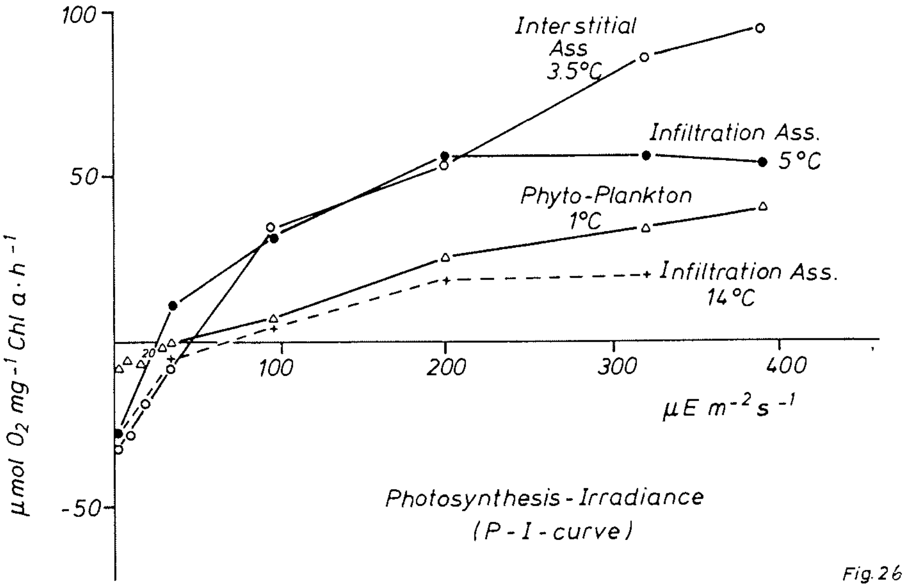


Fig. 2 6 Photosynthesis as a function of irradiance. Rates of various algal samples measured at temperatures as indicated.

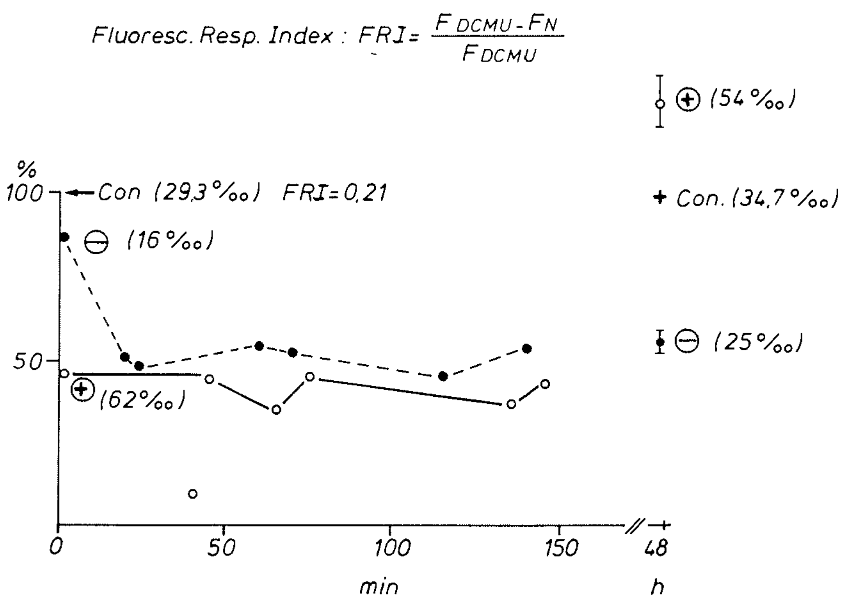


Fig. 27 Fluorescence response index (FRI) after osmotic shocks.
Con = control; O : hypo-osmotic conditions; O : hyper-osmotic conditions; F (DCMU) : Fluorescence in the presence of DCMU; F (N) : Fluorescence under control conditions.

2.2.6 MICROBIAL COMMUNITIES

F. Brandini, D. Delille, K. Kivi, H. Kuosa, B. Norrman

Objectives

The microbial loop (the regenerating community) is receiving increasing recognition as a major pathway of organic matter in marine pelagial. In order to study the influence of sea-ice on Antarctic microbial populations both regional and small scale investigations (ice-related studies) on the vertical distribution patterns of biomass and activity of bacteria, flagellates and ciliates were evaluated.

Work at sea

Microbial Counts: The total bacterial biomass was estimated by both acridine orange and proflavine direct counts. Flagellates were also counted from proflavine stained samples. Ciliates were counted with the Utermöhl-method.

Viable counts of aerobic heterotrophic bacteria were made by the spread plate technique with the 2216 E medium (Marine Agar Difco). Two sets of inoculated plates (6 replicates) were incubated for 2O days at 4°C and 10 days at 16°C, respectively.

Species Determination: 116 bacterial strains (56 psychrophilic and 60 psychrotrophic) were isolated from water column, under-ice seawater (diving), infiltration layer, normal ice, brown ice and brine. After purification of the isolates the 27 characters of the API 20B System were used for taxonomic analysis .

In complement of this numerical taxonomic analysis a RNA sequencing taxonomy should be conducted in Sweden on 40 selected strains.

Measurement of production and activity: Microbial activity were estimated by bacterial 3H Thymidine incorporation and by uptake of 32P-labeled DNA.

For studies on the uptake of DNA, a 32P-labeled plasmid was added to water sample in a polycarbonate bottle. 50-75 ml of the labeled plasmid was added and a 1 ml sample was drawn to determine the amount of radioactivity added. A 1 ml sample was also drawn to determine the amount of free phosphorus. This was done by adding a few drops of 30 mM sulfuric acid and activated carbon. After filtering through a 0.2 μm Gelman Supor filter, the radioactivity in the filtrate was determined by liquid scintillation counting. At regular time intervals, subsamples of 2 ml were drawn and filtrated through 10, 2, 0.6 and 0.2 μm Nucleopore filters and the radioactivity in the fractions was determined.

Aquarium experiments: The seeding effect of melting ice and its influence on the microbial population in the water column was studied by two aquarium experiments. In these six 100 liter aquaria were filled with surface water and different ice communities were added to certain units. Changes in the chlorophyll concentration, phytoplankton species composition and microbial community were followed for ten or twelwe days.

Extraction of macromolecules and levels of DOC/THAA as "In situ" parameters: To investigate the amounts of free dissolved macromolecules, especially proteins, "total" macromolecules were extracted from seawater and ice samples using C18 reverse phase extraction columns. Water samples (100-250 ml) were collected in acid-washed Teflon bottles and filtrated in the cold through 0.2 µm filters. Samples were collected for later analysis of DOC and THAA. The water was drawn through the extraction columns by vacuum pressure. Bound molecules were stepwise eluted with acetonitrile (30, 60 and 100 %), containing 0.1 % TEA, and 0.075 % TFA.

Preliminary results

The sea-ice microbial communities were characterized by a strong patchiness. However the ice was generally enriched compared to the water column. The ratio between sea ice microflora and underlying water can be three orders of magnitude as shown in Fig 28. The total number of bacteria and flagellates showed very similar trend to that of plate counts of heterotrophic bacteria. Numbers were in general far more greater in the sea ice than in the water column (about ten times). The seawater bacteria appeared as essentially psychrotrophic but the sea ice bacterial community is characterized by more psychrophilic strains.

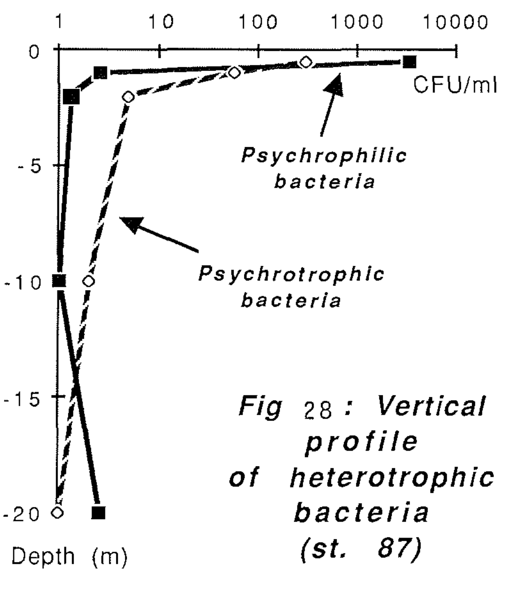


Fig 28 : Vertical profile of heterotrophic bacteria (st. 87)

The number of heterotrophic bacteria showed an obvious increase during the cruise due to yet undefined spatial or temporal factors (Fig. 29). Flagellate numbers were low except in the very end of the cruise in the water mass with the highest chlorophyll concentration. This points at a low activity of the whole microbial loop in the Antarctic winter water, but a possible greater activity during a spring bloom situation.

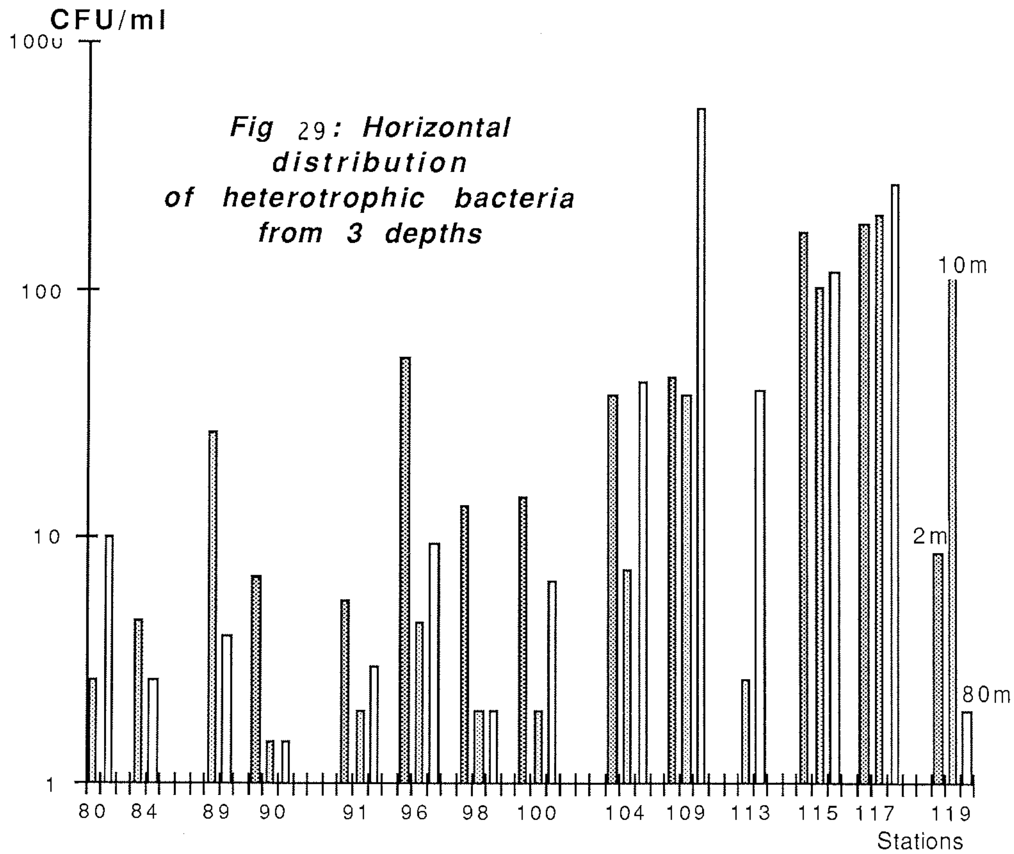


Fig 29: Horizontal distribution of heterotrophic bacteria from 3 depths

First analysis by reverse phase HPLC showed that in "brown ice", large amounts of dissolved organics could be found. Gel filtration experiments showed the occurrence of high molecular weight compounds. Further analysis at home will include determination of amino acids after acid hydrolysis and analysis by SDS-PAGE.

An example of the result obtained by uptake of 32P-labelled DNA is shown in figure 30. This is a sample from the infiltration layer of an ice floe. High bacterial activity is indicated by the rapid breakdown of the tracer and uptake in the 0.6 - 2 µm fraction. The uptake into larger size fractions is most likely due to predation by flagellates. The sample contained large amounts of choanoflagellates. Due to the silicous lorica of these organisms, they might well be retained on a >10 µm filter.

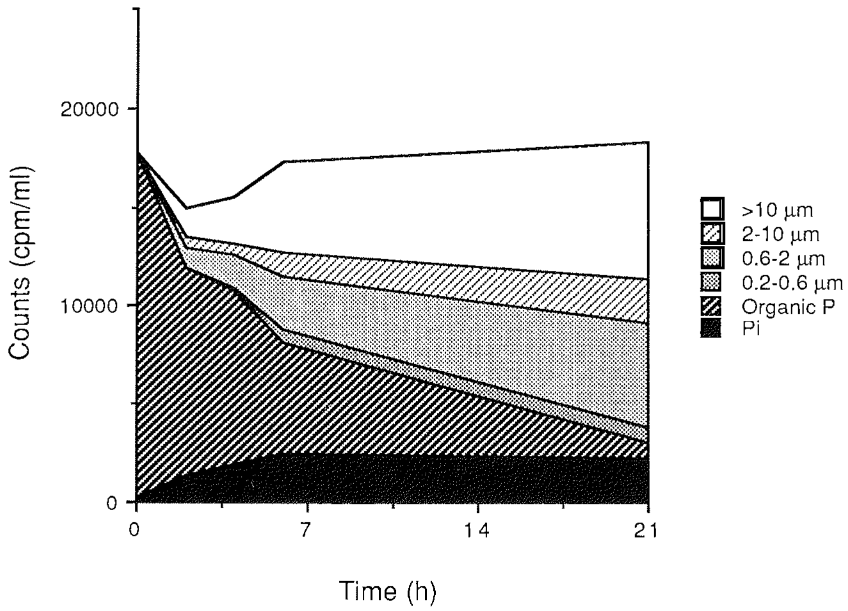


Figure 30 : Uptake of 32P-labeled DNA in infiltration layer of an ice floe (Data of "Isalg 1101 Q")

2.2.7 PHYTOPLANKTON COMMUNITIES

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The marginal ice zone has been found to be the site of enhanced biological activity in both polar regions. Apart from this recognition, processes involved in this zone are still poorly understood. It has been observed that in summer a receeding ice edge often stabilizes the water column due to the formation of melt water lenses on the surface. These conditions are considered to be favourable for the development of phytoplankton blooms. However, more recent investigations have revealed biological enhancement at the ice edge independent of ice melting and occurring at a stationary or advancing ice edge during winter.

Objectives

a) To follow the spring development of phytoplankton on a spatial scale.
b) To relate the biological and chemical properties: Biomass and species composition as well as oxygen and nutrient concentrations to hydrographic properties of the water column.
c) To determine the significance of sea ice cover and ice melting on the phytoplankton.

Work at sea

Bio Rosi casts (CTD probe, Neill Brown Smart version attached to a rosette sampler with 12x12L Niskin bottles) were done down to a depth of 300m along four transects normal to the ice edge from open water into the pack ice (see Fig. 8). The Bio Rosi provides a continuous profile of fluorescence and PAR (Photosynthetic Active Radiation) as well as temperature and salinity.

The twelve Niskin bottles were tripped at standard depths of 2, 10, 20, 30, 40, 60, 80, 100, 120, 150, 200 and 300m. A total of 75 casts were done at varying intervals usually 10 to 20 nm apart with occasional longer spacings between casts. The water was sampled to measure and analyze the following:

- salinity
- oxygen
- pH
- alkalinity
- nutrients
- primary production measurements
- nitrogen uptake
- ETS-activity of microplankton,
- chlorophyll a
- other pigments (HPLC)
- species composition (bacteria, phytoplankton, and protozooplankton)
- dry weight of seston
- particulate organic carbon and nitrogen
- fatty acid composition of phytoplankton
- additional chemical analyses

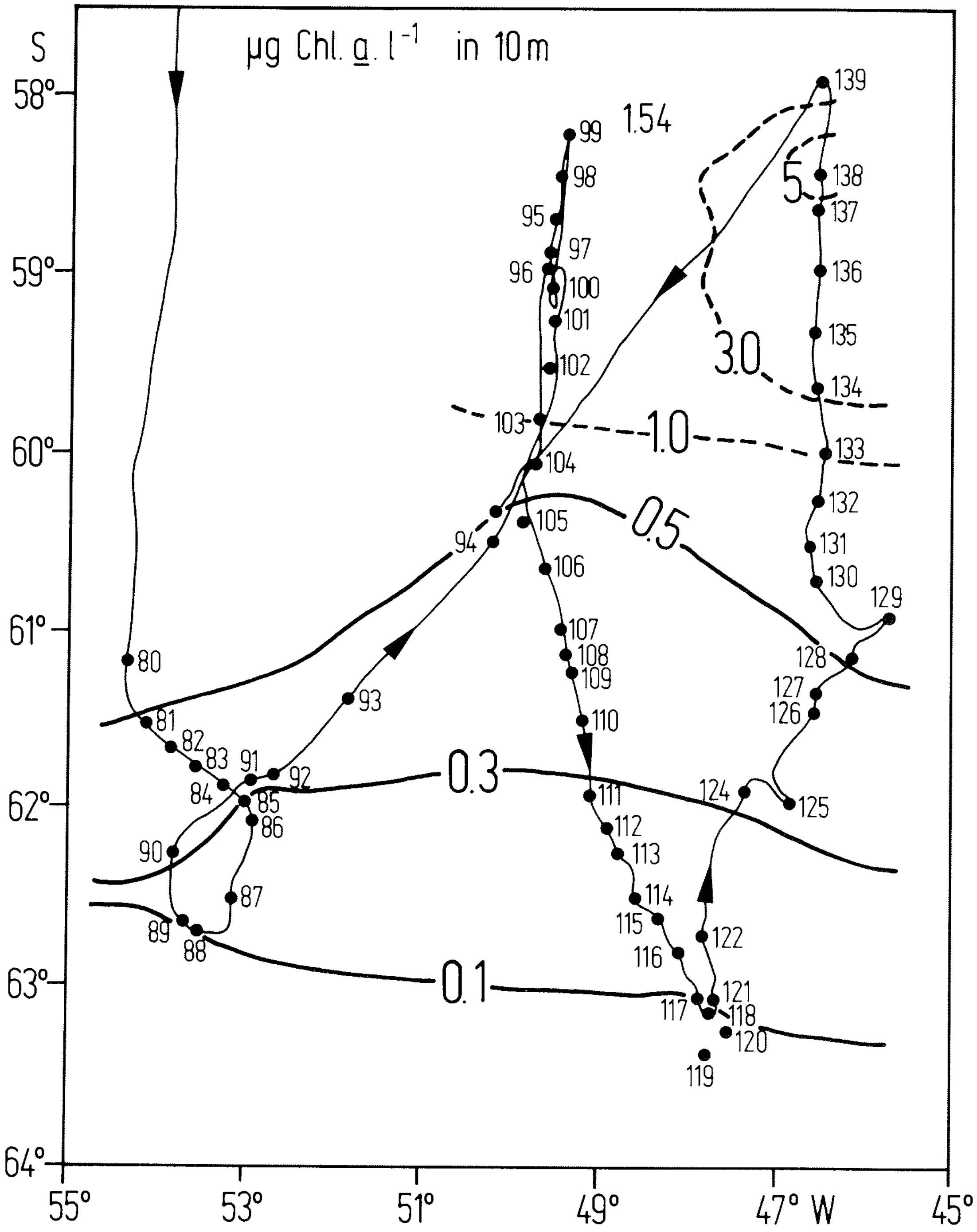

Figure 31.Chlorophyll a distribution at 10 m depth in relation to the cruise track. The pack-ice zone is the area south of the 0.5 isopleth, the ice edge zone lies between the 0.5 and 1.0 isopleths while the area north of the 1.0 isopleth represents the open water zone. Nos. 80 to 139 are Bio-Rosi stations.

