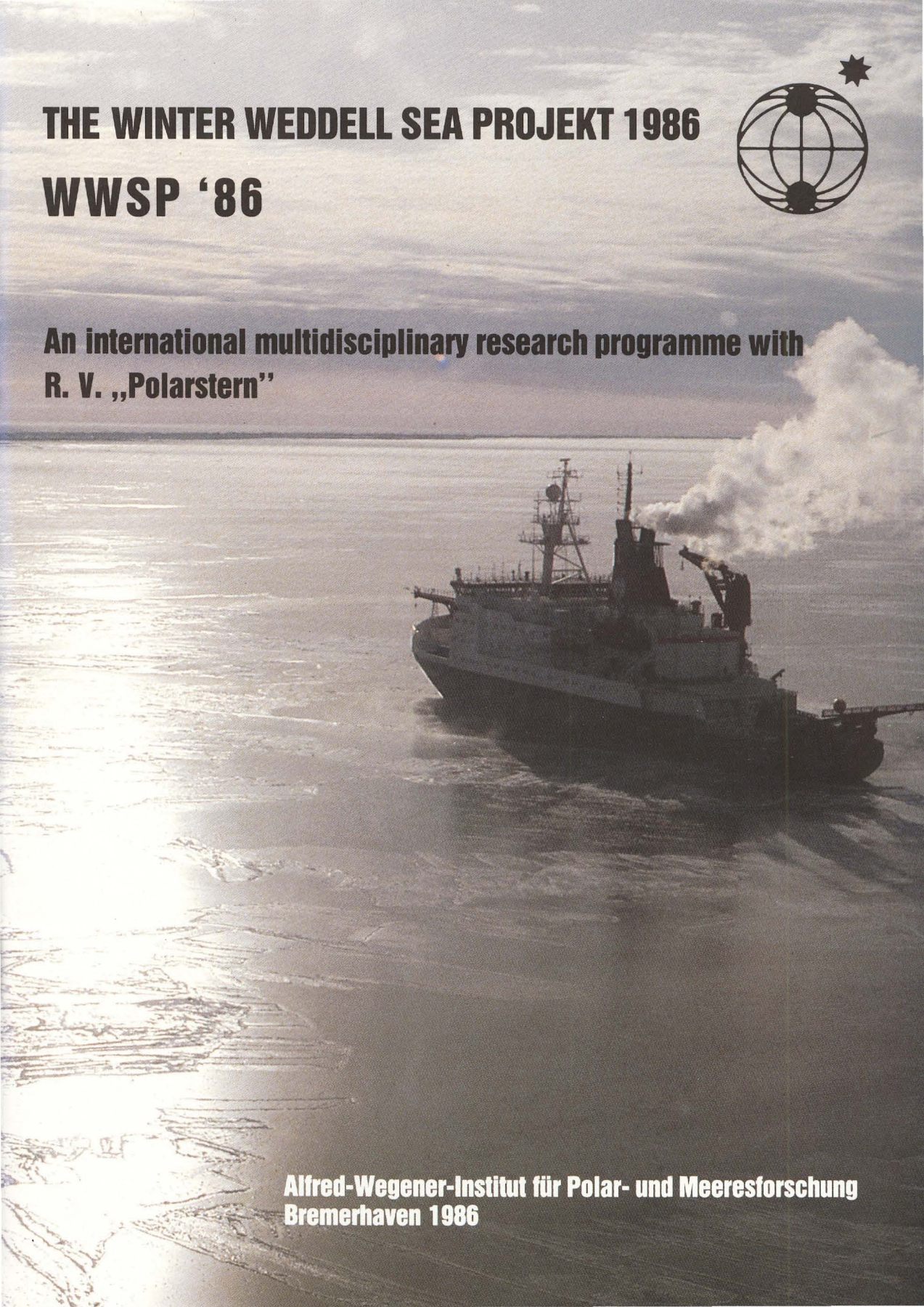
THE WINTER WEDDELL SEA PROJEKT 1986

WWSP '86

An international multidisciplinary research programme with R. V. „Polarstern"



Alfred-Wegener-Institut für Polar- und Meeresforschung
Bremerhaven 1986

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Alfred-Wegener-Institut für Polar- und Meeresforschung, Bremerhaven
1986

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Veröffentlichung Nr. 3 des
Alfred-Wegener-Instituts

Contribution No. 3 of the
Alfred-Wegener-Institute

Cover photograph: H. Kohnen

PREFACE

This delineation of the Winter Weddell Sea Project 1986 is based on the results of international planning meetings, which took place during the last two years in Palisades (USA), Bederkesa (FRG) and Cambridge (UK). Major contributions to and revisions of the text originate from E. Augstein, A. Gordon, G. Hempel, G. Hubold, D. Sahrhage, P. Wadhams and R. Weiss.