The processing of samples for: salinity, oxygen, pH, alkalinity, primary production measurements, nitrogen uptake, ETS-activity of microplankton, protozooplankton (bacteria, flagellates, ciliates), fatty acid composition of phytoplankton and additional chemical analyses are presented in other sections of this report.

Hand drawn 20 µm-plankton-net hauls were also done at each Bio Rosi Station from a depth of 10m to the surface to supplement the study of phytoplankton (mainly diatoms) species composition.

The nutrients analysed were: nitrogen (ammonia N-NH_3, nitrite N-NO_2, nitrate N-NO_3), silica (orthosilicate Si-SiO_4) and phosphorus (orthophosphate P-PO_4). The samples (411 in total) were analyzed on board automatically by a Technicon Autoanalyser (ammonia, nitrite, nitrate, silica) and manually (phosphate) by spectrophotometric method.

The methods used were those of Strickland & Parsons for nitrite, nitrate and orthophophate; Grasshoff for ammonia; Folkhard for orthosilicate. Concentrations were calculated by measuring the recorded peaks.

Chlorophyll a was determined in 1 liter filtered onto a GF/C Filter, extracted in Acetone (90%) and measured using a Turner flourometer.
Samples for HPLC analyses were filtered on GF/C filters and stored in a freezer until later analyses.
Samples to study phytoplankton species composition were fixed with buffered (hexamethylentetramin) formalin and stored in brown glass bottles for later enumeration on land.
The samples for suspended matter (dry weight and particulate organic carbon and nitrogen) were filtered on GF/C filters and stored in a freezer for later analyses.
The plankton net samples were devided into two parts, one was fixed with formalin for taxonomic work on land, the other one was put under an inverted microscope and recorded on video.

Preliminary results

According to the tentative results of the physical oceanography, the ice observations and our results of the area of investigation can be divided into three zones. The open water zone reaching from 58°S to approximately 60°S, the ice edge zone with increasing ice cover to the south until 62°30'S and finally the pack ice zone (Fig. 31).

Nutrients

From the beginning of the first transect, the nutrient levels show a typical late winter situation, with low stratification near Clarence Island: Ammonia and nitrite values were very close to zero, while nitrate showed average values of 32 µmol/l, silicate 98 µmol/l and phosphate 2.2 µmol/l. This partial stability decreased proceeding through the ice edge (Fig. 32 + 33).

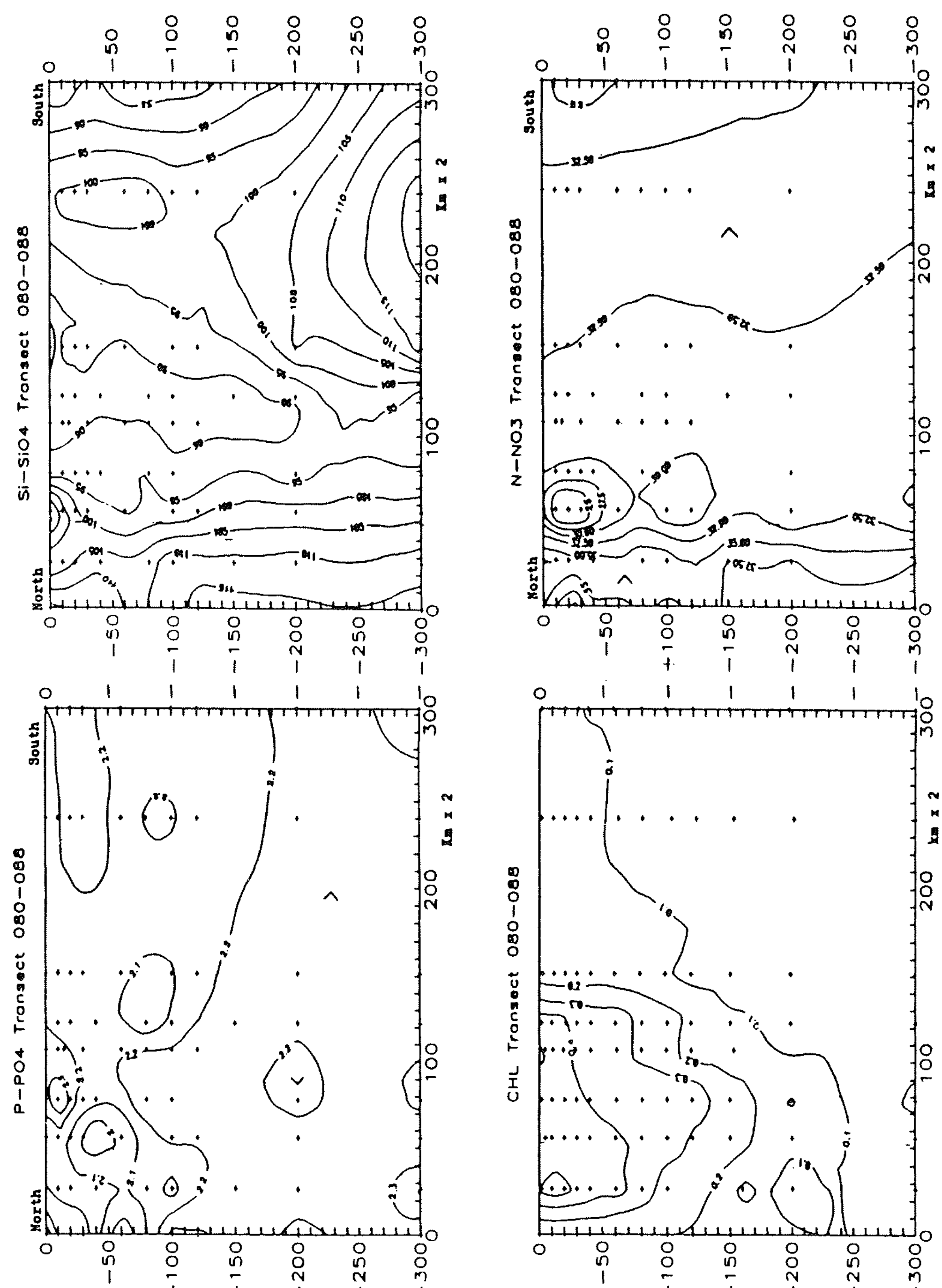

Figure 32. Vertical sections of nitrate, silicate, phosphate and chlorophyll a along transect 1 (station 80 to 88)

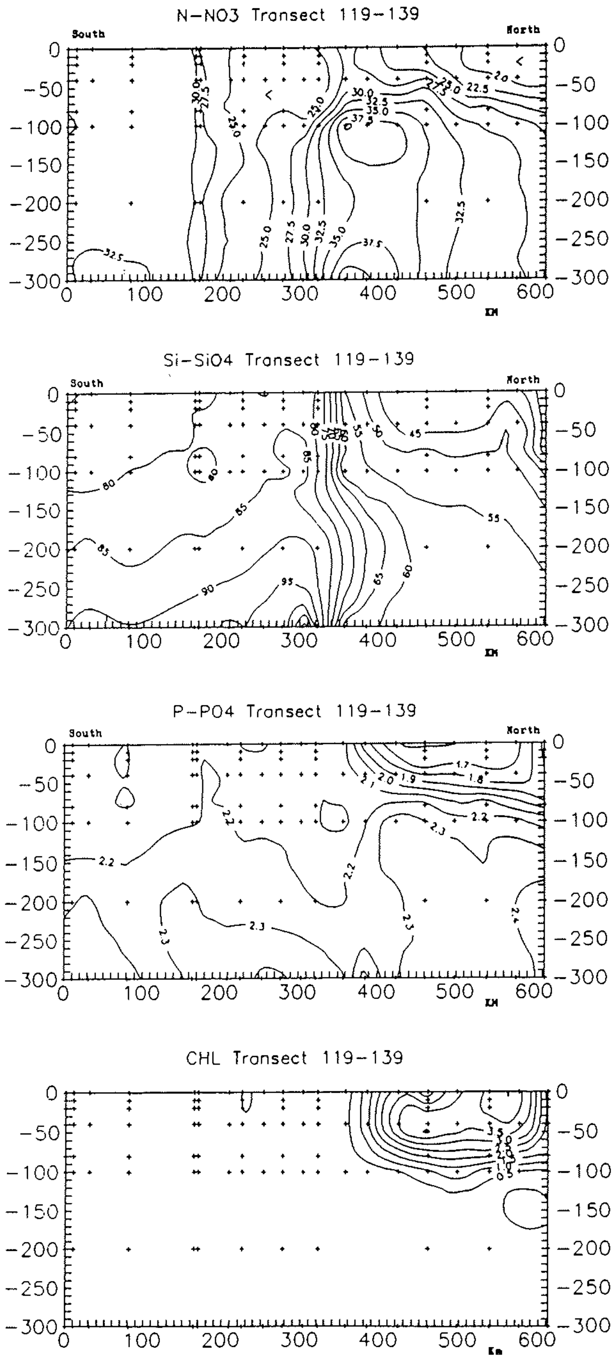

Figure 33 Vertical sections of nitrate, silicate, phosphate and chlorophyll a along transect 4 (station 119 to 139)

In the second and third transects some variations of the nutrient concentration can be related to the increase of phytoplankton biomass, with the consequent depletion of some nutrients (N-NO_3, S_i-S_iO_4 and P-PO_4), that occurred mainly in the open water zone. In the ice edge zone and mainly in the pack ice zone, however, the nutrient concentrations did not show a significant decrease indicating that phytoplankton biomass was still low. On the last transect a strong decrease of nutrients was observed at the northernmost stations . The measured values for nitrate, silica and phosphate were 18, 30 and 1,5 µmol/l respectively. This corresponds with a strong stratification of the surface water and high chlorophyll a values measured in the upper 80m of the watercolumn.

Chlorophyll a

In the southernmost zone the chlorophyll values were low throughout the period of investigation . The values ranged between 0,01- 0,2 µg/l in the 300 m water column and were more or less well mixed in the upper 100 meters (Fig. 34).

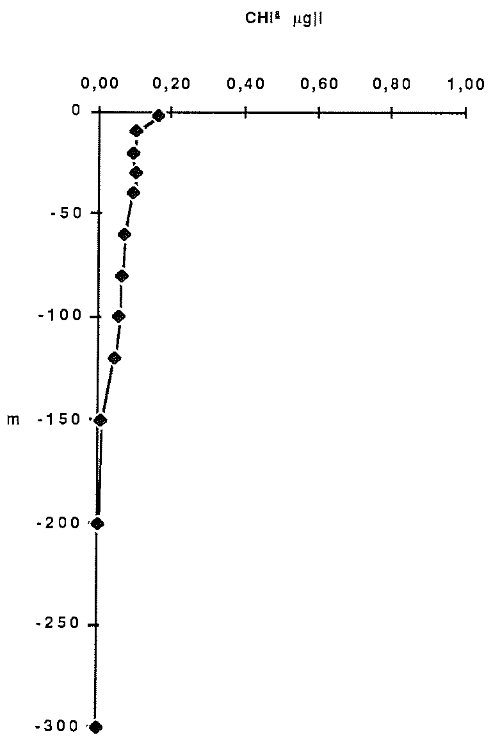

Fig. 34. Profile of Chl a at St 14/120 representing a typical situation in the pack-ice zone.

In the second zone an increase in Chl a was encountered attaining maximum values of approximately 0,5 µg/l (Fig. 35). The maximum being near the surface. After this slight maximum a decrease of chlorophyll a was again observed further north.

In the zone characterised by mostly open water, Chl a values were high compared to the more southern stations. Whereas on the second northgoing transect the values attained a maximum of 1,9 µg/l on the fourth transect the phytoplankton biomass had increased to a maximum of 7,2 µg/l (Fig. 36).

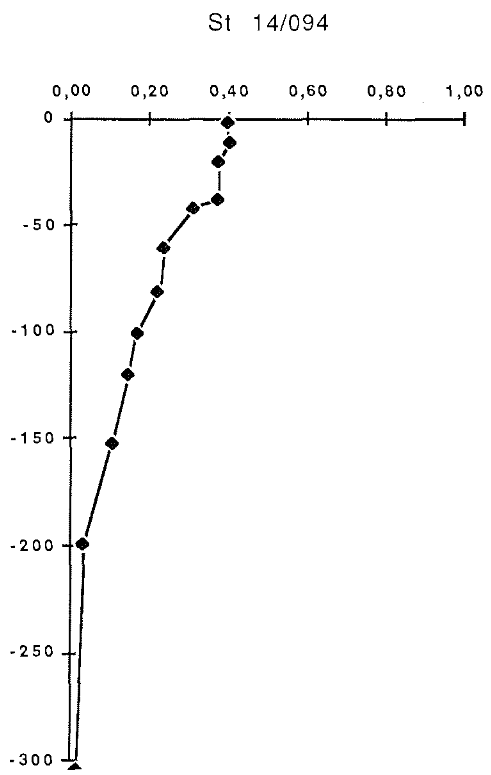

Fig. 35. Profile of Chl a at St 14/094 representing a typical situation in the ice edge zone.

The strong variations in the Chl a values correspond well with the nutrient data showing decreasing values to the north and real winter conditions still prevailing in the south. In the zone in-between, the enhanced biomass could be the first signal of the main biomass increase in spring bloom in this area.

The fairly high biomass found in the north could, on one hand, be due to melting processes or could be the result of an overlying water mass leading to a stabilization of the upper 80m thus favouring phytoplankton growth. If the latter is true, this situation lasts for more than two weeks. A detailed study of the hydrography is, however, necessary before final conclusions can be drawn.

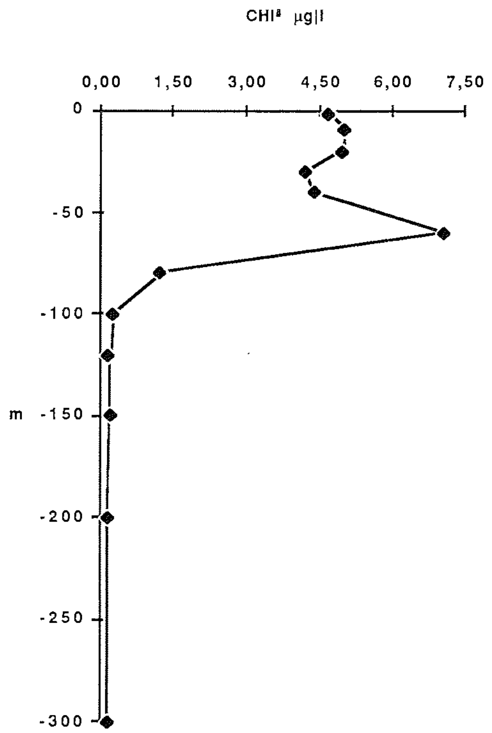

Fig.36. Chl a profile at Station 14/138 (open water) showing a high maximum at 60m depth.

On the other hand, results obtained with 20µm plankton-net showed a similar pattern with regard to the three zones described above. In the south almost no living phytoplankton was found. The samples contained empty frustules mainly of pennate diatoms, large amounts of detritus and some broken strings of zooplankton faeces. Further north, more living cells were found in the net samples. Most of these seemed to be ice related pennate diatom species mixed with some centric diatoms such as *Corethron criophlium*, *Rhizosolenia spp, Stellarima microtrias, Actinocyclus sp., Chaetoceros* spp.. In the most productive area of this investigation a highly diverse phytoplankton assemblage was found consisting mostly of pelagic centric diatoms forming long chains, e.g., *Thalassiosira* spp., *Porosira* spp., *Eucampia balaustium, Chaetoceros neglectum* and others. On the fourth transect large colonies formed by a *Thalassiosira* sp could be encountered and probably caused clogging of the various nets used for the zooplankton catches at these stations.

2.2.8 ECOPHYSIOLOGY OF PHYTOPLANKTON

2.2.8.1 The productivity of phytoplankton

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G. Kraay, S. Kristiansen, W. Overloop, M. M. Tilzer

Nutrients are never exhausted during the growing season in the Southern Ocean and the carrying capacity for phytoplankton to be anticipated from nutrient availability is not reached. This has lead to the now widely accepted conclusion that the phytoplankton in the Antarctic Ocean are limited by energy rather than by nutrient supply. We therefore concentrated on studies dealing with aspects of the energy balance of the primary production process.

Objectives

i) To quantify the efficiency of light harvesting by the phytoplankton community in situ.

ii) To evaluate the photosynthetic activity as a function of the light history of the algae (light-shade adaptation).

iii) To examine the relationship between carbon fixation and oxygen evolution.

iv) To compare photosynthetic rates as measured in light incubators with in situ measurements.

v) To estimate potential phytoplankton growth rates under the same temperature conditions as found in situ but under saturating light conditions.

vi) To evaluate new versus recycled production by measuring the uptake rates of nitrate, ammonia and urea.

vii) To develop a procedure to realistically estimate in situ production from incubator measurements in conjunction with assessments of the spectral properties of the underwater light field and light absorption cross-sections of the phytoplankton community.

Work at sea

i) Photosynthetic rate measurements in an incubator ("in vitro"): The incubator consisted of seven aquaria, each of which had an approximate volume of 20 litres. The chambers were temperature-controlled within ± 0.1 degrees C to in-situ water temperatures. Light from six fluorescence tubes was partially shielded by glass neutral density filters. Thus a light gradient ranging from ca. 5 to ca. 800 $\mu mol \cdot m^{-2} s^{-1}$ was created. The spectral composition of the fluorescence tubes was checked with the spectroradiometer. It is rather uniform but has two slight maxima at 441 and 583 nm.

On 22 dates photosynthetic rate measurements were performed by using the radiocarbon technique. In addition, at 14 stations the oxygen light-and-dark-bottle method was used in parallel. In all but 2 experiments phytoplankton from two water depths were used (10 and 80 or 100 m, corresponding to surface light levels of 50 and 0.1 - 1 %, respectively) for photosynthetic rate measurements with the ^{14}C technique. Incubations by using the oxygen technique were performed with plankton from 10 m only. Incubations lasted for 8 - 12 hours each. All values were recalculated to hourly rates. Several times the kinetics of radiocarbon uptake were examined in time-series experiments of 2-14 hours duration. These experiments showed linear uptake indicating that recalculations to hourly rates did not introduce any errors (Fig. 37).