1. INTRODUCTION

The pack ice zone of the Southern Ocean, covering almost twenty million square kilometres in winter, is still one of the least explored oceanic regions of the Earth. Our present knowledge of the oceanic and atmospheric winter conditions in the pack ice zone south of 60°S is based on data from a few coastal stations, some current meter moorings, satellite observations of ice cover, and particularly on the observations during Filchner's drift with RV "Deutschland" in 1912 and of the joint USA-USSR "Somov" expedition in 1981.

The great importance of the Antarctic pack ice zone in winter for the oceanic and atmospheric circulation as well as for the biological and biochemical processes within and beneath the sea ice is well known. Nevertheless, relatively little attention has been paid to these conditions in the past due to logistical constraints imposed on ship operations in heavy sea ice, particularly during periods of darkness.

In order to extend marine research in this area into the winter season, the ice breaking research vessel "Polarstern" was built by the Federal Republic of Germany in 1982. The ship is equipped with laboratories and technical facilities for physicists, chemists, biologists and geologists to facilitate interdisciplinary studies in polar oceans.

After successful summer cruises to the Antarctic and to the Arctic the Alfred Wegener Institute for Polar Research initiated the planning of a winter expedition to the Weddell Sea for the year 1986. Scientists from other German institutes, from USA and Great Britain joined in the development of a research programme with RV "Polarstern" as the main experimental platform. The ship-based measurements will be supported by two helicopters, instrumented drifting buoys and satellite data. The observational activities at the wintering stations Georg-von-Neumayer and Halley will also be tuned to assist the expedition at sea.

The Weddell Sea sector - where the German Antarctic field work has been concentrated since 1982 - was chosen for the winter investigations since:

- it is considered to be the major source of Antarctic Bottom Water and a region of deep reaching convective mixing,
- it experiences a strong variability in the distribution of sea ice,
- the oceanic Weddell Gyre and the atmospheric Weddell Cyclone form closely coupled important features of the general circulation,
- the biological activity is high in this region.

The water mass modifications within the Weddell Gyre induce a significant oceanic ventilation on a global scale. However, they seem to be caused by processes at rather small spatial and temporal scales which are controlled by the local thermohaline structure, the varying ice cover and the winter mixed layer development. Consequently, the air-sea-ice interactions gain an important rôle in the understanding of water mass development. In this context lead and polynya formations and their maintenance in the pack ice as well as at the coast will be given special attention.

Variations in the intensity of the Weddell Gyre circulation due to changes of the atmospheric forcing may result in alterations of the sea ice cover, the thermohaline vertical structure and the front which separates the inner cold core from the outer warmer waters (see Figure 1). Therefore, the large scale flow needs to be observed as well as meso- and small scale processes in the ocean, atmosphere and sea ice.

In polar waters the use of geochemical tracers is of special significance in studying water mass formation and mixing processes. The nutrient concentrations in water and sea ice form an essential element of the environmental conditions for biological processes and they serve as a further aid in determining physical events. At present the nutrient distributions are poorly known in the ice covered oceanic regions during winter.

The biological work will address a variety of phenomena such as

- formation and survival of the sea ice biota, i.e. the communities of algae, proto- and metazoans living within the solid sea ice and their interaction with the surrounding water,
- the life of plankton, fish and benthos as well as crabeater seals in the ice covered sea and in a narrow coastal polynya,
- the biological processes in the coastal polynya in early spring in relation to the physical and chemical conditions,
- the life of Weddell Seals and Emperor Penguins in an inlet of the eastern Weddell Sea during the reproduction period.

The cruise is subdivided into two legs, the track lines of which are indicated on Figure 1. The first period, from 24 June to 15 September 1986, concentrates on sea ice, oceanographic and meteorological measurements along a transect on the Greenwich Meridian from the ice edge to the Antarctic coast. The second one, from 29 September to 15 December 1986, focusses primarily on biological and chemical investigations in coastal open water areas of the eastern Weddell Sea. During both phases the research work of the various disciplines is strongly coupled so that a comprehensive, quantitative description of the interacting system, involving the atmosphere, the ocean, the sea ice and biology in winter and early spring will be obtained.

In between the two legs a port call is planned in Cape Town for exchanges of scientific personell and the crew members as well as for re-fuelling the ship.

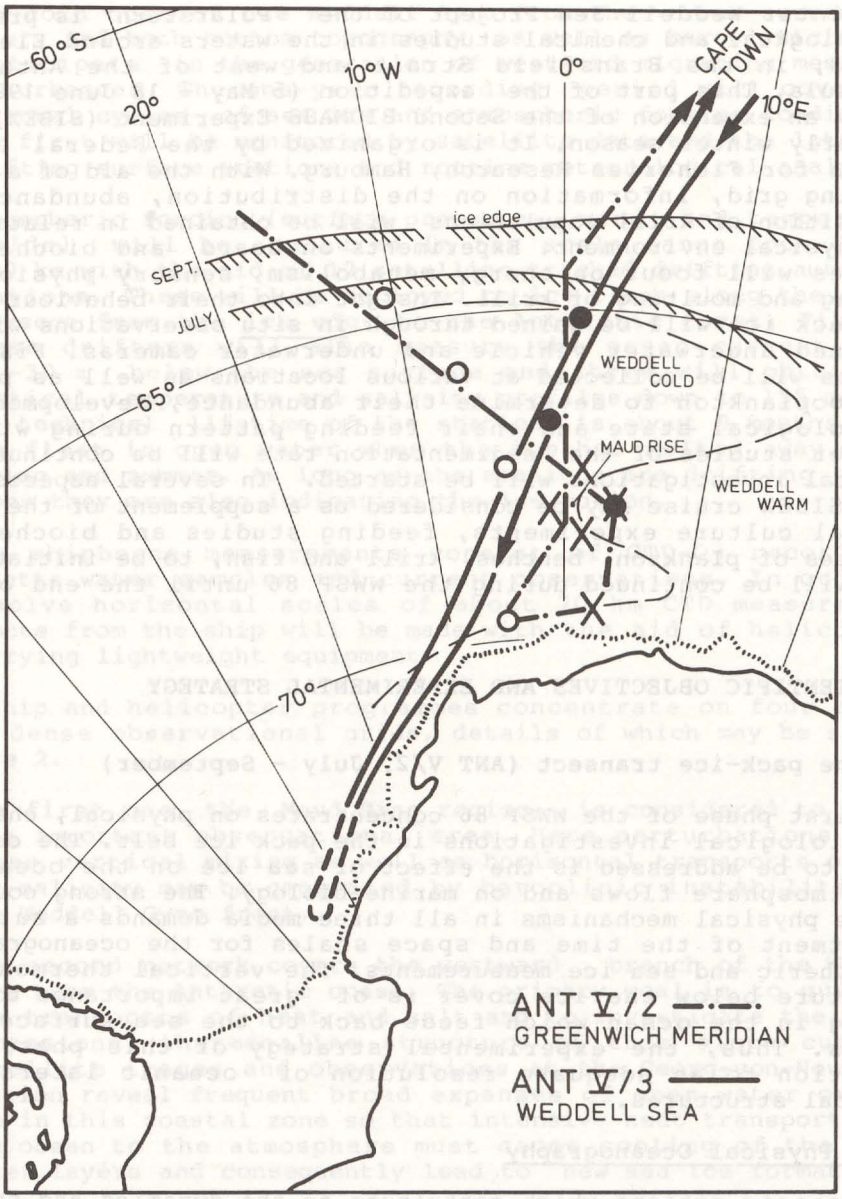

Figure 1 Rough sketches of the ship tracks of ANT V/2 (dash-dotted) and ANT V/3 (full and dashed lines). Launching positions of ARGOS stations are indicated by open circles (meteorological data only), crosses (met data and and current meter) and full circles (met data and thermistor-chaines).