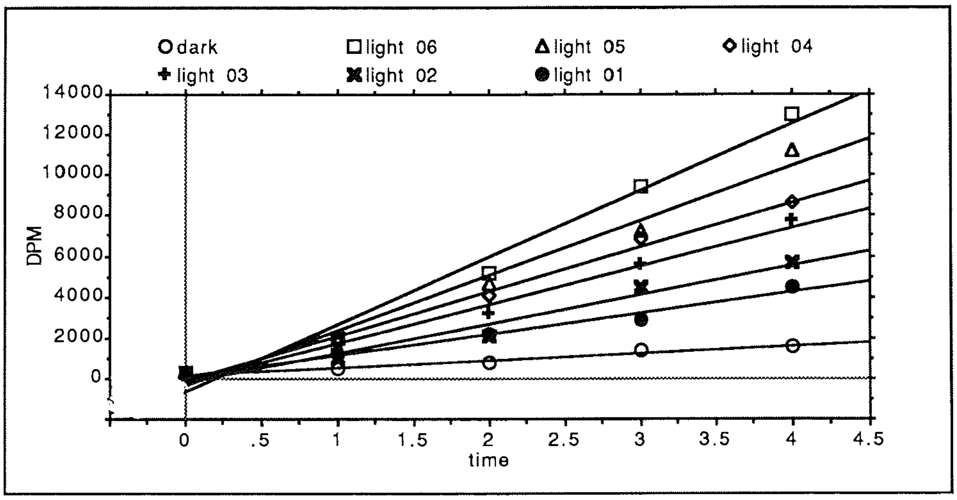

Figure 37. Production kinetics: Carbon assimilation as a function of time at different light levels ranging from 0.018 · 10^7 to 0.44 · 10^7 Quanta/sec/m^2

ii) Photosynthetic rate measurements in the ocean ("in situ"):On two occasions photosynthetic rates in addition were measured in the ocean by suspending triplicate light and single dark bottles at their respective depths of collection ranging from the water surface to a maximum depth of 60 m.

iii) Oxygen was continuously recorded from 11 m depth.

iv) The time-course of light-shade adaptation was followed by incubating replicate samples of phytoplankton from 10 and 80 m to two light levels (363 and 6-7 $\mu mol \cdot m^{-2} \cdot s^{-1}$) each.The photoperiod was 15.4 hours, the temperature was -1.5°C. During a period of 14 days chlorophyll concentrations and photosynthetic rates at the two light levels of incubation were followed. At the beginning and at the end of the experiment photosynthesis versus irradiance curves ("P vs.I curves") were assayed in the incubator and samples for enumeration were withdrawn.

v) The growth potential of phytoplankton was examined by incubating phytoplankton samples collected at three stations from two water depths (10 m and 80 m) in 10-liter glass bottles at a temperature of -1.8°C and an irradiance of 120 $\mu mol \cdot m^{-2} \cdot h^{-1}$. The bottles were covered by black plastic sheets at 23.00 hrs and uncovered at 7.30 hrs to simulate a light-dark cycle of 15.5 : 8.5 hrs. Nutrient concentrations were measured at the beginning and the end of the incubation period. The experiments lasted from between 18 and 22 days each. Water samples were withdrawn from the incubation bottles every two days. Chlorophyll and production rate measurements (the latter by using the radiocarbon technique) were carried out, and samples were preserved in formalin for species composition analysis and enumeration at a later date.

vi) The uptake of different nitrogen species by phytoplankton: Uptake rates of nitrate, ammonium and urea were measured at ten stations from 10-15 meters and 100 meter depths (the latter only at one station). The samples were incubated at -1.5°C and 250 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (10-15 m samples) or 10 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (100 m sample). Uptake rates were measured by the 15N-technique. No values are available yet because the samples will have to be analyzed at home.

vii) The light absorption cross-section of phytoplankton assemblages: By light absorption cross-section (kc) we understand the efficiency of light absorption by photosynthetic pigments, normalized to chlorophyll (dimension: m^2 (mg chl a)$^{-1}$). When the light absorption cross-section and the chlorophyll concentration are known, it is possible to quantify the amount of light harvested by a phytoplankton assemblage. Kc values were estimated by using a similar procedure as for the assessment of the in vivo absorption spectra (see section on the underwarter light field): five volumes of seawater of known chlorophyll concentration were filtered onto GF/C filters and their absorption measured in the same 12 wavelengths in which underwater light was measured by using the spectroradio-meter. From the slope of a linear regression analysis of light absorbance at each measured wavelength against chlorophyll concentration, chlorophyll-specific light absorption could be estimated.

By integrating wavelength-specific light absorption cross-sections of phytoplankton over the spectrum of PAR in the sea and in the incubator, true mean light absorption cross-sections will be obtained which will be instrumental for the quantification of light harvesting by phytoplankton in situ and for the estimation of the quantum yield of photosynthesis in the incubators.

Preliminary results

i) The photosynthethic light responses of phytoplankton from different water depths:
Photosynthesis-irradiance curves ("P vs. I curves") were examined to accomplish objectives ii, iv, v, vi, and vii. Because a more extensive data analysis will be required to draw major conclusions, this section of the report will be restricted to a description of the photosynthesis-irradiance relationships. Two parameters are sufficient to characterize the photosynthetic responses of phytoplankton to light when photosynthesis is expressed on a per-chlorophyll-basis. They are a function of the physiological conditions and the species composition of the algal assemblage: By the maximum assimilation number we understand the maximum photosynthethic rate (per chl a) at light saturation. This parameter expresses the maximum potential of a community to fix carbon. It was determined by forming the arithmetic mean of all light-saturated photosynthetic rates of a P vs. I curve. The initial slope of the light-limited portion of the P vs. I curve ("alpha", aB is a measure of the maximum quantum yield of photosynthesis (phi, mol CO_2 fixed per mol PAR absorbed) and of the efficiency at which light is harvested (light absorption cross-section, kc) by the antenna pigments. Alpha was determined by linear regression analysis of the data points in the light-limited portion of the P vs. I curve .
Fig. 38 shows that in phytoplankton from deep water high irradiances are inhibitory to photosynthesis.

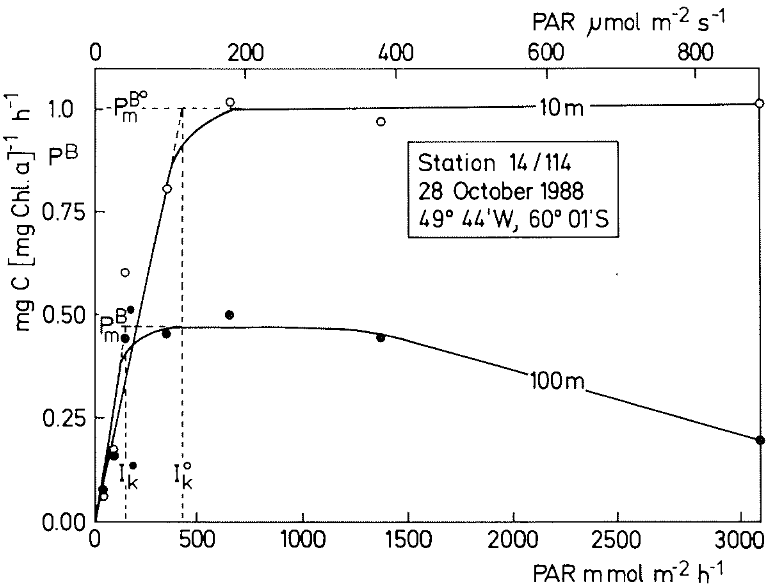

Figure 38. Two characteristic P vs. I curves as obtained by incubating phytoplankton from 2 water depths (10 m and 80 m) to the same light gradient. Phytoplankton from near the water surface exhibited higher light-saturated maximum assimilation numbers (Pbm) and phytoplankton from 80 m shows an increased initial slope (aB). This pattern is characteristic of phytoplankton whose light-shade adaptation differs.

Both maximum assimilation numbers and initial slopes were significantly lower than those of phytoplankton at lower latitudes which previously had been attributed to the effect of low water temperatures. However, they were not correlated with each other because they are controlled by independent mechanisms. Particularly low figures were observed during the first phase of the cruise and in deep phytoplankton which suggests low overall photosynthetic activity in light-limited winter and/or deep phytoplankton.

Despite extremely low water column stability both chlorophyll concentrations and photosynthetic light responses exhibited considerable vertical differentiation. Careful analysis of the hydrographic data obtained during this cruise will be required to evaluate the degree of vertical mixing.

Most of the time, no clear difference could be detected between constant and fluctuating light incubations (Fig. 39).

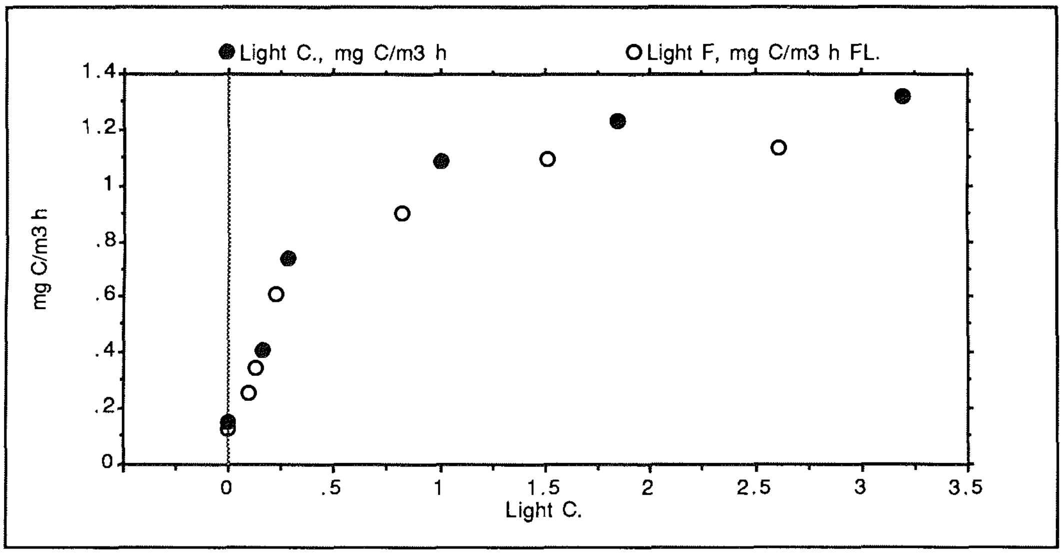

Figure 39. Production in mgC/m^3/h as a function of different light intensities (Quanta:10^7/s/m^2): constant versus fluctuating light

ii) The time-course of photoadaptation:
Marine ecosystems are characterized by high turbulence of the water column. Therefore, planktonic organisms are exposed to a highly variable light field within short time-intervals. The aim of our experiments was to find out the time scale in which a phytoplankton assemblage is capable of adapting both to saturating (323 µmol m^{-2} s^{-1}) and to limiting (6-7 µmol m^{-2} s^{-1}) quantum fluxes.

Incubations at high irradiances: Algae from shallow and deep water increased markedly in biomass and photosynthetic rates after a lag phase of several days (Fig. 40). At the end of the experiments, phytoplankton biomass from 10 m was 20, from 100 m 10 times as high as in the inoculum. In 10-m phytoplankton the initial lag phase was 3 days, followed by an exponential increase of chlorophyll concentrations at a growth rate of 0.37 d^{-1}, corresponding to a doubling time of 1.9 days. The increase of photosynthesis was even greater. Hence maximum assimilation numbers increased, from 0.8 mg C(mg chl a)$^{-1}$h^{-1} to 2.7 mg C(mg chl a)$^{-1}$h^{-1}.

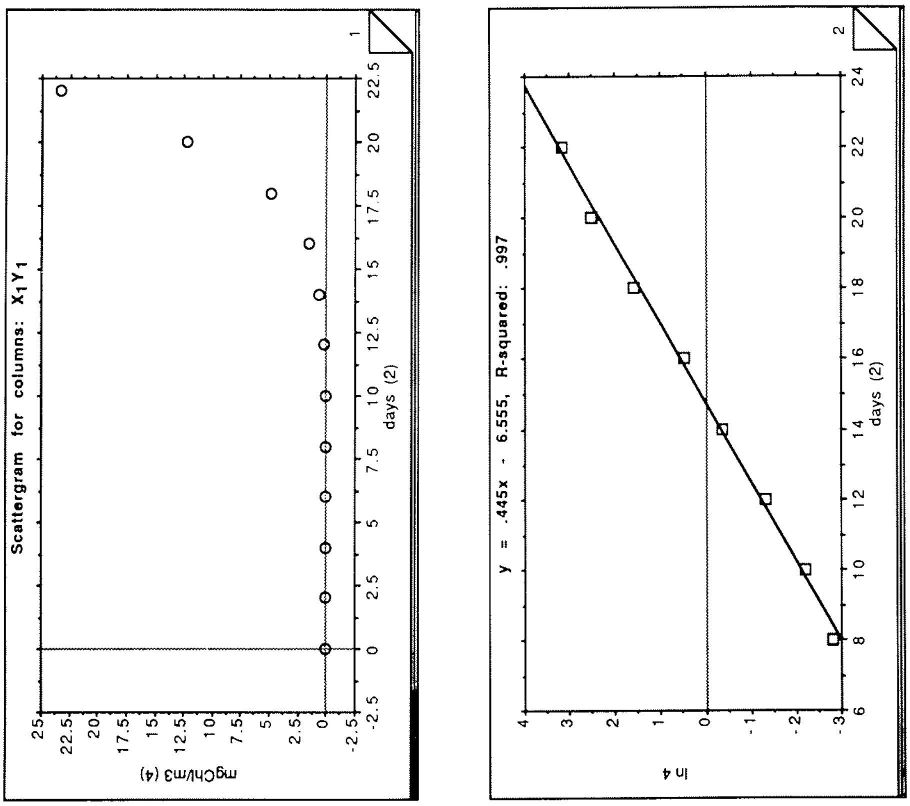

Figure 40.Chlorophyll concentration in µg/l plotted logarithmically against time in days. Samples from 10 m depth (Fig. a) and 100 m depth (Fig. b) incubated at 363 µE/m^2/h.

In the sample from 100 m depth the lag-phase was much longer (8 days), which was also followed by an exponential growth phase with an even higher growth rate (μ = 0.5 d^{-1}; doubling-time 1-4 d). Also the increase of the assimilation number was greater, from an initial value of 0.2 mg C (mg chl a)$^{-1}$h^{-1} to a final 1.4 mg C(mg chl a)$^{-1}$h^{-1}.

P vs. I curves were assayed at the beginnning and the end of the experiment in samples from both water depths. The initial slope alpha (a) did not change significantly. Because of the above-mentioned increase in maximum assimilation numbers, Ik values increased markedly.

Incubations at low irradiances did not lead to changes either in chlorophyll concentrations or photosynthetic rates. Obviously, carbon uptake was balanced by losses due to respiration, extracellular release, lysis and consumption by heterotrophs. Thus the irradiance to which these samples were exposed was at the maintenance level.

iii) In situ measurements of primary productivity:

At two stations samples were incubated both in situ and in the incubator in order to compare primary production under artificial irradiance and under natural light conditions. The level of in situ production was 2 times higher than in the incubator. This difference is tentatively ascribed to the fact that in the sea algae are irradiated by blue light whereas the artificial light source in the incubator provides roughly uniform irradiance over the spectrum of PAR (see methods i). The incubator light has possibly inhibited the production efficiency of the phytoplankton.

iv) Comparison of carbon uptake with oxygen evolution and consumption:
In most of the survey area primary production of the phytoplankton was extremely low. We were unable to determine diurnal variations of CO_2 and O_2 in the water because of this low activity and water mass variability. For the same reason planktonic respiration could often not be determined by using an O_2 electrode. However, the precision of our highly sensitive oxygen light and dark bottle method was so great that in spite of low values we were able to find a significant correlation between the amount of carbon fixed during the incubations and the oxygen increase due to photosynthesis. In Fig. 41 the data set is summarized. The mean photosynthetic quotient (mol O_2 produced per mol CO_2 taken up) was 2.56. This rather high value suggests that photosynthetic carbon fixation and oxygen evolution due to photosynthesis were not entirely in balance. This may be explained by the low rate of the processes of primary production (mean phytoplankton production at all stations with a sea-ice cover was only 0.063 μmol O_2 m^{-3} h^{-1}). High PQ values of up to 2.0 have previously been found in temperate waters in natural phytoplankton that uses nitrate as a nitrogen source. At the Northern open-water stations net oxygen production was high (up to 0.49 μmol O_2 $m^{-3}h^{-1}$), in line with the much higher phytoplankton biomass in this area.

The respiration that was registered (initial oxygen concentration in the bottles minus the dark values at the end of the incubation) was low everywhere. Assuming that respiration is equal during day and night we can extrapolate respiration rates during the incubation period to respiration during 24 hrs. The mean value of respiration rates was 0.29 μmol O_2 $m^{-3}(24hours)^{-1}$ at all stations in the sea-ice zone.

v) The light absorbance by algal suspensions and the effect of detritus:
At most stations the absorption spectra obtained by direct scanning of suspended matter retained on glass-fiber filters revealed the presence of detritus which absorbs light in the blue and near-ultraviolet part of the spectrum. At stations with higher chlorophyll a concentration (> 0.25 μg dm^{-3}), the detrital component was as important as phytoplankton in terms of light absorption, especially towards the shorter wavelengths, that is, below 500 nm.

We refer the interested reader to the corresponding section iii in the chapter about the underwater light climate (p. 77).

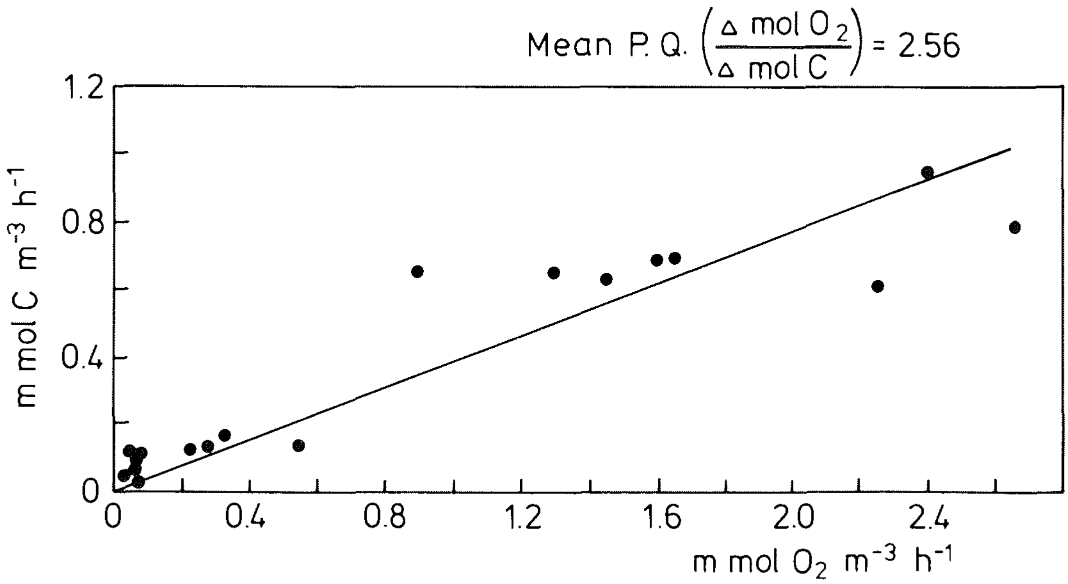

Figure 41.Comparison of primary production values obtained by the ^{14}C method and the oxygen light-and-dark bottle method until Nov. 7. The mean photosynthetic quotient (µmol O_2 produced per µmol CO_2 taken up) is 2.56.