The Winter Weddell Sea Project of the "Polarstern" is preceded by biological and chemical studies in the waters around Elephant Island, in the Bransfield Strait and west of the Antarctic Peninsula. This part of the expedition (5 May - 18 June 1986) is mainly an extension of the Second BIOMASS Experiment (SIBEX) into the early winter season. It is organized by the Federal Institution for Fisheries Research, Hamburg. With the aid of a large sampling grid, information on the distribution, abundance and composition of krill populations will be obtained in relation to the physical environment. Experiments on board and biochemical studies will focus on energy metabolism, sensory physiology, feeding and moulting of krill. Insight into their behaviour under the pack ice will be gained through in situ observations with an unmanned underwater vehicle and underwater cameras. Fish and benthos will be collected at various locations as well as phyto- and zooplankton to determine their abundance, development and physiological state and their feeding pattern during winter. Earlier studies of the sedimentation rate will be continued and chemical investigations will be started. In several aspects this Post-SIBEX cruise may be considered as a supplement of the WWSP. Several culture experiments, feeding studies and biochemical analyses of plankton, benthos, krill and fish, to be initiated in May, will be continued during the WWSP 86 until the end of the year.

2. SCIENTIFIC OBJECTIVES AND EXPERIMENTAL STRATEGY

2.1 The pack-ice transect (ANT V/2, July - September)

The first phase of the WWSP 86 concentrates on physical, chemical and biological investigations in the pack ice belt. The central topic to be addressed is the effect of sea ice on the ocean and the atmosphere flows and on marine biology. The strong coupling of the physical mechanisms in all three media demands a suitable adjustment of the time and space scales for the oceanographic, atmospheric and sea ice measurements. The vertical thermohaline structure below the ice cover is of great importance to deep mixing in the ocean which feeds back to the sea surface processes. Thus, the experimental strategy of this phase pays attention to an adequate resolution of oceanic lateral and vertical structures.

2.1.1 Physical Oceanography

The oceanic motions which contribute to the dynamics and thermodynamics of the Weddell Sea during winter cover a wide spectral domain. They range from the dimension of the Weddell Gyre to the baroclinic Rossby radius of deformation at some ten kilometers and even down to convection events of a few hundred metres diameter. Since a one-ship expedition of about two months duration cannot adequately cover all scales current meter moorings and drifting automatic stations are included into the experimental design. The observational strategy will be as follows:

- Large scale currents and their fluctuations will be measured by moorings at one year duration in the vicinity of Maud Rise. This area was chosen because the easterly front which separates

the cold core of the Weddell Gyre from the warmer surrounding water, and both bottom topography as well as baroclinicity may participate in the generation of westward migrating mesoscale disturbances. The one-year recording period will cover the seasonal cycles of sea ice and atmospheric forcing conditions. The first will be monitored by satellite data and the latter by drifting surface stations and routine meteorological analyses.

- Atmospheric forcing (surface pressure-, wind- and temperature fields) will be measured in the scale range from 200 to 1000 km with the aid of 12 satellite-tracked drifting automatic stations. These will be deployed on ice floes along the ship's transect from the ice edge to the Antarctic coast. Five of these drifters will also measure the ocean current about 10 -30 m below the sea surface and three will obtain the vertical temperature and salinity profiles down to 155 metres. The technical lifetime of the stations is about 9 months. They can float in open water when the ice has melted away during spring and summer. As long as the stations are drifting on ice floes they are also indicating the ice motion.

- The shipborne measurements consist of CTD-O_2 recordings, rosette water samples and current observations. In order to resolve horizontal scales of about 20 km CTD measurements remote from the ship will be made with the aid of helicopters carrying lightweight equipment.

The ship and helicopter programmes concentrate on four arrays with dense observational grids, details of which may be seen on Figure 2.

- The first one, the Maud Rise region, is considered to be the most important observational area. Here perturbations which cause vertical mixing as well as horizontal transports of heat and salinity may be generated by baroclinic instabilities at the Weddell Gyre front.

- The second network covers the westward branch of the Weddell Gyre near the Antarctic coast. The primary goal is to quantify the transports of heat and salt and to investigate the three-dimensional thermohaline structure of this slope current. Satellite images and observations at the Georg-von-Neumayer-Station reveal frequent broad expanses of open water or thin ice in this coastal zone so that intensive heat transports from the ocean to the atmosphere must cause cooling of the upper water layers and consequently lead to new sea ice formation.