Only light that has been absorbed by active antenna pigments can be utilised energetically for photosynthesis. Therefore, the efficiency of light harvesting is of crucial importance for the understanding of the energetics of the primary production process. Light absorption cross-sestions exhibited maximum values of 0.029 - 0.041 m^2 (mg chl a)$^{-1}$ at 441 mn where chlorophyll has its absorption peak in the blue. In the green spectral range, absorption by algal pigments is minimal (0.004 - 0.006 m^2 (mg chl a)$^{-1}$). Mean values of wavelength - specific absorption cross sections over the spectrum are 0.014 m^2 (mg m^{-3} chl a)$^{-1}$ which is typical for blue-green water. In blue Antarctic water much higher values can be expected and indirect estimates during a previous cruise actually suggested this.

vi) The growth potential of Antarctic phytoplankton:
In all six experimental bottles an exponential increase both in chlorophyll levels and production rates was observed. Linear regression analyses were carried out on the natural logarithms of the chlorophyll and production data. Growth rates of biomass thus estimated were 0.211-0.445 ln-units d^{-1} which corresponded with doubling times of 1.56 and 2.41 days, or 37.38 and 78.84 hours. The rate of increase in photosynthetic rates was 0.288-0.446 d^{-1} and

the doubling time of carbon uptake accordingly was 1.55 - 2.41 days, or 37.3 to 57.76 hrs.

A lag phase of 4-8 days was observed in the bottles. A marked decrease in nutrient concentrations within the bottles was observed but growth continued to be supported (Fig. 42).

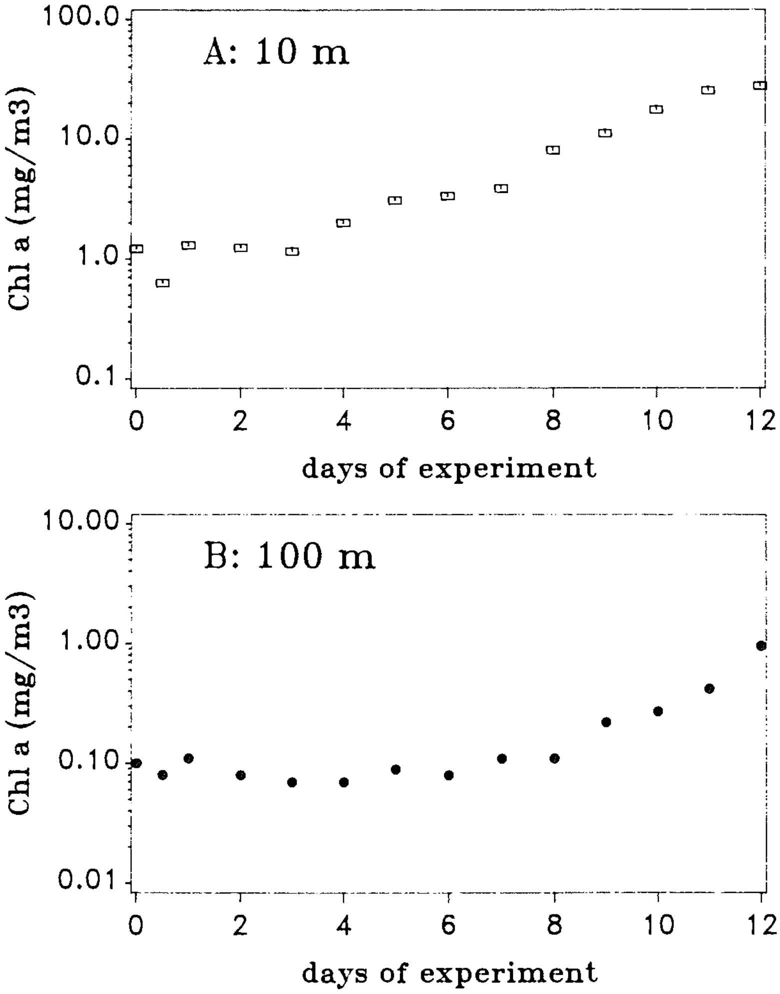

Figure 42 Growth curves of chl a concentrations at saturating light (120 µmol m^{-2} s^{-1}) and ambient temperatures (-1.8°C) of a plankton sample originating from 80 m depth. The top panel shows a linear representation of the chl a data, in the lower panel the same data set is plotted logarithmically.

In conclusion, phytoplankton which had been sampled from beneath the ice where they had lived unter extremely low light conditions, resumed their growth after some delay when brought to light and achieved much higher biomass than occurring in the natural habitat. These results clearly indicate that phytoplankton growth in the Southern Ocean is limited by shortage of light and not by low tempetratures or nutrients.The above experiments were carried out in conjunction with E.M. Nöthig.

vii) Comment: Primary production and the oxygen regime in the Weddell Sea. The primary production measured both in the incubator and in situ in the ice-covered zone (i.e. in most of the survey area) does in fact not represent true productivity of the phytoplankton. The cells are transfered from the near-darkness under the ice to the light in the incubator or, when performing in situ incubations, to the light in a narrow area of open water. In reality as much as 90 % of the survey area was covered by ice and snow. Therefore, only 10 % of the carbon fixation and oxygen evolution measured by us was really fixed (and produced) by the phytoplankton, i.e. for oxygen (assuming a mean daylight period of 14 hours) the maximum potential production of oxygen was 14 times 0.06 μmol O_2 m^{-3} h^{-1} = 0.88 μmol O_2 m^{-3} d^{-1}, while the actual production was only 10 % of this figure: 0.09 μmol m^{-3} d^{-1}. This is much less than the respiration (consumption of oxygen) that was registered (0.29 μmol O_2 m^{-3} $(24\ h)^{-1}$, see "results" iv).This excess of respiration over oxygen production must cause an undersaturation of oxygen in the ice-covered Weddell Sea. The hydrographers on board did in fact find significant undersaturation with oxygen in the water column at 10 m depth: 82 % (A.-M. Larsson, pers. comm. and see tab. 10).

In the Northern ice-free region of the survey area, primary productivity was much higher and oxygen production during photosynthesis was far in excess of community respiration. Oxygen concentrations in the water were correspondingly high, up to oversaturation (see tab. 11). This indicates that the bloom North of the marginal ice zone was in its exponential phase.

Table 10: Photosynthetic parameters during our light adaptation experiments

Station	Date	depth	% I_o	Chl a	P^B_m	alpha	I_K
084	19.10.	14.7	25.2	0.27	0.873	0.0075	56.1
		82.1	1.13	0.13	0.959	0.0036	78.9
087	20.10	10.5	33.6	0.12	0.855	0.0048	56.0
		82.3	0.75	0.11	0.824	0.0061	53.1
089a	21.10	10.0	33.6	0.09	0.692	0.0022	86.8
		80.0	1.64	0.09	0.678	0.0038	59.2
089i	22.10	10.0	36.1	0.09	0.292	0.0013	63.6
		80.0	1.9	0.08	0.600	0.0018	97.1
091	23.10	10.0	22.0	0.33	0.821	0.0036	66.3
		80.0	1.0	0.30	0.727	0.0032	81.7
094	24.10	14.7	30.0	0.41	0.689	0.0051	46.7
		102.6	0.06	0.17	1.244	0.0053	68.9
096	25.10	9.7	25.0	0.35	4.430	0.0074	167.0
		99.6	0.5	0.21	0.367	0.0066	119.3
100a	26.10	10.0	26.0	1.18	0.779	0.0032	74.7
		101.7	0.42	0.17	0.204	0.0016	30.7
100e	27.10	10.4	25.5	1.31	1.230	0.0052	73.5
		100.5	0.40	0.21	0.321	0.0040	44.7
104	28.10	10.0	21.1	0.77	1.007	0.0024	111.6
		100.0	0.15	0.14	0.475	0.0027	42.2
111	30.10	10.0	25.0	0.24	0.827	0.0049	55.0
		80.0	0.94	0.19	0.766	0.0040	55.5
113	31.10	10.0	39.4	0.28	0.774	0.0056	46.3
		80.0	0.06	0.12	0.527	0.0026	48.9
115	01.11	10.0	37.4	0.16	0.757	0.0034	64.2
		80.0	0.70	0.15	0.407	0.0018	61.3
117	02.11	10.0	29.1	0.15	0.655	0.0037	58.1
119	03.11	10.0	25.0	0.14	0.760	0.0038	85.1
122	06.11	10.0	29.0	0.14	1.130	0.0065	53.4

Table 10 continued.

Station	Date	depth	% I_o	Chl a	$P^B{}_m$	alpha	I_k
125a	08.11	10.2	27.4	0.20	1.429	0.0008	49.0
		80.0	0.72	0.10	1.052	0.0061	40.0
126	09.11	10.0	31.9	0.34	0.826	0.0063	44.0
131	11.11	10.0	26.7	0.33	0.955	0.0044	62.3
		80.0	0.14	0.25	1.149	0.0063	58.5
135	12.11	10.0	15.9	0.20	1.276	0.0023	146.5
		80.0	0.01	1.33	1.665	0.0073	64.3
139a	13.11	10.3	15.4	2.02	0.677	0.0021	87.2
		81.3	0.06	1.83	1.404	0.0050	306.3
140	14.11	10.0	25.0	0.55	1.059	0.0020	143.3
		80.0	0.80	0.49	1.146	0.0022	137.9

Definitions and dimensions of parameters used in the table

% I_o: Percent light level of surface irradiance from which samples have been collected

Chl a: concentration of chlorophyll a, mg m^{-3}

$P^B{}_m$: Maximum light-saturated assimilation number mg C (µg chl a)$^{-1}$h^{-1}

Alpha: slope of the light-limited portion of the photosynthesis versus irradiance curve, mg C (µg chl a µmol PAR)-1 $m^2(a^B)$

I_k : Irradiance at onset of light-saturation, µmol m^{-2} s^{-1} PAR

Table 11. Primary production measured by the oxygen light and dark bottle method. Values are means of the oxygen produced under incubator irradiances of 860, 380 and 190 μmol $m^{-2}s^{-1}$ during incubations of 8-9 hrs. Chlorophyll values courtesy of G. DIECKMANN and E.-M. NÖTHIG.

Station	gross prod. μmol $m^{-3}h^{-1}$ light-dark	Net prod. μmol $m^{-3}h^{-1}$ light-initial	Chl a mg m^{-3}	Oxygen %-sat.
100a	0.243	0.195	1.18	95
104	0.148	0.123	0.77	94
113	0.040	0.038	0.28	81
117	0.054	0.045	0.11	81
112	0.038	0.013	0.14	80
115	0.066	0.060	0.16	80
124	0.065	0.052	0.32	79
126	0.050	0.050	0.34	87
131	0.042	0.042	0.13	88
135	0.602	0.472	3.20	102
136	0.548	0.488	3.60	101
137	0.573	0.403	4.00	99
139	0.353	0.328	1.80	99
140	0.044	0.009	0.55	86

2.2.8.2 The activity of the respiratory electron transport system in microplankton

R. Martinez

Objectives

Phytoplankton biomass and production in the Southern Ocean are known to be low during early spring. The respiratory metabolism should be accordingly low, although in open water areas was expected to be higher than in ice-covered ones. The activity of the enzymes that constitute the respiratory electron transport system (ETS) was used to estimate the respiratory capacity of microplankton (less than 240 µm in size). The method yields real-time activity measurements and allows to measure very low oxygen consumption rates that are difficult or impossible to be detected by other techniques.

Specific objectives were:

1. To assess the respiratory capacity of microplankton in different zones of the Weddell Sea in early spring, especially in relationship to latitude, season and ice cover.

2. To examine the relationship between respiratory ETS activity and phytoplankton biomass (chlorophyll) in the euphotic zone.

3. To relate the respiratory ETS activity to the hydrographic parameters (salinity, temperature, pH) and to oxygen.

4. To get a first insight into the ETS activity in ice and snow microbial populations.

Work at sea

Microplankton samples were collected by prefiltering sea water through 243 µm nytal mesh, and then filtering through Whatman GF/F glass fiber filters. The plankton coated filters were immediately frozen in liquid nitrogen until they were assayed. The water volumes filtered depended on the plankton biomass, ranging from 5 to 10 liters for chlorophyll concentrations of 0.3 mg/m^3 or more. For water very poor in biomass 15 to 20 liters were filtered.

The ETS activity assay was performed according to the method by Packard (1971), as modified by Kenner and Ahmed (1975). Further minor modifications have ben introduced to adapt it to the present conditions. A kinetic study was previously run to determine the optimum temperature and time for the in vitro enzyme incubation.

ETS activity depth-profiles have been obtained at 13 stations, consisting of 8 to 14 depths, for the water column between surface and 300 m. At additional 4 stations five size fractions of microplankton at one or two depths were obtained and on each one chlorophyll and ETS analyzed.

Other additional samples were obtained from surface and 10 m depth. Ice samples were also collected at 5 stations and ETS activity and chlorophyll were determined.

Preliminary results

1. Enzyme, reaction, kinetics: Subsamples from a single water sample were assayed at a preset water bath temperature and 6 different times. The temperatures were: in situ (-1 to 1°C), 6°, 10° and 15°C, and the times: 0, 5, 10, 15, 20 and 25 min.

   The optimum conditions for the enzyme incubation were found to be 10°C and 15 min. This fully agrees with what has been recently found for arctic microplankton from the Barents Sea (Martinez, unpublished). All the subsequent assays were done under these conditions.

2. ETS and chlorophyll-specific ETS activity in the water column: Only some results are as yet available. They show that ETS activity was lowest at the stations in the pack-ice, and increased in the open water or ice edge areas. Fig. 1 shows profiles of ETS and chlorophyll-specific ETS activity for stations 14/084, 14/089-2 and 14/092 down to 300 m. Maximum values were often observed at the surface, specially at the beginning of the cruise. An enhancement of respiration at the water/atmosphere interface is a common occurrence, and the surface samples included this layer. At some of the stations Gieskes (this report) found fairly large amounts of detrital matter, and this could sustain an increased actively respiring bacterial population. An explanation for this maxima being due to surface nutrients provided by melting ice was rejected on the basis of hydrographic data (Larsson and Sehlstedt, this report).

   An apparently anomalous situation appeared at Sta. 117, where biomass (chlorophyll) was very low, but ETS values were among the highest found during the cruise. Results by DeLille (this report) show large bacterial numbers at several depths of this station, and that was likely to cause this high ETS acticity.

   Chlorophyll-specific ETS activity values (ETS/Chl a, μmol O_2h/μgChl a) are also shown in Fig. 43. The ratio ranged from 0.015 to 0.090 μmol O_2/μg Chl/h at Stas. 84 to 100 for the water column down to 80 or 100 m, showing an increase with depth. Here the activity was mostly due to phytoplankton biomass. At deeper zones the activity was likely to be mostly due to heterotrophs. Any increase of the ratio in the upper 100 m could be an indication of a more active phytoplankton. These hypotheses need to be contrasted with results of primary production (Tilzer et al., this Report) and bacterial biomass (Delille, this report).

   From the depth profiles the total column respiratory activity was estimated. Complete data sets are as yet available only for Stas. 84

through 92. The total respiratory ETS activity for the water between 0 and 300 m ranged between 1200 and 2000 µmol $O_2/m^2/h$.

3. Latitudinal variation of ETS activity: Some results of maximum ETS values, or in some cases, single results from the upper meters, were used to gain a first insight into the latitudinal variation, and are shown in Tab. 12 . The results are not definitive, and they could vary when all the data have been analyzed. But they seem to indicate a clear trend in ETS activity according to latitude. During the second transect I found a northward variation in ETS activity from 11 µmol O_2/l/h at Sta. 89 (62.20°S) to 18.1 µmol O_2/l/h at Sta. 100 (58.58° S). During the fourth transect the activity varied between 11.5 µm O_2/l/h at Sta. 119 (63.20° S) and 56 µm O_2/l/h at Sta. 139 (57.49° S). Whether this increase was solely due to a parallel phytoplankton biomass or to a more metabolically active plankton has yet to be determined.

Table 12: Latitudinal variation of ETS activity

Second Transect

Lat S	62°40'	61°48'	59°09'	58°58'
Sta.no.	14/089	14/092	14/96	14/100
ETS act. (µmol $O_2m^{-3}h^{-1}$)	11.0	12.3	15.0	18.1

Fourth transect

Lat S	63°20'	62°37'	60°19'	59°11'	58°30'	57°49'
Sta.no.	14/119	14/122	14/131	14/135	14/137	14/139
ETS act. (µmol $O_2m^{-3}h^{-1}$)	11.5	19.9	16.0	17.8	30.0	56.0

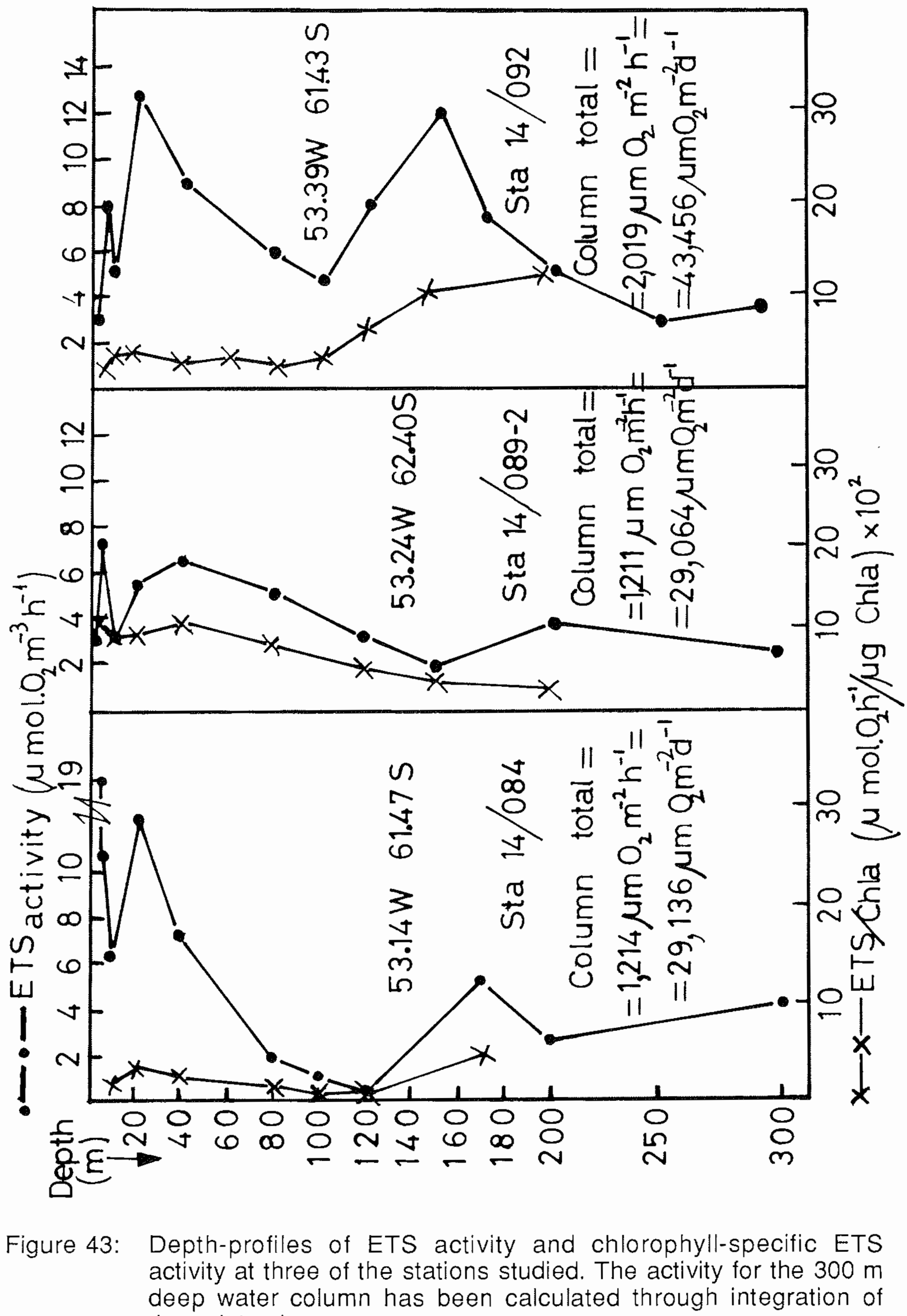

Figure 43: Depth-profiles of ETS activity and chlorophyll-specific ETS activity at three of the stations studied. The activity for the 300 m deep water column has been calculated through integration of the point values.

2.2.9 ZOOPLANKTON DISTRIBUTION, BIOCHEMISTRY AND GENETICS

B. Battaglia, A. Goffart, I. Hempel, V. Siegel

Objectives

Over the past few years composition and distribution of zooplankton communities in the Weddell Sea during summer has been studied by German expeditions. There is also information available on the winter plankton in the eastern Weddell Sea ("Polarstern" ANT V/3, 1986). Little, however, is known about the zooplankton in late winter in the northwestern Weddell Sea. Hitherto, no sampling in the pack ice zone of the inner Weddell Sea had been conducted. Main objective of the zooplankton sampling during leg 1 of EPOS was to provide the basis for comparisons on composition of zooplankton in respect to

- geographical distribution : western, eastern/southern, inner Weddell Sea
- shelf and oceanic communities
- communities in and under the ice and in open water
- temporal variation: seasonal summer/winter and short term within weeks

(sampling will be repeated on leg 2 and 3 on one of the transects).

All the data may also serve for comparisons to earlier data from the Peninsula region, southern Scotia Sea, eastern and southern Weddell Sea (Boysen-Ennen, Hempel, Hubold, Piatkowski, Siegel).

Researchers in phytoplankton and nutrients should become enabled to relate their results to the zooplankton as consumers and as producers of ammonia as well.

The zooplankton should also provide material for specialised laboratory studies.

The link between phyto- and zooplankton was to be studied by A. Goffart using the fatty acid composition as "finger prints" of food chain relationships. In the Antarctic ecosystem, like in other areas where the phytoplanktonic productivity is highly limited in time and space, storage of lipids during phytoplankton blooms helps herbivorous zooplankton to support the alternance of nutrition and diet periods. Moreover, lipids accumulation by herbivorous zooplankton provides energetic food for many pelagic consumers. The study of stored lipids (mainly triacylglycerols and wax esters) and their fatty acids composition will improve our understanding of the nutritional state of Weddell Sea zooplankton during the austral spring.

Genetic stock separation on euphausiid, fish and amphipod species was planned by B. Battaglia. Studies of this kind may prove useful when carried out in populations of pelagic species having a broad distribution in order to evaluate the amount of gene flow, to throw light on certain taxonomical aspects, and possibly to detect mechanisms of speciation and strategies of genetic adaptation to the particular features of the Antarctic ocean. The following objectives could be pursued: 1) To investigate on the genetic structure of krill populations along the various stations of the transects and extend the study to other planktonic species. Measurements of genetic variability in various species and populations of the same species will be included. 2) To search for other possible cases of deviation from the Hardy-Weinberg equilibrium at the PGI locus.

According to the planned cruise track we wanted to sample zooplankton

1) in the open water just in front of the marginal ice zone,
   within the marginal ice zone,
   within the pack ice zone.
2) from the shelf region of Joinville Is. into the deep water of the Powell Basin including the slope, or on the way back from the deeper part of the Powell Basin to the shelf region of South Orkney Is.

Work at Sea

In the pack ice of the southern Weddell Sea vertical hauls by Bongo Net had proven particularly easy and effective. Therefore and for reason of comparison the same method was employed this time again for the zooplankton community study. The standard fishing depth was from 300 m to the surface, the mesh size of both nets 300 micron and the total filtered volume of water was about 168 m^3. Few hauls were taken from 600 m to the surface, to see whether resting stages of copepods stay deeper than 300 m. Due to the poor abundance of zooplankton within the pack ice we took both Bongo net samples as one. We hauled the gear usually two times per station, one haul was for A. Goffart's fatty acids and lipids study and the second one for Hempel's community study. In addition, the Fransz Net (equipped with 50 micron mesh size) was hauled vertically from 200 m to the surface. It filtered about 12.3 m^3 per catch. On the transect out of the ice in direction to the South Orkney Islands and from there farther to the North an opening closing net - Multinet - was deployed. This transect will be repeated on leg 2 and 3. The Multinet sampled five distinct layers from 1000 m and 300 m resp. to the surface for comparable studies of the vertical distribution of zooplankton.

Whenever there was enough open water the opening/closing version of the RMT (Rectangular Midwater Trawl) was used by V. Siegel, mainly to catch *Euphausia superba* in three distinct water layers from 300 m depth to the surface for length/frequency studies. This was done by the RMT 8 (4500 micron) and the results will be reported later in this issue. The simultaneously taken RMT 1 samples (300 micron) will serve for zooplankton community studies as well and will be compared with those of the Elephant Island region.

The zooplankton caught by the different gears was preserved in 4% formalin.

Altogether	53	Bongo hauls
	10	Fransz net hauls
	8	Multinet hauls

were carried out.

The methods utilized for the genetic structure research include electrophoretic analyses and estimations of PGI activity, which can only be applied on land. For these purposes, the specimens were classified immediately after collection and deep frozen. Samples mainly from the RMT catches (very few from Bongo Net) of the following species have been collected and preserved

Euphausia superba	301	specimens
E. crystallorophias	66	
Thysanoessa sp.	176	
Clio pyramidata	57	
Notolepis sp.	27	
Cyllopus lucasii	2	
Cyllopus magellanicus	5	
Eusirus sp.	49	

In the present preliminary report the samples taken by RMT at different depths have been pooled together. In most cases, however, data are available for catches at various depths and the specimens have been separated and preserved accordingly.

Preliminary Results

On both transects into the pack-ice zone of the inner Weddell Sea zooplankton abundance was poor even compared with the findings in the south eastern Weddell Sea at the same time of the year two years ago. The paucity of zooplankton was mainly concerned to biomass, less to diversity. Larval or juvenile stages of molluscs, echinoderms, ctenophores, polychaetes were regularly found. Most of them looked more transparent than in summer. Also pteropods, different species of ostracods and chaetognaths were met on all Bongo stations. Unusually rare were the typical Antarctic copepods *Calanus propinquus* and *Calanoides acutus* as well as *Metridia gerlachei*, which had been relatively abundant in the southern Weddell Sea in this time of the year. At the end of the cruise, station 94 was repeated. Within the three weeks after the first sampling no obvious changes had taken place in the zooplankton. We found the same paucity as before. Only on the shelf stations off Signy I. we found few appendicularians, gammarids and cumaceans. Hyperiid amphipods were also very rare in general. When continuing the transect from Signy Is. onwards to the North we encountered for the first time on this cruise a large amount of phytoplankton (*Thalassiosira* sp.) and together with the phytoplankton a much richer abundance of zooplankton, especially mature *Calanus propinquus* and *Calanoides acutus* as well as cyclopoid copepods. On the northernmost station of this transect we caught some euphausiid calyptopes and furcilias presumably belonging to *Thysanoessa* sp. and even some juvenile *Euphausia triacantha.* As the standard fishing depth was from 300 m to the surface we checked just by one haul from 600 m to the surface whether we would encounter richer zooplankton in this deeper layer. We found some deeper living species like carnivore copepods and few more adult *Calanus propinquus* and *Calanoides acutus*.

Furcilia stages of *E. superba* were expected to stay in the very surface layer. Due to the heavy ice conditions the neuston net was only used 13 times and no *E. superba* larvae were encountered.

The RMT 8 catches were rather poor for all depths strata in the open water area as well as in the ice-covered zone. The megazooplankton very much resembled the samples collected during the "Polarstern" winter cruise in 1986 to the Antarctic Peninsula region. Gelatineous plankton species were most abundant in the entire survey area. Salps were common in the oceanic ice-free waters, while they were almost absent in the pack ice zone, here ctenophores and siphonophores occurred in higher numbers. In the upper 60 m of the water column the Antarctic Krill, *Euphausia superba*, was one of the dominant species of the megazooplankton community. Krill as well as *Thysanoessa macrura* was also found in the deeper samples of the ice free zone. *Thysanoessa macrura* seemed to prefer the depth layers beneath 60 m. Other euphausiid species only occurred in certain parts of the research area. The neritic species *Euphausia crystallorophias* was restricted to the south western stations, obviously influenced by the shelf of Joinville Island. The oceanic species *Euphausia triacantha* and *E. frigida* were only found north of the Scotian Arc Ridge and did not penetrate into the pack ice zone of the Weddell Sea. One deep haul down to 1000 m (station 141) made evident that the composition of the megazooplankton was totally changing below 500 m depth, here we encountered primarily decapods, amphipods, medusae and mesopelagic fish species.

General overlook about the abundance of main zooplankton taxa

By looking through the freshly caught samples we found out of 27 Bongo stations

Euphausiids: *Thysanoessa* sp., mainly juveniles, few subadults on 21 stations
Euphausia superba, mainly juveniles, few subadults on 17 stations
No other euphausiids.

Copepods: *Calanus propinquus* and *Calanoides acutus* (few adults, more younger stages) and smaller species on 11 stations

Fish larvae: Myctophids (*Electrona antarctica*), Ice fish (*Chionodraco rastrospinosus*), *Bathylagos antarcticus, Notolepis* spp. (information by A. Kellermann) on 6 stations.

No larvae of *Pleuragramma antarcticum* have been caught which is by far the most abundant fish in the southern and eastern Weddell Sea and dominant in the ichthyoplankton of that region also in late winter.
The richest samples of zooplankton within the pack ice we received on the southernmost position the ship reached (63°20' S) on the second transect into the pack ice zone of the inner Weddell Sea.

Any further conclusions concerning the influence of water depth or special characteristics of sea ice on the composition of the zooplankton are not yet possible and will be given at a later date, when the material has been worked up.

The analyses concerning the fatty acids composition and the lipids accumulation will also be performed in the laboratory at home. After determination of zooplankton biomass by dry weight, total proteins and total lipids contents will be analysed using spectrophotometric techniques. Phospholipids, triacylglycerols and wax esters will be separated by column chromatography and fatty acids identified by gas liquid chromatography (GLC).

2.2.10 ANTARCTIC KRILL (EUPHAUSIA SUPERBA)

B. Bergstrom, G. Hempel, I. Hempel, H.-P. Marschall, A. North, and V. Siegel, J.-O. Strömberg

Objectives

During the "Polarstern" winter expedition to the Antarctic (1986, ANT V/1-3) krill were observed feeding on algae on the under-side of the sea ice. Krill preferred ice habitats with hollows and crevices found under ice ridges as opposed to flat under-ice surfaces. The German winter expedition in 1986 was focused on the eastern and south-eastern parts of the Weddell Sea, while until now the conditions in the north-western part where thicker, multi-year ice is abundant and has been virtually unexplored.

It was thus of considerable interest to learn more about krill behaviour and distributional pattern to see whether earlier conclusions can be generalized over a wider geographical area and different seasons.

A possible separation of the size-classes of krill in different areas of the Weddell Sea has been proposed. Therefore it is also vital to obtain information on the demography of the krill stock in these ice-covered areas.

Other objectives were to investigate further the habitat preferences, feeding habits, and diurnal behaviour of krill in different ice habitats and in the water immediately below the ice. If possible also the food preferences of krill with respect to different algal species were to be revealed .

The relationship between the diminishing ice cover in the spring and changes in krill behaviour, such as swarm formation and maintenance, also needs to be clarified.

Feeding on ice algae may be less energy demanding than when the krill are harvesting the water mass. This could mean a more rapid growth as well as earlier maturation of gonads under such conditions. Obviously this hypothesis would need testing and other factors influencing metabolic rates and thus growth and maturation would have to be taken into account.

Because it is impossible to work with conventional zooplankton sampling methods under the ice, one objective was also to further develop and evaluate alternative methods.

Work at sea

1. Visual observations during icebreaking.

The abundance of krill on overturned ice floes as the ship broke ice was estimated by means of visual observations from either the winch control room or the working deck. Krill density was classified in relation to ice cover, ice type and the presence of ice algae in four categories: absent, present, common and abundant. Observations were made for 5-10 minutes each hour during most of the passage through ice covered areas.

2. Assessment of krill abundance, diurnal behaviour, and preferred habitat under sea ice by means of a remotely operated vehicle (ROV).

As in 1986 a SPRINT 101 equipped with colour, low light level and still camera were used. For details of the handling of the vehicle during under-ice studies, see Reports on Polar Research 35 (1987).

Observations on ice type, presence or absence of ice algae under the ice or in an infiltration layer, and occurrence of krill was recorded on video tape for subsequent analyses. The ROV was employed on all transects through the sea ice. Altogether 46 dives were performed with a total of over 50 hours of video recordings and 1250 still photographs. A typical dive lasted for about one hour and consisted of a transect of about 200 m and additional detailed inspections of habitats with high krill abundance. Towards the end of many of the dives an excursion down to 30 m (maximum 55 m) was included.

During 5 dives at station 140, (at times of 16.00, 19.00, 22.00, 04.00 and 07.00) an appreciation of changes in diurnal behaviour was obtained.

3. Use of divers for estimating krill abundance and behaviour, taking stereophotographs, and collecting krill.

Visual observations of krill abundance and behaviour were made by divers on 22 occasions.

At one station direct comparison of abundance and size distribution was made simultaneously under the same ice floe by divers and the ROV. At ali other stations the divers worked far away from the ship to avoid any effects of the ship's propellers and thrusters.

Krill were sampled by hand nets at 19 stations and the collected specimens were used for size-frequency analyses in the laboratory (Fig. 44).

A stereo camera was used in an effort to document krill abundance and the structure of the underside of the ice.

Diving was performed under strict safety measures, and thus no excursions under the ice were made longer than 30 min or deeper than 10 m.

4. Collecting of krill by means of a multiple rectangular midwater trawl (RMT1+8 M).

Sampling by means of RMT was carried out in the open water as well as in open or re-frozen leads. This was motivated by the need for comparable samples from the water column both in ice covered areas and in areas with no ice.

Sex- and size-distribution analyses of krill were made on RMT samples from 20 stations. The sampling depths were generally 300-200 m, 200-60 m, and 60 to the surface , but one deeper cast was made (1000-750 m, 750-500 m, and 500-300 m). However, when ice cover made trawling difficult sampling was restricted to 200 m depth.

5. Bongo-net sampling.

Search for krill larvae and juveniles was carried out by vertical tows of a Bongo net in the upper 300 m. (See 2.2.9)

6. Growth experiments

Live krill collected by the divers and RMT were used for growth increment and moulting frequency studies under laboratory conditions. Individual krill was kept in 200-500 ml jars in a cold-room container at -0.9°C with diurnal light rhythm. Daily inspections were carried out and exuviae were collected for measurements (H.P. Marschall).

7 Studies of maturation in female krill.

Ovaries from adult female krill specimens were dissected out and preserved in 2 per cent glutaraldehyde in phosphate buffer with sucrose added. These were embedded and will be sectioned for studies of sizes of oocytes and eggs. Adult females were collected at 3 stations (J.-O. Strömberg).

8. Morphology and histo-chemistry of krill.

Live krill of various size groups were kept without food for evaluation of gut clearance rates. Afterwards they were dissected and preserved as described for studies by electron microscopy of their sense organs and stomach. Krill were also fed on cultures of Antarctic phytoplankton and were brought home alive for biochemical and behavioural studies (H.P. Marschall).

Preliminary results

1. Geographical distribution and size frequency distribution.

A. Open water areas

Mostly juvenile krill were caught by the RMT in areas not covered by ice. The overall abundance was low in these areas, however no "zero" catches were obtained. Standardized abundances can not be given at this stage, because the analysis of the flow-meter parameters and consequently the calculation of the filtered water volume has not yet been done.

In general the juvenile krill were caught in the 0-60 meter depth layer. The size frequency distributions in these samples are characterized by a dominance of

13- 24 mm long specimens with a modal length of 17,5 mm. (Fig. 44). Only few specimens in the sub-adult and adult stages occurred in the open water area, except at station 79 located between Elephant Island and Clarence Island. At this station juveniles were again exclusively found in the upper 60 meters of the water column, while 30-55 mm long krill were only caught in the 60- 200 meter depth layer. The adult females were still in the resting stage (III a) except in station 141, where two females carried spermatophores.

B. Ice covered areas

1. Visual observations during ice breaking

Observations of krill washed up on ice-floes as the ship is breaking ice is at best qualitative.Many factors are involved,such as ship speed, ice thickness, snow cover on ice, presence or absence of eroded infiltration layer, etc. Because of these factors the absence of krill at a particular part of the transect does not mean that krill are not present under the pack-ice or floes. This is probably particularly valid in the outer parts of the marginal sea ice zone, where floes are well separated from each other and therefore rarely turned over by the ship. In spite of the apparent difficulties, this observational method gives information about the geographical distribution of the krill where other methods are impossible to use. However, presence of krill gives an indication of approximate relations between abundance of small or large krill. In some cases animals thrown up on the ice could be collected and actual size measured.

The observations indicate that krill are most abundant in the outer and inner marginal ice zone and rather sparse in the closed pack-ice of the inner Weddell Sea. Presence of krill in conjunction with so called brown ice (with rich algal growth in the infiltration layer) is striking.

Adult krill (or sub-adults) were observed in the middle ice edge zone where they in a few places dominated in abundance over the juveniles. Otherwise juveniles were clearly dominating in the outer and inner marginal ice edge zones. The smallest juveniles (ca 15 mm) were seen in the outer part of the most eastern transect, i.e west and north-west of the South Orkney Islands.

2. RMT and Bongo samples

Krill samples from the ice covered zone showed marked differences in length frequency composition. However, in the northern part of the marginal ice zone, the samples (e.g. st. 94) were highly dominated by juveniles having the same modal length (17,5 mm) as in the samples from the open water stations.

Further to the south the composition changed and medium sized krill dominated the water column of the ice covered area (e.g. st. 109 and 113) (Fig. 44). In samples from these stations size classes of 25 to 40 mm were most abundant. In the southernmost area with the densest pack-ice concentration the situation changed again. The abundance of 30 - 40 mm sub-adults and larger adult krill decreased and juveniles of 20 to 25 mm length dominated the water column (e.g. st. 87, 116 and 119).