- The third array represents conditions at the centre of the Weddell Gyre, in the middle of the sea ice belt. At this latitude of about 62°S the cold inner part of the Weddell Gyre extends farthest to the east. Here the satellite observations frequently indicate high ice concentrations in contrast to the area further south.

- Finally, the marginal ice zone will be studied where the Weddell Gyre Water interacts with the Circumpolar Deep Water and several meso- and small scale processes contribute to the lateral heat exchange across the ice edge.

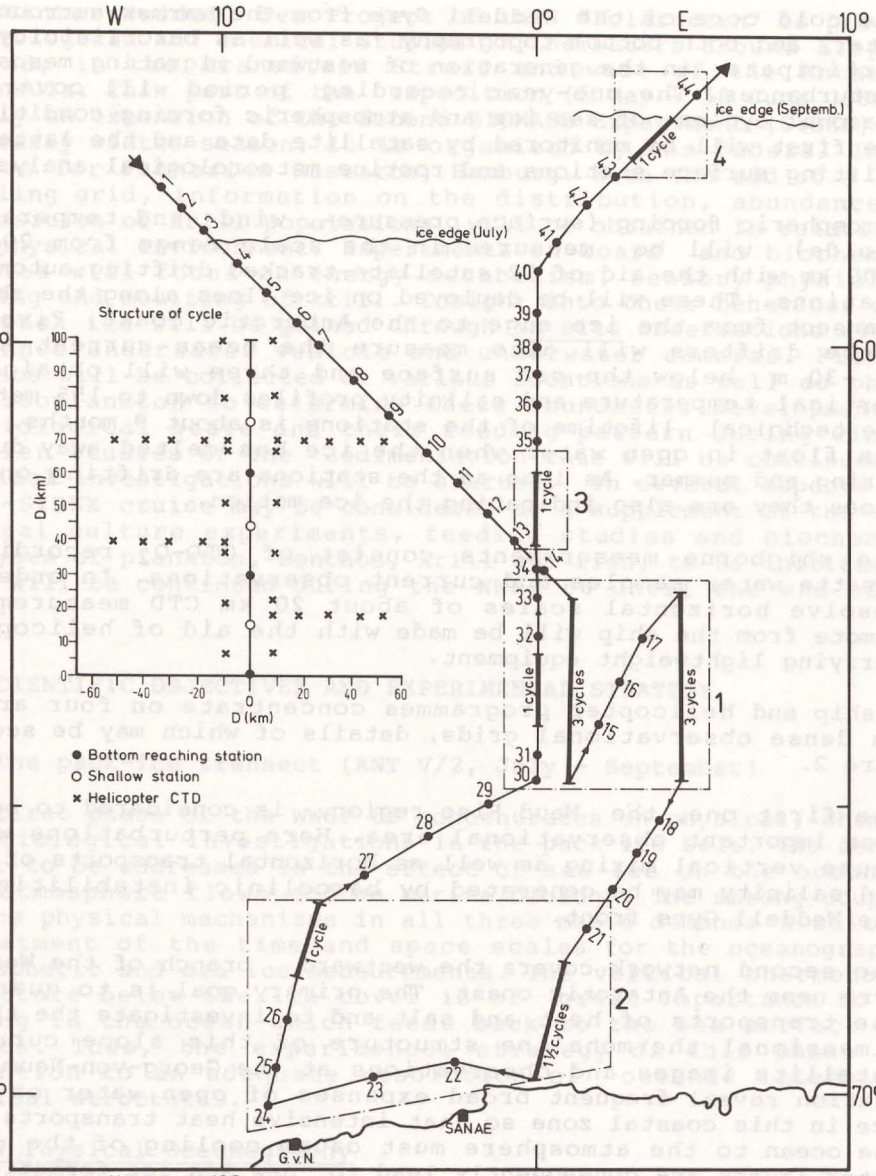

Figure 2 Station plan of ANT V/2. The insert on the left hand side resolves the structure of the measurement cycles which are marked by thick lines on the cruise track.

2.1.3 Meteorology

The meteorological programme forms the atmospheric component of the air-sea-ice interaction studies. The major effort is directed towards continuous measurements of the atmospheric surface quantities in order to derive the large scale horizontal pressure, wind velocity, air- and sea surface temperature fields. These data are firstly needed to compute the air-sea heat and momentum exchanges and to link these fluxes to large scale values. Secondly, they provide the interface conditions for the development of the atmospheric and oceanic boundary layers.