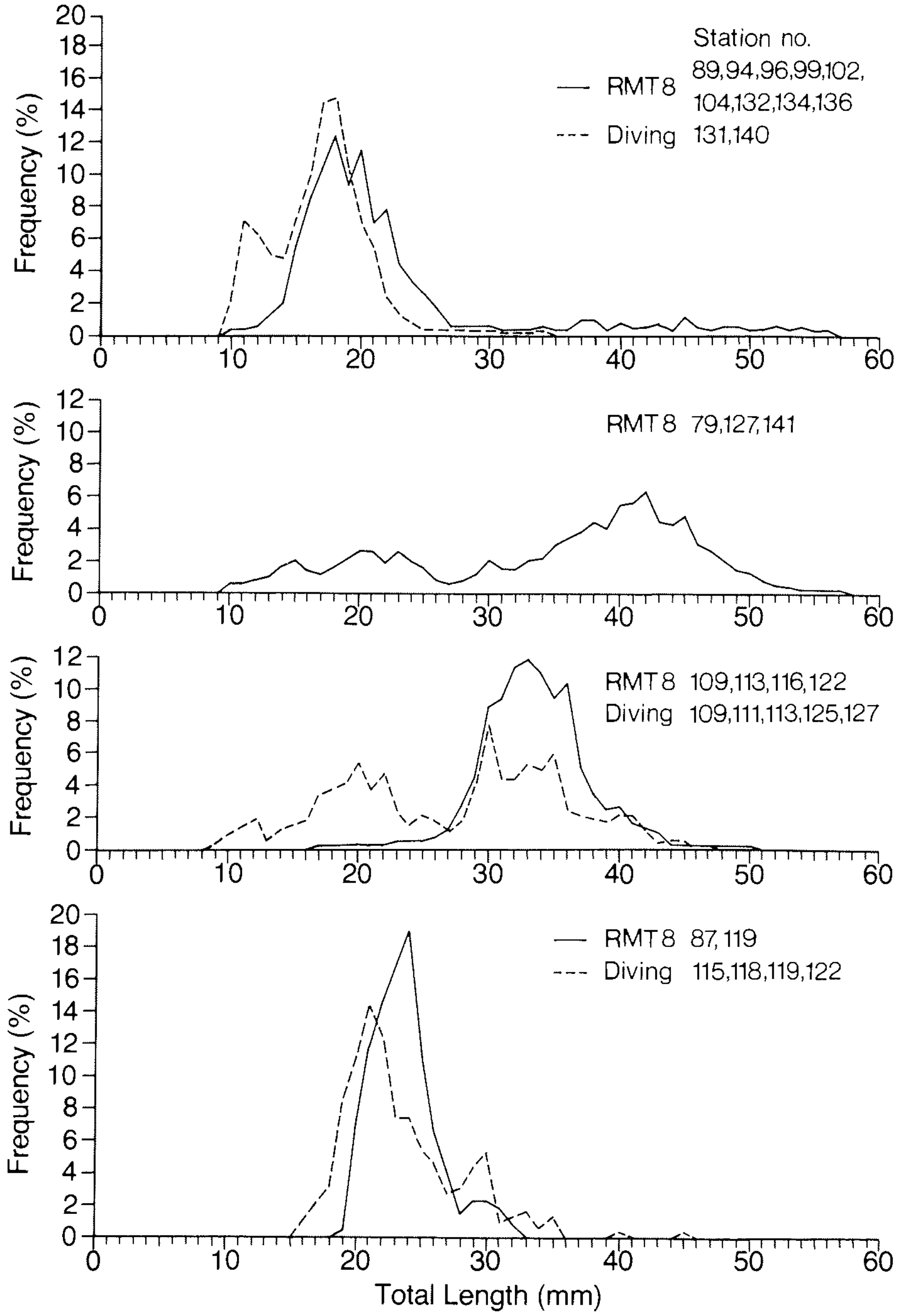

Figure 44. Size frequency distributions of krill *Euphausia superba* sampled by RMT8 net and by handnets during diving operations.

As in the open water area krill were most abundant in the 0-60 m depth layer under the pack-ice. Krill were caught in all the hauls made in the ice covered area, although at stations 116 and 131 only 2 and 4 specimens were obtained respectively.

The largest samples of all were taken at station 122(> 10 000 specimens per standard haul) and at station 127 (ca. 4000 specimens).

Out of the 27 Bongo stations 17 were positive for *E. superba.* Most specimens were juveniles, some were subadults. No larvae were found. The geographical distribution of size-classes was similar to that found in the RMT.

3. ROV studies

At least some krill were observed on all but two dives. Abundance differed greatly on the geographical scale but even more in relation to the thickness and the structure of the sea ice. In general concentrations were highest in the zone of relatively small ice floes at 6o to 61 degrees South. Overall krill abundance was considerably higher than found in 1986 in the eastern and south-eastern Weddell Sea in the same time of the year.

As far as one can judge from the videos most of the krill were juvenile, while no juveniles were seen in the eastern and southern Weddell Sea in 1986. No furciliae were observed nor large numbers of adult krill, the latter again in contrast to the findings in 1986.

4. Dive samples

Generally the size frequency distributions of krill in samples collected by the divers correspond very well with the distributions in samples obtained with the RMT net in the water column. These data fit into the described north- south geographical distributional pattern of size classes. There are only a few exceptions like station 122 where divers caught krill of 20 mm modal size from under the ice, while the RMT caught exclusively larger krill of 27-40 mm length (Fig. 44).

35 Observations on habitat preferences, feeding behaviour, diurnal activity patterns and the formation of "swarms ".

A. Observations by divers

On the majority of the stations, the divers observed krill feeding on ice-algae either in submerged infiltration layers present in ridges or rafted areas or in infiltration layers on the edges of the floes.This was especially obvious in the earlier part of the cruise until station 119 which was visited on the third of November, when the formation of aggregates, "mini swarms", of krill in the water under the ice was first observed during an evening dive (18:00-20:00

hrs.). This phenomenon was further observed a few days later during a mid-day dive on station 120.

A very dense and large aggregation ("swarm") of krill was found on station 122 under a flat large floe. This aggregate of krill began 5 meters away from the edge of the floe and extended horizontally for at least 60 meters under the floe. In this large aggregate of krill the topmost animals were feeding on the sub- ice algal assemblage in densities of 100 or more per meter^2.

When swimming into this aggregate krill started to shun the diver at a distance of about 4-5 meters not by tail flicking but rather by pleopod swimming.

B. Observations by means of ROV

In areas where melting had not started, i.e. early in the cruise and in the southern regions, krill concentrated in the shallower parts of the ridges under the ice where light penetrated through tilted or upright floes.

The smoothly undulating undersurface of old floes with several decimeters of snow cover were almost devoid of krill, while rugged areas of pressure zones were well populated in places, even if the total thickness of the ice there exceeded that of the flat areas. From the observations on small but thick floes (average thickness 1.5 m and above) it can be suggested that the kilometer wide "giant floes" of multiyear ice of the western Weddell Sea will house very few krill, except for the edges of the floes. On the other hand the smaller, often thinner floes in between the "giants" seem to be preferred habitats with fair numbers of krill.

Only a few days old grey nilas do not sustain krill, while older, white nilas of 20 - 30 cm thickness were already well populated by ice algae and krill, particularly if rafted. The occurrence of krill is very patchy under the apparently homogeneous underside of such young ice. The same holds for the distribution of ice algae. Sometimes, but by no means regularly, krill concentrated at the brown algal patches of a meter or less in diameter.

In the northern parts of the transects and with advance of the season, krill were mainly found in the submerged and eroded brownish infiltration layers between the snow cover and the sea ice as well as in the highly eroded sponge-like habitat of melting ice floes.

Amazingly high concentrations of juvenile krill were encountered at the edges as well as in the caverns, funnels, balconies and terraces of one year old melting ice. Here aggregations estimated at several thousand specimens were found in former brine pockets of a cubic meter or so. Occasionally krill were so crowded that not all of them could graze at the same time at the walls of the caverns. Where floes of half a meter thick or less were rafted, krill grazed on algae on the upper side of the lower floe as well as on the overhanging underside of the upper floe. Particularly at the final time station (st. 140) in the Powell Basin the relation of krill to ice algae and light was very obvious.

Within the highly structured sponge-like habitat of melting floes krill seemed to concentrate in places where light and algae were most abundant. At the same station some older floes occurred up to more than two meters thick with a heavy snow cover and little erosion by melting. Those floes did not house any great numbers of krill, not even at algal patches at their flanks .

In daytime most of the krill moved gently, most of them grazing but some swimming slowly close to the undersurface. In the larger hollows of former brine pockets some krill had their feeding baskets extended while swimming. The dark colour of the gut indicated active feeding in most krill, particularly in the morning hours. At this time of the day escape distance to the ROV amounted to about 30 cm only, compared to the normal distance of ca 70 cm when swimming in open water under the ice.

At dusk more krill swam around at a distance of several decimeters from the ice floe undersurface and also in the water next to the ice. Observations by the low light level camera showed only at a few occasions the formation of small, distinct swarms of less than 100 specimens staying about half a meter below the ice. Greater numbers of krill left the caverns and brine channels and scattered in the water column, mostly less than one meter under the ice. Some of them had their feeding basket opened. Only few krill were observed down to 30 meters during any of the day or night dives.

In the night krill responded to the lights of the ROV by leaving the caves and holes and moving straight downward into the open water, while in daylight flight reaction was normally into the holes and crevasses. The nightly escape movement revealed the presence of krill in narrow brine channels where the ROV could not see them in daytime.

4. Gonadal status of female krill

Female krill specimens of a size big enough for spawning were found and collected only at three stations (94, 122, and 141).

Ovaries were dissected out and preserved for later microscopical studies. A visual inspection through the dissecting microscope showed that none of them were ready to spawn there eggs.

2.2.11 FISH EGGS AND LARVAE

A. Kellermann

Objectives

There were two main questions : Is there a correlation between the distribution and the occurrence of larval icefish (Channichthyidae) and juvenile Antarctic krill Euphausia superba, which are known to form major portions of the diets of larval icefish? And second, what is the composition of the larval fish community with respect to the pack-ice cover? Other objectives were the collection of eggs and of larval for age determinations from their otoliths and for validation of ageing by analysing the otoliths of reared larvae of known age.

Methods

Eggs and larvae were collected by means of an Rectangular Midwater Trawl RMT 1+8 M and by the Neuston catamaran. The first net allows for subsequent fishing of discrete depth strata while the latter net samples the top 40 cm of the surface layer. Further specimens of larval fish were obtained from the Bongo net and the Multinet (see 2.2.9), and some were caught by the diving group. Eggs and larvae were reared in 60 l plastic tanks under controlled water temperature (-1.3 to -1.0°C) and light regimes (16 hours light/8 hours darkness). Larvae were freshly measured soon after capture and were preserved in 75 % alcohol.

Preliminary results

Larval distribution

A total of 32 eggs (2 species) and 119 larvae and early juvenile fishes of at least 11 species were captured by the RMT 1+8 M and the Neuston net. The bulk of notothenioid larvae were represented by species which had hatched during winter and which extend their pelagic phase into the following summer season, e.g. the icefishes Pagetopsis macropterus (36-41 mm, n=8), Chionodraco rastrospinosus (21-30 mm, n=11), and Pseudochaenichthys georgianus (17-23 mm, n=23). The remaining were nototheniids which hatch in austral summer and have a long pelagic development such as Nototheniops larseni (30-43 mm, n=6). No recently hatched small notothenioid larvae were caught by the nets; however, larval P. georgianus had preyed on small N. larseni larvae over the South Orkney Islands shelf.

In notothenioid fishes, there was an apparent correlation between larval occurrence and water depth, i.e. most specimens were obtained from the vicinity of or from right over shelf areas. On the westernmost transect (St. 79-89) larval P. macropterus were recorded off Clarence Island, while on the easternmost transect (St. 119-139) larval P. georgianus occurred over the shelf and slope of the South Orkney Islands. C. rastrospinosus larvae were captured at both locations. The most frequently recorded and most abundant species in terms of larval numbers was Pleuragramma antarcticum with overwintering age group1 larvae and some age group 2 juveniles. They occurred in the open water as well as in the marginal ice zone.

P. macropterus larvae were only found in few catches of juvenile Antarctic krill, and first stomach content analysis revealed that these were the staple food of larvae. However, only single icefish were obtained in the pack ice at all transects though the juvenile krill was observed to be very abundant there (see respective sections).

In the pack ice, the larval fish community consisted chiefly of Notolepis spp. and Bathylagus antarcticus, where water depths exceeded 600 m. However, these were also recorded in ice free areas. Both are mesopelagic species and are known to be confined to oceanic waters. Since notothenioid larvae occurred only in pack ice covered shelf or near shelf waters, it may be tentatively assumed that pack ice cover does not affect larval fish distribution. It was only the myctophid Electrona antarctica that was found in open waters and in the marginal ice zone, but not further south.

Rearing experiments

A total of 21 eggs of Notothenia neglecta was collected. They were found in the neuston layer as well as in the layer between 300 and 200 m depth. There was no apparent difference in developmental stage between eggs from these depths. Hydrographical data indicated that the layer between 200 and 300 m was within the upper limit of the Warm Deep Water. One of the 21 eggs died due to previous damage of the egg shell during hauling. By the end of the cruise, six larvae had hatched, and these were marked with tetracycline as an increment tracer for later otolith analysis.

Larval searching behaviour and attempts to engulf food particles were observed 3-5 days after hatch, though large yolk sacs were still present. Later on, larvae could be fed individually by dropping food items such as invertebrate eggs into the visual field of cruising larvae. Periods of activity were followed by resting phases during which larvae slowly came up to the surface due to positive buoyancy of their yolk. Larval Notothenia neglecta are known to occur in the neuston layer. Larvae and eggs were transported to the AWI, Bremerhaven by plane for further rearing and later analysis of otoliths as part of a project to be carried out jointly with R. Radtke at the University of Hawaii.

2.2.12 HIGHER TROPHIC LEVELS: SEABIRDS, SEALS AND WHALES

C. Joiris

In order to calculate the ecological role of the animals belonging to the higher trophic levels, i.e. the energy fluxes they provoke (food consumption and release of nutrients through the faeces), it is necessary to determine their density in the different ecosystems of the region.

Seabirds

The main problems in determining densities of seabirds, are the existence of "followers" accompanying the ship sometimes for long periods; and the possible movements of birds, eg. between breeding place and feeding grounds or from one zone to another (migration).

These two types of observations clearly cannot be expressed as density ; more especially, such results are not influenced by the speed of the ship and should not be extrapolated.

Only the third type of observations, concerning birds belonging to the immediate zone (showing only local movements or no movement) can be translated into density, knowing the ship's speed and evaluating the width of the transect actually surveyed.

A summary of the raw results obtained during EPOS I - from Rio Grande to station 14/140 - is presented in Tab. 13 as the total amount of birds observed during the whole period, without any correction. For comparison, the results of two summer cruises of the US icebreaker Glacier in the Weddell Sea are added.

- Chinstrap Penguin: one of the most numerous species, was mainly observed within the Outer Marginal Ice Zone (OMIZ), in high numbers standing on icebergs with such a slope that the top was accessible to penguins - sometimes with great effort. Such icebergs, stained brownish-red by the penguins' faeces, could be seen from long distances, which leads to an overestimation of the density of the penguins. Such icebergs were occupied by thousands of penguins in the region of stations 14/95 to 103, but were almost deserted when we came back in the same zone (stations 14/135-140): it is reasonable to suppose that the Chinstrap Penguins partially left the region in between in order to join the colonies and start breeding. This also explains our high score, compared with the summer period.

- The Adélie Penguin is in fact the most numerous, taking into account that the figures for Chinstrap overestimate their relative density. The distribution of both species is complementary, with Adélies at more southern stations with a higher ice cover and Chinstraps closer to the ice edge (Fig. 45). Both species form the bulk of the Antarctic avifauna, with 80% of the birds recorded.

Table 13: Total numbers of birds recorded during various cruises.

		spring 10.10.- 14.11.88 (C. Joiris) EPOS 1	summer 30.01.- 15.03.68 (Cline et al. 1969)	summer 09.02.- 29.02.76 (Zink 1981)
1	Chinstrap Penguin	20490	23	91
2	Adélie Penguin	19525	6571	4698
3	Cape Pigeon	6266	25	694
4	Antarctic Fulmar	2072		709
5	Snow Petrel	1097	1686	3527
6	Antarctic Prion	624	202	112
7	Giant Petrel	412	8	106
8	Antarctic Petrel	278	24	1757
9	Blue Petrel	256	13	
10	Emperor Penguin	195	310	16
11	Dominican Gull	166		4
12	Atlantic Petrel	157		
13	Black-browed Albatros	87		16
14	Tern	76	567	1547
15	White-chinned Petrel	70		6
16	Wilson Storm-Petrel	66	31	949
17	Wandering Albatros	61		23
18	Great Shearwater	51		
19	Great Skua	45	4	10
20	Black-bellied Str.-Petrel	35		27
21	White-bellied St.-Petrel	11		
22	Soft-plumaged Petrel	14		
23	Sooty Shearwater	11		24
24	American Sheathbill	12		6
25	Cory Shearwater	3		21
26	Grey-headed Albatros	3		21
27	Arctic Skua	1		
28	Light-mantled S.Albatros	0		29
	Total	52084	9451	14376
	Nb. 1/2 hour stations	327	190	200

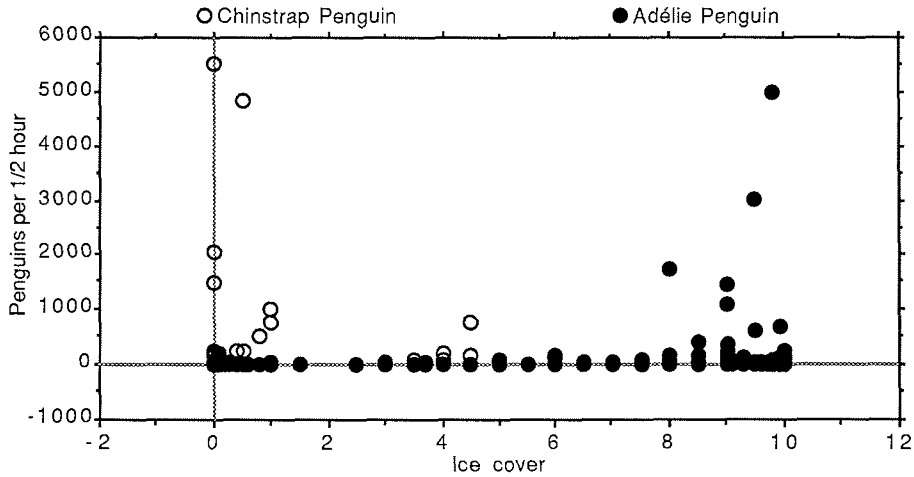

Figure 45 : Penguin observations

Important concentrations of Adélies of thousands birds were encountered at stations 14/86 and 90. At station 90, a clear movement was observed from the ship, and this was confirmed by further observations from the helicopter (G. Hempel, I. Hempel, C. Joiris): 12000 penguins were counted during a one hour flight (not included in the table), they were moving around a big ice floe and then following two main routes (SW and W) and a third, less important one (NNW). Our hypothesis is that the birds were moving towards their various breeding grounds, respectively at the tip of the Peninsula (100 nmiles away), on the Southern Shetlands (75 nmiles) and possibly Elephant Island (75 nmiles). Such long distances of travel seem to be a record among the small penguins. Their traveling speed was determined later, by watching smaller groups: their normal speed on ice (gliding on the belly) is 1.1 knot (approx. 2 km/h); their rhythm consists in 4 minutes walk and 8.3 minutes rest. In the water, their normal swimming speed ("porpoising") is about 4 knots, and reached more than 8 knots while swimming in front of the vessel and trying to escape the ship.

- The Cape Pigeon was the third most numerous species, but was often following the ship, so that major corrections have to be applied before expressing the results as densities.
- The Antarctic Fulmar shows a very limited distribution in the OMIZ, where it reaches high densities.
- The Snow Petrel was clearly bounded in distribution by ice edges and was present in the MIZ, in leads and polynyas within the pack-ice.
- Only a few Terns were encountered; part of them were bound to Clarence and Signy Islands and are obviously Antarctic Terns. Possibly, the Arctic Terns have not reached the Southern Ocean yet at this time of the year, which explains the low umbers recorded.

- The Black-bellied Storm-Petrel was absent during the first part of the trip and only appeared after station 14/130.
- Other species not belonging to the avifauna of the Weddell Sea were encountered in the Sub-Antarctic zone: Atlantic Petrel, White-chinned Petrel, Wandering Albatros, White-bellied Storm-Petrel, Soft-plumaged Petrel and the Shearwaters.

Seals

- Crabeaters (1278 recorded, by 8th November) were present as individuals, but principally as pairs and trios (pair plus pup); the number of pups declined after November 4th, indicating the end of the suckling period. Pairs without pup regularly showed active courtship.
  Their distribution (Fig. 46) shows a preference for extensive ice cover. Some very high local concentrations were recorded, e.g. around station 14/113: 95 crabeaters were around a small polynya close to an iceberg, and 97 in one hour transect immediately after. These results were confirmed from an helicopter flight (G. Hempel, I. Hempel, C. Joiris), with a mean value of 284 for the same route. At station 14/115, similar comparisons between a census from the vessel (C. Joiris) and from helicopter (G. hempel) resulted in 99 resp. 135 seals.
- Southern Fur Seals (205 recorded) were all males belonging to different age classes, mainly in the OMIZ (Fig. 46).
- Leopard Seals (63 recorded) were registred as individuals and as mother with pup; the first new-born pup was noted on November 2nd, and their numbers then increased.
- The Weddell Seal was almost absent from the region (4 near Signy Island), indicating that they had not yet dispersed after the breeding season.
- Ross's and Elephant Seals were only recorded once.

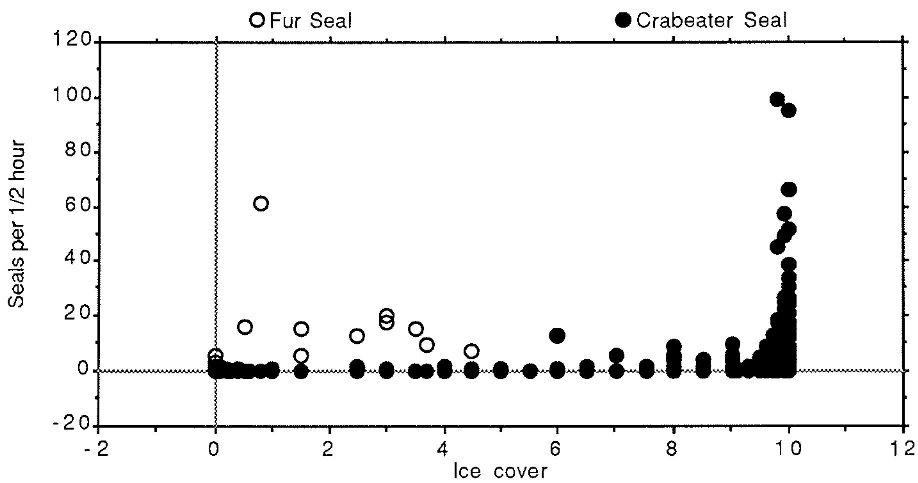

Figure 46 : Seal observations

Whales

Few whales only were seen in the antarctic zone, the vast majority being Minke Whales in the leads and polynyas (37 records, state on 8 November); other "Finners" were present also, with 3 probable Fin Whales. These relatively low numbers could mean that the big baleen whales had not yet returned from lower latitudes to their southern summer feeding grounds (this was confirmed later by the observation of about 30 Fin Whales in two hours, on November 16th in the open water of the Drake Passage at 58°S56°W).
In the Sub-Antarctic zone, a group of 16 Hourglass Dolphins, 80 Pilot Whales in 3 groups, 2 Sperm and 2 unidentified big whales were encountered.

ANNEX

STATIONSLISTE / STATION LIST

Abkürzungen / Abbreviations

APN	Apstein net
BO	Bongo net
BRO	Bio-Rosette
CTD	Conductivity Temperature Depth sonde
DIV	Diving group
EYE	Irradiance measurement
FRA	Fransz net
ICE	Ice coring/collecting excursion
MN	Multi net
NAS	Nansen bottles
NEU	Neuston net
PH	pH meter
RMT	Multiple Rectangular Midwater Trawl
SEC	Secchi disc
UV	Ultraviolet light measurement
UWE	Remotely operated vehicle
D	Daylight
DA	Dawn
DU	Dusk
N	Night

Station No.	Date	Position		Echo Depth (m)	Gear	Haul No.	Day Time	Start (GMT)	Haul Dur. (min.)	Max. Gear depth m	Comment
14/078	15/10/88	50°39,6'S	53°13,0'W	1.986	BRO	1	D	10:07	43	300	Test Station
					BO	1	D	11:20	15	100	
					UV	1	D	12:00	3	27	
					CTD	1	D	12:08	30	300	
					EYE	1	D	12:32	13	70	
					RMT	1	D	15:12	33	300	
					NEU	1	D	15:59	12	0	
					FRA	1	D	16:10	10	100	
					CTD	2	D	16:34	16	150	
14/079	18/10/88	61°08,3'S	54°15,6'W	1.051	CTD	3	N	07:18	4	-	
					CTD	4	N	07:38	7	-	
					SEC	1	D	11:22	4	28	
					BO	2	D	11:43	16	300	
					UWE	1	D	12:33	52	-	Test Run
					RMT	2	D	15:55	32	300	
					NEU	2	D	15:42	40	0	
14/080	18/10/88	61°21,6'S	54°17,5'W	1.003	BRO	2	D	18:42	16	80	
					EYE	2	D	19:08	12	70	
					UV	2	D	19:26	3	27	
					BRO	3	D	19:45	21	300	
					CTD	5	D	20:27	14	350	
					BO	3	D	20:49	13	300	
14/081	18/10/88	61°28,7'S	54°01,5'W	811	CTD	6	D	22:52	25	600	
					BRO	4	D	23:24	42	300	
14/082	19/10/88	61°35,9'S	53°48,3'W	507	BRO	5	DU	01:57	26	300	
14/083	19/10/88	61°42,1'S	53°35,8'W	585	BRO	6	DA	08:09	23	300	
					CTD	7	DA	08:36	13	300	
14/084	19/10/88	61°50,1'S	53°17,6'W	447	BRO	7	D	11:00	21	300	
					CTD	8	D	11:33	14	300	
					BRO	8	D	12:09	10	100	
					BO	4	D	12:15	15	300	
					BO	5	D	13:21	15	300	
					BRO	9	D	13:57	27	300	
					EYE	3	D	14:30	13	70	
					UV	3	D	14:50	8	27	
					SEC	2	D	14:59	10	29	
					FRA	2	D	15:10	10	200	
					UWE	2	D	13:30	42		
14/085	19/10/88	61°53,5'S	52°58,9'W	2.068	BRO	10	D	18:32	27	300	
					APN	1	D	18:35	3	10	
					ICE	1	D	19:00	75	-	
					CTD	9	D	19:06	24	600	
					EYE	4	D	19:40	12	70	
					UV	4	D	19:56	7	27	
14/086	19/10/88	62°02,3'S	52°47,8'W	2.496	BRO	11	D	22:46	23	300	
					APN	2	D	22:51	5	10	
					CTD	10	D	23:16	22	600	
14/087	20/10/88	62°26,3'S	52°56,9'W	2.612	NEU	3	D	08:14	7	0	Clogging by ice crystals
					RMT	3	D	08:32	30	300	
					BO	6	D	09:16	18	300	
					APN	3	D	09:22	3	10	
					RMT	4	D	10:13	40	300	
					BRO	12	D	11:29	29	300	
					ICE	2	D	11:40	230	-	
					CTD	11	D	12:03	26	630	
					BRO	13	D	12:37	13	80	
					FRA	3	D	13:02	7	200	
					EYE	5	D	13:17	22	70	
					UV	5	D	13:42	7	27	
					SEC	3	D	13:53	7	54	
					UWE	3	D	14:03	38		
					DIV	1	D	15:05	62	10	Test dive
14/088	20/10/88	62°43,2'S	53°20,5'W	1.396	BRO	14	D	23:47	22	280	
	21/10/88				CTD	12	DU	00:16	24	650	
14/089	21/10/88	62°40,2'S	53°24,7'W	1.038	BRO	15	DA	08:29	24	300	Time station in the ice
					CTD	13	D	08:58	24	600	
					BRO	16	D	09:29	10	80	
					BO	7	D	09:43	22	300	
					BRO	17	D	10:15	21	300	
					ICE	3	D	11:30	300	-	
					FRA	4	D	12:10	10	200	
					EYE	6	D	12:36	5	70	
					UV	6	D	13:04	8	27	
					SEC	4	D	13:12	4	52	
					DIV	2	D	12:45	140	10	
					BRO	18	D	14:13	22	300	
					CTD	14	D	14:41	25	600	
					BRO	19	D	15:11	23	300	
					UV	7	D	15:45	10	27	
					CTD	15	D	15:50	60		lowered from the ice

Station No.	Date	Position		Echo Depth (m)	Gear	Haul No.	Day Time	Start (GMT)	Haul Dur. (min.)	Max. Gear depth m	Comment
					UWE	4	D	16:10	29		
					BO	8	D	18:15	15	300	
					BO	9	D	18:30	15	300	
					BO	10	D	19:05	15	300	
					BRO	20	D	20:01	23	300	
					CTD	16	D	20:29	20	600	
					BRO	21	D	20:56	24	300	
					DIV	3	D	21:30	90	10	
	22/10/88				BRO	22	N	02:00	24	300	
					CTD	17	N	02:28	27	600	
					BRO	23	DA	08:03	26	300	
					CTD	18	D	08:33	29	600	
					BRO	24	D	09:05	24	300	
					DIV	4	D	10:30	60	10	
					NEU	4	D	11:30	6	0	Ice crystals in surface waters
					NEU	5	D	11:40	6	0	
					RMT	5	D	11:47	37	300	
					EYE	7	D	12:38	18	70	
					UV	8	D	12:55	7	27	
					SEC	5	D	13:06	4	50	
					RMT	6	D	13:43	36	300	
14/090	22/10/88	62°11,9'S	53°52,4'W	1.000	BRO	25	D	19:26	26	300	
					EYE	8	D	19:57	19	70	
					UV	9	D	20:20	8	27	
					APN	4	D	20:20	8	10	
					CTD	19	D	20:38	21	600	
					UWE	5	D	21:05	92		
					ICE	4	D	21:40	130	-	
14/091	23/10/88	61°52,2'S	53°01,8'W	1.442	BRO	26	DA	08:01	23	300	
					CTD	20	D	08:27	28	600	
					BRO	27	D	08:59	12	80	
14/092	23/10/88	61°50,0'S	52°36,1'W	1.387	BRO	28	D	12:00	29	300	
					ICE	5	D	12:00	195	-	Ice Station AN 722970
					CTD	21	D	12:34	36	650	
					DIV	5	D	13:30	120	10	
					BRO	29	D	13:17	22	300	
					UWE	6	D	14:07	50		
					CTD	22	D	15:15	15	300	
					FRA	5	D	15:30	14	200	
					UV	10	D	15:47	6	27	
					BO	11	D	15:49	24	300	
					SEC	6	D	15:55	6	24	
					BO	12	D	16:25	10	300	
					BO	13	D	16:39	49	600	
14/093	23/10/88	61°20,4'S	51°44,0'W	547	BRO	30	D	23:02	32	300	
					CTD	23	D	23:38	22	500	
14/094	24/10/88	60°26,9'S	50°09,1'W	3.742	NEU	6	D	11:31	23	0	
					RMT	7	D	11:38	29	300	
					BRO	31	D	12:29	29	300	
					APN	5	D	12:56	4	10	
					CTD	24	D	13:03	37	1000	
					BRO	32	D	13:46	14	80	
					BO	14	D	14:10	16	300	
					UV	11	D	14:39	7	27	
					SEC	7	D	14:51	3	34	
					NEU	7	D	15:17	17	0	
					RMT	8	D	15:38	39	300	
					UWE	7	D	16:38	69		
14/095	25/10/88	58°53,9'S	49°29,6'W	3.992	BRO	33	N	06:05	25	300	
					APN	6	N	06:28	12	10	
					CTD	25	N	06:34	46	1500	
14/096	25/10/88	59°05,6'S	49°29,8'W	4.000	NEU	8	D	08:45	40	0	
					RMT	9	D	09:07	42	300	
					BRO	34	D	10:00	25	300	
					APN	7	D	10:18	5	10	
					CTD	26	D	10:27	25	600	
					BRO	35	D	10:56	13	100	
					BO	15	D	11:20	21	300	
					BRO	36	D	11:48	15	300	
					FRA	6	D	12:10	8	200	
					UV	12	D	12:24	9	27	
					SEC	8	D	12:33	3	22	
					MN	1	D	13:00	15	200	Test haul, no net release
					NEU	9	D	13:37	48	0	
					RMT	10	D	13:56	40	300	
14/097	25/10/88	58°37,0'S	49°29,0'W	3.528	BRO	37	D	17:27	33	300	
					APN	8	D	17:30	14	10	
					CTD	27	D	18:03	30	1000	
					UV	13	D	18:36	5	27	
					SEC	9	D	18:43	3		
14/098	25/10/88	58°20,7'S	49°28,9'W	3.292	BRO	38	D	20:30	28	300	

Station No.	Date	Position		Echo Depth (m)	Gear	Haul No.	Day Time	Start (GMT)	Haul Dur. (min.)	Max. Gear depth m	Comment
					APN	9	D	20:48	10	10	
					CTD	28	D	21:02	40	1000	
14/099	25/10/88	58°13,1'S	49°25,1'W	3.827	NEU	10	D	22:37	37	0	
					RMT	11	D	22:59	40	300	
					BRO	39	D	23:53	29	300	
	26/10/88				APN	10	DU	00:00	6	10	
					CTD	29	DU	00:24	39	1000	
					NAS	1	N	01:10	70	1000	
14/100	26/10/88	59°00,0'S	49°30,0'W	3.984	BRO	40	DA	08:02	25	300	Open water time station
					CTD	30	D	08:31	21	600	
					BRO	41	D	08:58	19	100	
					BRO	42	D	10:00	11	100	
					EYE	9	D	10:17	17	70	
					UV	14	D	10:41	5	27	
					SEC	10	D	10:47	5	15	
					BO	16	D	13.55	10	300	
					BRO	43	D	14:16	25	300	
					CTD	31	D	14:45	32	600	
					BRO	44	D	15:21	20	300	
					EYE	10	D	15:47	12	70	
					SEC	11	D	15:52	2	15	
					UV	15	D	16:04	5	27	
					BRO	45	D	20:02	27	300	
					CTD	32	D	20:35	27	1000	
	27/10/88				BRO	46	N	02:01	23	300	
					CTD	33	N	02:28	34	1000	
					BRO	47	DA	08:02	25	300	
					CTD	34	D	08:32	56	2000	
					BRO	48	D	09:30	12	100	
					NAS	2	D	09:54	90	2000	
					BRO	49	D	14:01	22	300	
					CTD	35	D	14:27	17	600	
					EYE	11	D	14:49	10	70	
					SEC	12	D	14:59	2	15	
					UV	16	D	15:06	11	27	
14/101	27/10/88	59°10,4'S	49°39,1'W	3.936	BRO	50	D	17:05	21	300	
					APN	11	D	17:22	4	10	
					EYE	12	D	17:59	10	70	
					SEC	13	D	18:09	1		
					UV	17	D	18:13	5	27	
14/102	27/10/88	59°26,9'S	49°39,3'W	4.010	NEU	11	D	20:17	33	0	
					RMT	12	D	20:28	33	300	
					BRO	51	D	21:42	21	300	
					BO	17	D	22:11	23	300	
					NAS	3	D	22:40	78	2000	
	28/10/88				CTD	36	D	00:01	97	3500	
14/103	28/10/88	59°43,5'S	49°40,7'W	3.917	BRO	52	DA	08:02	21	300	
					CTD	37	D	08:31	23	600	
					APN	12	D	08:32	3	10	
14/104	28/10/88	60°00,5'S	49°41,5'W	3.705	ICE	6	D	11:13	128	-	Ice collecting from mummychair
					BRO	53	D	12:10	22	300	
					CTD	38	D	12:35	35	1085	
					BRO	54	D	13:14	8	100	
					BO	18	D	13:28	21	300	
					BO	19	D	13:56	19	300	
					EYE	13	D	14:22	12	70	
					SEC	14	D	14:27	2	18	
					UV	18	D	14:33	11	27	
					UWE	8	D	14:56	9	-	Technical problems of gear
					RMT	13	D	15:23	42	300	
					UWE	9	D	16:28	20	-	
					ICE	7	D	17:10	30	-	Ice station AN 723020
14/105	28/10/88	60°17,8'S	49°41,5'W	3.205	ICE	8	D	19:30	90	-	Ice station AN 723021
					BRO	55	D	20:46	25	300	
					APN	13	D	20:48	5	10	
					CTD	39	D	21:14	40	1000	
					UWE	10	D	22:00	47	-	
14/106	29/10/88	60°36,4'S	49°31,8'W	3.237	BRO	56	N	01:00	25	300	
					APN	14	N	01:00	2	10	
					CTD	40	N	01:29	37	1000	
14/107	29/10/88	60°56,4'S	49°22,9'W	2.740	BRO	57	N	05:15	20	300	
					APN	15	N	05:21	4	10	
					CTD	41	N	05:39	31	1000	
14/108	29/10/88	61°03,2'S	49°22,1'W	2.843	BRO	58	DA	08:05	19	300	
					APN	16	DA	08:09	4	10	
					CTD	42	D	08:28	32	1080	
14/109	29/10/88	61°12,1'S	49°15,9'W	2.969	BRO	59	D	12:23	17	300	
					ICE	9	D	12:00	225	-	Ice station AN 723030
					BRO	60	D	12:52	24	300	
					CTD	43	D	13:20	60	1000	
					BO	20	D	14:24	22	300	