- The surface values will be obtained from twelve automatic stations deployed on ice floes covering initially, an area of about 1000 (meridional) by 600 (zonal) km^2. The grid-net is irregular (Figure 1), its smallest mesh-width is about 200 km over Maud Rise.
- The thermal and kinematic vertical structure of the atmospheric boundary layer and the entire troposphere will be measured with the aid of radiosondes, OMEGA-windfinding equipment and with a three component Doppler SODAR for the low level wind profile. Furthermore, attempts will be made to derive the surface heat and momentum fluxes from measurements by a Sonic device exposed on the bow crane of the ship. Continuous measurements of all radiation components, the Earth's surface temperature, air- and water temperatures, air humidity, wind velocity and air pressure supplement the observational programme.

During the experimental period the upper air programme of the coastal stations Georg-von-Neumayer and Halley will be intensified to improve the information on the tropospheric large scale flow.

Selected data of the automatic stations and the shipborne measurements will be injected regularly into the GTS and enter into the near real time objective analysis of the European Center for Medium Range Weather Forecasts (ECMWF). The improved atmospheric fields will form the large scale background for mesoscale model computations.

2.1.3 Sea Ice

Sea ice conditions intensively control the air-sea heat and momentum exchanges and thus implicitly influence the thermodynamics and dynamics of the ocean and the troposphere at least on longer time scales. Therefore, modelling of the thickness and horizontal distribution of sea ice is an important component in coupled ocean-atmosphere models in particular during winter. In order to achieve this goal the rheology, mass and thermal energy variations, and coverage of sea ice need to be sufficiently treated in such computations. Besides its physical impact, sea ice forms the habitat of a complex community of microorganisms. Rather little is known about the influence of ice on the marine ecosystem during winter so that exploratory studies of this field are gaining increasing attention.

During the meridional transect the following measurements will be carried out to serve the physical and biological objectives:

- The deformation of the pack ice due to atmospheric and oceanic forcing will be detected through tracking of targets on ice floes. Over the Maud Rise and in the coastal and the mid-pack ice, arrays of microwave transponders will be deployed and tracked automatically during at least three days at each location. The observations are supplemented by monitoring OMEGA navigational sondes which will also be mounted on ice floes.

- The surface morphology, thickness and areal distribution of sea ice will be intensively documented by various means during the deformation experiments and with less priority during the entire leg of the cruise with various means. Aerial photography, a photoelectric device and a microwave radar applied from a helicopter will provide images of the ice cover, measures of the floe size distribution and the areas of open water as well as ice thickness, respectively.

- Ship-based instruments including a microwave radiometer, profiling laser, sonic range finder, and video cameras, will more or less continuously record ice ridging and small-scale surface roughness. These measurements will be completed by visual observations, ice coring and surface sampling. Arrangements are made to use these data also as ground truth information for satellites such as SPOT, DMSP and NIMBUS which carry microwave, visible and infrared sensors.

- Ocean surface waves propagate from the open water into the pack ice with a distinct dependence of the wave amplitude on distance from the outer ice edge. In order to determine wave forcing on the ice a wave rider buoy will measure the water motions just outside the ice edge and pitch-roll-heave buoys together with ice-based strain meters will be deployed at various distances inside the ice edge. The low frequency deep penetration of swell will be detected farther inside the ice (> 200 km) by strain meters and an accelerometer.

- Physical, chemical and biological properties of ice cores help to identify the growth and deformation history of the sea ice. Measurements of salinity, temperature, ice structure, density, nutrients, and counts of phytoplankton and bacteria will be taken on the cores sampled from a variety of ice floes.

2.1.4 Biology

The biological investigations across the pack-ice belt will focus mainly on the sea ice community and the associated cryopelagic fauna. Biological processes in sea ice and the underlying water column during winter are still poorly understood. Many organisms enclosed in the sea ice obviously survive harsh winter conditions and may provide the inoculum for the spring or summer bloom when the marginal ice zone recedes. Sea ice organisms therefore form a specialized community, adapted to extremely low temperatures, large salinity fluctuations, prolonged periods of low light levels and accompanying changes in other parameters such as nutrients and oxygen.