Station No.	Date	Position	Echo Depth (m)	Gear	Haul No.	Day Time	Start (GMT)	Haul Dur. (min.)	Max. Gear depth m	Comment
				BO	21	D	14:48	22	300	
				DIV	6	D	15:00	60	10	
				SEC	15	D	15:21	2	34	
				EYE	14	D	15:17	17	70	
				UV	19	D	15:39	5	27	
				FRA	7	D	15:45	10	200	
				BRO	61	D	16:04	22	300	
				UWE	11	D	17:01	29	-	
				RMT	14	D	17:53	17	200	
14/110	29/10/88	61°28,0'S 49°06,7'W	3.203	ICE	10	D	21:23	90	-	Ice station AN 723031
				UWE	12	D	21:23	61	-	
				APN	17	D	22:00	7	10	
				BRO	62	D	22:32	25	300	
				CTD	44	D	22:58	56	3500	
14/111	30/10/88	61°51,6'S 49°01,1'W	3.326	BRO	63	D	08:47	23	300	
				CTD	45	D	09:14	39	1000	
				BRO	64	D	09:57	11	80	
				BO	22	D	10:16	20	300	
				ICE	11	D	10:24	208	-	Ice station AN 723040
				BO	23	D	10:39	20	300	
				DIV	7	D	10:42	156	10	
				SEC	16	D	11:12	4	46	
				UV	20	D	11:20	9	27	
				UWE	13	D	10:40	114		
				EYE	15	D	12:39	9	70	
14/112	30/10/88	62°05,3'S 48°51,0'W	3.357	ICE	12	D	21:10	66	-	Ice station AN 723041
				UWE	14	D	21:11	84	-	
				BRO	65	D	22:51	10	300	
				CTD	46	DU	23:05	29	1000	
14/113	31/10/88	62°10,1'S 48°45,5'W	3.355	BRO	66	D	08:19	19	300	
				CTD	47	D	08:45	35	1000	
				BRO	67	D	09:24	9	80	
				BO	24	D	09:38	21	300	
				BO	25	D	10:05	19	300	
				APN	18	D	10:25	11	10	
				EYE	16	D	10:34	10	70	
				SEC	17	D	10:37	3	36	
				ICE	13	D	10:40	180	-	Ice station AN 723050
				UV	21	D	10:49	6	27	
				DIV	8	D	10:55	141	10	
				UWE	15	D	11:28	22	-	
				RMT	15	D	14:21	31	285	
14/114	31/10/88	62°29,3'S 48°27,9'W	3.451	BRO	68	D	21:19	23	300	
				APN	19	D	21:24	6	10	
				ICE	14	D	21:24	88	-	Ice station AN 723051
				CTD	48	D	21:48	37	1000	
				UWE	16	D	22:44	59	-	
14/115	01/11/88	62°32,3'S 48°18,1'W	3.443	BRO	69	D	10:03	19	300	
				CTD	49	D	10:27	38	1000	
				ICE	15	D	10:27	210	-	Ice station AN 723060
				APN	20	D	10:35	4	10	
				DIV	9	D	10:55	134	10	
				BRO	70	D	11:08	11	80	
				BO	26	D	11:24	20	300	
				BO	27	D	11:49	17	300	
				EYE	17	D	12:12	11	73	
				SEC	18	D	12:21	5	38	
				UV	22	D	12:26	8	27	
				UWE	17	D	12:45	36	-	
14/116	01/11/88	62°43,2'S 48°02,5'W	3.278	RMT	16	D	18:59	34	200	
				BRO	71	D	20:12	23	300	
				APN	21	D	20:32	5	10	
				UWE	18	D	20:52	105	-	
				ICE	16	D	18:59	184	-	Ice station AN 723061
				DIV	10	D	20:03	154	10	
				CTD	50	DU	22:55	24	600	
				RMT	17	DU	23:28	38	192	
14/117	02/11/88	63°01,3'S 47°45,2'W	2.861	ICE	17	D	10:24	184	-	Ice station AN 723070
				BRO	72	D	10:24	20	300	
				CTD	51	D	10:51	35	1100	
				APN	22	D	11:00	6	10	
				BRO	73	D	11:30	11	80	
				BO	28	D	11:45	21	300	
				BO	29	D	12:08	22	300	
				BRO	74	D	12:36	12	120	
				EYE	18	D	12:53	9	73	
				SEC	19	D	12:56	5	49	
				UV	23	D	13:08	8	27	
				PH	1	D	13:18	20	70	
				FRA	8	D	13:39	7	200	
				UWE	19	D	13:54	41	-	

Station No.	Date	Position		Echo Depth (m)	Gear	Haul No.	Day Time	Start (GMT)	Haul Dur. (min.)	Max. Gear depth m	Comment
14/118	02/11/88	63°10,7'S	47°36,9'W	3.109	BRO	75	D	20:59	25	300	
					DIV	11	D	21:05	77	10	
					UWE	20	D	21:35	57	-	
					ICE	18	D	21:05	125	-	Ice station AN 723071
					CTD	52	D	22:33	156	3000	
					UWE	21	DU	23:55	37	-	
14/119	03/11/88	63°21,4'S	47°40,4'W	3.354	RMT	18	D	17:25	34	196	Time station in the ice
					UV	24	D	18:35	6	27	
					SEC	20	D	18:45	2	56	
					EYE	19	D	18:45	28	73	
					PH	2	D	18:53	15	70	
					BRO	76	D	19:25	19	300	
					UWE	22	D	19:51	94	-	
					ICE	19	D	20:15	120	-	Ice station AN 723081
					DIV	12	D	20:15	120	10	
					CTD	53	D	21:36	59	2000	
					NAS	4	D	22:39	89	2000	
	04/11/88				UWE	23	D	08:06	33	-	
					BRO	77	D	08:54	26	300	
					CTD	54	D	09:23	31	1000	
					BRO	78	D	09:59	9	100	
					BO	30	D	10:14	22	300	
					BO	31	D	10:38	22	300	
					ICE	20	D	10:47	133	-	Ice station AN 723090
					DIV	13	D	10:49	91	10	
					BO	32	D	11:02	40	600	
					PH	3	D	11:49	15	70	
					BRO	79	D	12:16	16	300	
					UWE	24	D	13:01	37	-	
					BRO	80	D	14:16	22	300	
					CTD	55	D	14:43	36	1000	
					DIV	14	D	15:45	65	10	
					EYE	20	D	15:45	65	-	lowered from the ice
					ICE	21	D	15:45	65	-	Sampling from the Mummychair
					UWE	25	D	15:51	62	-	
					UWE	26	D	17:38	42	-	
					BRO	81	D	18:47	22	300	
					PH	4	D	19:14	14	70	
					ICE	22	D	19:15	75	-	
					UWE	27	D	19:36	37	-	
					CTD	56	D	19:33	20	600	
					DIV	15	D	20:19	50	10	
					CTD	57	D	20:24	66	-	From on the ice
14/120	05/11/88	63°15,4'S	47°40,3'W	3.146	BRO	82	D	11:59	21	300	
					CTD	58	D	12:24	36	1000	
					DIV	16	D	12:25	95	10	
					ICE	23	D	12:25	180	-	Ice station AN 723100
					BRO	83	D	13:03	12	100	
					BO	33	D	13:20	20	300	
					BO	34	D	13:42	20	300	
					SEC	21	D	14:03	6	48	
					EYE	21	D	14:09	9	72	
					UV	25	D	14:21	5	27	
					PH	5	D	14:28	13	70	
					APN	22	D	14:39	1	10	
					FRA	9	D	14:44	10	200	
					APN	23	D	14:45	2	10	
					UWE	28	D	15:01	53	-	
					CTD	59	D	14:35	55	-	lowered from the ice
14/121	05/11/88	63°04,0'S	47°41,9'W	3.027	ICE	24	D	23:50	45	-	Ice station AN 723101
					BRO	84	D	23:55	28	300	
	06/11/88				CTD	60	DU	00:28	98	2000	
					NAS	5	N	02:13	150	2000	
14/122	06/11/88	62°37,6'S	47°46,8'W	3.466	CTD	61	D	11:35	40	1000	
					ICE	25	D	11:45	102	-	Ice station AN 723110
					DIV	17	D	12:06	89	10	
					BRO	85	D	12:19	14	80	
					CTD	62	D	12:27	75	-	lowered from the ice
					BO	35	D	12:39	19	300	
					BO	36	D	13;00	21	300	
					EYE	22	D	13:27	12	75	
					SEC	22	D	13:31	3	28	
					APN	24	D	13:39	4	10	
					UV	26	D	13:42	7	27	
					BRO	86	D	13:53	22	300	
					PH	6	D	14:22	11	70	
					BRO	87	D	14:49	21	300	
					UWE	29	D	15:14	48	-	
					RMT	19	D	16:23	36	200	
14/123	07/11/88	61°59,4'S	47°24,4'W	2.760	UWE	30	N	00:15	75	-	
14/124	07/11/88	61°51,5'S	47°13,9'W	1.721	BRO	88	D	08:02	22	300	

Station No.	Date	Position		Echo Depth (m)	Gear	Haul No.	Day Time	Start (GMT)	Haul Dur. (min.)	Max. Gear depth m	Comment
					CTD	63	D	08:28	37	1000	
					BRO	89	D	09:08	18	300	
					BO	37	D	09:33	19	300	
					BO	38	D	09:57	22	300	
					BRO	90	D	10:25	22	300	
					EYE	23	D	10:57	15	75	
					SEC	23	D	11:00	3	22	
					UV	27	D	11:13	6	27	
					ICE	26	D	12:10	101	-	Ice station AN 723120
					DIV	18	D	12:10	57	10	
					CTD	64	D	12:33	54	-	lowered from the ice
					UWE	31	D	14:03	45	-	
					PH	7	D	14:53	9	70	
					ICE	27	D	16:12	108	-	
					DIV	19	D	16:22	38	10	
14/125	07/11/88	61°55,7'S	46°45,7'W	910	UWE	32	D	21:44	28	-	Time station in the ice
					CTD	65	D	22:17	33	900	
					BRO	91	D	22:56	23	300	
					UWE	33	DU	23:34	40	-	
	08/11/88				CTD	66	N	02:02	26	880	
					BRO	92	N	02:32	17	300	
					CTD	67	N	05:59	31	815	
					BRO	93	N	06:34	28	300	
					BRO	94	DA	08:00	15	80	
					EYE	24	D	08:21	10	72	
					UV	28	D	08:33	6	27	
					BRO	95	D	09:01	9	23	
					CTD	68	D	10:00	27	800	
					BRO	96	D	10:30	23	300	
					DIV	20	D	10:53	87	10	
					ICE	28	D	10:53	259	-	Ice station AN 723130
					UWE	34	D	11:33	33	-	
					BO	39	D	12:13	19	300	
					BO	40	D	12:35	21	300	
					PH	8	D	13:03	4	70	
					CTD	69	D	13:58	20	580	
					BRO	97	D	14:22	22	300	
					EYE	25	D	14:56	9	75	
					SEC	24	D	15:00	1	-	
					UV	29	D	15:09	5	27	
					MN	2	D	15:26	38	300	No net release
					UWE	35	D	16:49	54	-	
					CTD	70	D	18:08	26	900	
					BRO	98	D	18:38	19	300	
					EYE	26	D	19:59	11	75	
					UV	30	D	20:13	7	27	
					DIV	21	D	20:20	95	10	
					CTD	71	D	20:20	87	-	lowered from the ice
					ICE	29	D	20:20	72	-	
					CTD	72	D	21:59	30	1000	
					APN	25	D	22:06	4	10	
					BRO	99	D	22:34	31	300	
					UWE	36	DU	23:22	44	-	
14/126	09/11/88	61°28,7'S	46°33,9'W	381	BRO	100	D	08:09	21	300	
					CTD	73	D	08:39	43	300	
					BRO	101	D	09:29	17	80	
					ICE	30	D	08:10	27	-	
					EYE	27	D	09:51	10	74	
					UV	31	D	10:03	6	27	
					UWE	37	D	10:14	48	-	
14/127	09/11/88	61°21,3'S	46°28,6'W	328	BRO	102	D	12:26	8	20	
					ICE	31	D	12:26	180	-	Ice station AN 723141
					BO	41	D	12:41	21	300	
					CTD	74	D	12:52	76	-	lowered from the ice
					BO	42	D	13:05	21	300	
					EYE	28	D	13:34	11	73	
					SEC	25	D	13:39	3	-	
					UV	32	D	13:50	5	27	
					UWE	38	D	14:10	61	-	
					DIV	22	D	14:26	52	10	
					MN	3	D	15:11	41	300	
					BRO	103	D	15:59	24	300	
					CTD	75	D	16:27	13	300	
					RMT	20	D	17:11	34	200	
					NEU	12	D	17:16	23	0	
14/128	09/11/88	61°04,5'S	46°04,0'W	272	ICE	32	D	21:09	-	-	
					BRO	104	D	22:13	30	250	
					CTD	76	D	22:48	11	250	
					UWE	39	DU	23:32	43	-	
14/129	10/11/88	60°50,0'S	45°34,9'W	376	BRO	105	D	08:01	20	300	
					CTD	77	D	08:25	12	320	

Station No.	Date	Position		Echo Depth (m)	Gear	Haul No.	Day Time	Start (GMT)	Haul Dur. (min.)	Max. Gear depth m	Comment
					BRO	106	D	08:56	13	80	
					BO	43	D	09:15	20	300	
					BO	44	D	09:45	19	300	
					EYE	29	D	10:08	12	73	
					UV	33	D	10:21	6	27	
					ICE	33	D	10:53	76	-	
14/130	11/11/88	60°37,2'S	46°28,2'W	520	BRO	107	D	08:02	18	300	
					CTD	78	D	08:25	13	300	
					UWE	40	D	09:13	45	-	
14/131	11/11/88	60°27,5'S	46°26,7'W	612	RMT	21	D	11:07	42	186	
					BRO	108	D	12:25	20	300	
					ICE	34	D	12:42	43	-	
					CTD	79	D	12:49	13	300	
					BRO	109	D	13:11	9	80	
					BO	45	D	13:27	18	300	
					BO	46	D	13:50	22	300	
					EYE	30	D	14:18	10	75	
					SEC	26	D	14:20	2	22	
					UV	34	D	14:30	5	27	
					ICE	35	D	14:30	20	-	
					MN	4	D	14:43	62	500	
					DIV	23	D	14:50	52	10	
					UWE	41	D	16:06	65	-	
14/132	11/11/88	60°09,8'S	46°26,9'W	3.406	RMT	22	D	20:33	51	298	
					BRO	110	D	21:45	21	300	
					CTD	80	D	22:09	23	650	
					FRA	10	D	22:34	8	200	
					UWE	42	DU	23:05	77	-	
14/133	12/11/88	59°53,1'S	46°22,0'W	3.967	BRO	111	N	02:38	24	300	
					CTD	81	N	03:06	21	650	
14/134	12/11/88	59°31,8'S	46°27,6'W	3.102	BRO	112	N	06:36	21	300	
					CTD	82	DA	07:02	31	1000	
					RMT	23	D	08:01	54	300	
					MN	5	D	09:10	53	1000	
14/135	12/11/88	59°13,2'S	46°27,7'W	2.880	BRO	113	D	12:03	14	80	
					APN	26	D	12:15	3	10	
					CTD	83	D	12:22	19	600	
					BRO	114	D	12:52	20	300	
					EYE	31	D	13:16	8	75	
					SEC	27	D	13:23	2	11	
					UV	35	D	13:26	6	27	
					BO	47	D	13:35	23	300	
					BO	48	D	14:02	20	300	
					APN	27	D	14:13	4	10	
					FRA	11	D	14:30	10	200	
					BRO	115	D	14:45	18	300	
14/136	12/11/88	58°52,3'S	46°29,7'W	2.610	BRO	116	D	17:05	18	300	
					CTD	84	D	17:27	29	1000	
					APN	28	D	17:46	3	10	
					EYE	32	D	17:59	7	75	
					UV	36	D	18:10	7	27	
					MN	6	D	18:19	60	1000	
					RMT	24	D	19:33	-	295	
14/137	12/11/88	58°31,1'S	46°30,8'W	3.210	MN	7	D	22:41	114	1000	
					APN	29	D	22:48	2	10	
	13/11/88				BRO	117	N	00:40	22	300	
					CTD	85	N	01:05	22	600	
14/138	13/11/88	58°19,3'S	46°30,5'W	3.065	BRO	118	N	02:33	20	300	
					CTD	86	N	02:57	24	620	
14/139	13/11/88	57°50,8'S	46°29,6'W	3.363	RMT	25	D	08:04	65	295	
					BRO	119	D	09:11	15	80	
					BO	49	D	09:39	23	300	
					APN	30	D	09:55	4	10	
					BO	50	D	10:08	23	300	
					BRO	120	D	10:38	24	300	
					EYE	33	D	11:07	8	75	
					SEC	28	D	11:09	3	13	
					UV	37	D	11:18	9	27	
					MN	8	D	11:28	57	1000	
					CTD	87	D	12:32	42	2000	
					BRO	121	D	13:17	7	20	
14/140	14/11/88	60°21,6'S	50°10,2'W	3.472	ICE	36	D	12:27	187	-	Ice station AN 723190
					BRO	122	D	12:36	6	80	
					DIV	24	D	12:40	117	10	
					CTD	88	D	12:47	39	1000	
					BRO	123	D	13:35	18	300	
					BO	51	D	13:58	22	300	
					BO	52	D	14:43	21	300	
					UV	38	D	14:59	5	27	
					UWE	43	D	18:25	73		
					DIV	25	D	21:11	83	10	

Station No.	Date	Position		Echo Depth (m)	Gear	Haul No.	Day Time	Start (GMT)	Haul Dur. (min.)	Max. Gear depth m	Comment
					UWE	44	D	21:20	84		
	15/11/88				UWE	45	N	00:03	69		
					UWE	46	N	06:02	63		
					UWE	47	D	08:33	68		
14/141	15/11/88	59°40,9'S	51°50,1'W	3.143	RMT	26	D	18:27	48	300	
					CTD	89	D	19:22	31	1000	
					RMT	27	D	20:05	201	1000	
					NEU	13	D	20:15	32	0	

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AWI	Alfred-Wegener-Institut Polar- und Meeresforschung Columbusstrasse D-2850 Bremerhaven	Baranski, Krause, Schneider, Walker
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MPI	Max-Planck-Institut für Chemie Abt. Luftchemie Saarstraße 23 D-6500 Mainz	Harris, Klemp, Zenker
RUB	Ruhr-Universität Bochum Lehrstuhl für Phys. Chemie I Universitätsstraße 150 D-4630 Bochum	Papenbrock
SWA	Deutscher Wetterdienst Seewetteramt Hamburg Bernhard-Nocht-Straße 76 D.2000 Hamburg 4	Köhler
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UEL	Unité d'Ecohydrodynamique B5 Université de Liège Sart-Tilman B-4000 Liège	Goffart
LEB	Vrije Universiteit Brussel Laboratorium voor Ecotoxicologie Pleinlaan 2 B-1050 Brussel	Joiris, Overloop

Brazil

CBM	Universidade Federal do Paranà Centro de Biologia Marinha Trav. Alfredo Bufrem, 140 Curitiba- 80020 PR	Brandini
IOSP	Instituto Oceanografico da Universidade de Sao Paolo Butanta CEP 05508 Sao Paulo	Paviglione

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TZS	Tvärminne Zoological Station SF-10900 Tvärminne	Kurosa, Kuparinen
IZH	University of Helsinki Institute of Zoology Dept. of Ecology P. Rautatienkatn 13 SF-00100 Helsinki	Kivi

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IBM	Istituto di Biologia del Mare CNR Riva 7 Martini 1364/A I-30122 Venezia	Battaglia, Bianchi, Cioce, Socal

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