To increase our understanding of the seasonal changes of biological quantities in the sea ice belt area we will

- investigate the spatial distribution and biomass of the sea ice community on micro-, meso- as well as large scales,
- examine the morphological and physiological conditions of organisms, their overwintering mode as well as the respiratory, photosynthetic and heterotrophic activity,
- conduct experiments on board to establish the viability of sea ice organisms upon thawing.

Fundamental to the understanding of the biological régime in the sea ice, is a thorough knowledge of the chemical and physical properties of the sea ice and underlying water column. These give an insight into ice formation processes and the environment in which the sea ice community lives. Detailed studies of the sea ice as well as the underlying water column include analyses of ice stratigraphy, temperature, salinity, nutrients and light penetration. The biological investigations are therefore inextricably linked to the physical and chemical sea ice data and to the oceanographic measurements during this cruise.

The biological studies will be extended to the investigation of the physiological and biochemical conditions of zooplankton in the water column and finally a census of birds and seals encountered during the cruise will be carried out.

2.1.5 Chemistry

The geochemical studies are closely related to the programmes of physical and biological oceanography. Chemical methods will be applied to specify the mechanisms and rates of wintertime deep and bottom water formation in the Weddell Gyre. The chemical properties of the surface waters and shelf waters are strongly affected by the air-sea gas and matter exchanges, biological processes and sea ice cover. Thus, the analysis of a number of independently varying chemical and radioactive tracers provide a means by which the contribution of the various possible influences on the modification of the oceanic state can be identified. Properties of time dependent tracers used in regional and global studies of propagation rates will be applied to determine the sources of wintertime deep and bottom water. These analyses will also help to understand better the deep convection in the ice covered Antarctic ocean.

The following quantities will be measured: -

- Nutrients and oxygen to detect effects of biological processes, sediment-water interactions and air-sea exchange,
- Radiocarbon and Argon-39 to provide information concerning the carbon cycle, air-sea exchange and deep-sea mixing,
- Stable isotopes to enable the determination of the rôle of evaporation, precipitation, as well as melting and freezing of sea ice and shelf ice,

- Chlorofluoromethanes (Freons), Krypton-85, Tritium and Helium-3 to quantify rates of subsurface mixing and water transports as well as air-sea gas exchange
- Total inorganic, alkalinity, Carbon-13, pCO_2 and atmospheric CO_2 to indicate the carbon cycle and air-sea exchange processes
- Radon and Radium-226 to derive air-sea exchange rates and sediment-water interactions
- Radium-228 to represent sediment-water interactions and deep-sea mass transport rates
- Trace elements to determine the composition of nascent Bottom Water.

2.2 The coastal polynya programmes (ANT V/3, October -December)

The existence of coastal polynyas along the southern and eastern coast of the Weddell Sea has been verified from satellite observations. Such open water areas along the coast line support a considerable heat flux from the ocean to the atmosphere, particularly in winter and early spring. Their existence may also be essential for the survival of Emperor Penguins in the high Antarctic. Since sunlight is not shielded by the ice cover, phytoplankton production in the polynya may start in early springtime. But this process also requires that the destabilization of the water column through surface cooling is in some way set off in order to keep the phytoplankton in the euphotic zone.

To obtain more insight into the actual conditions the physical, chemical and biological processes during the winter to spring transition will be studied in a coastal polynya in the eastern Weddell Sea south of Kapp Norvegia. In the vicinity of Vestkapp a dense station grid is planned on transects normal to the coast with biological and hydrographic measurements. If ice conditions permit, an attempt will be made to investigate the bottom water formation in the southern part of the Weddell Sea.

2.2.1 Biology

Summer observations have shown a strong variability of several components of the marine ecosystem near the coast of the Weddell Sea. These changes are obviously correlated with the hydrographic structure and the currents of the coastal waters. The plankton and its changes perpendicular to the coastline should reflect the early spring primary production in open water areas. The investigations have to account for advective effects and temporal variations. Certain components of the system may be transported into or out of the investigated region. Time series at specified positions as well as repeated sampling in a grid box are required to quantify temporal and advective influences. The observational site is planned to be off Vestkapp, a region which represents typical conditions of the eastern Weddell Sea. Since relevant hydrographic structures, such as meltfronts and sea ice features are expected to fall primarily into the 10 km scale the observational grid will be given a mesh size of about

5 km. The time series will cover at least 25 hours each in order to include the main tidal periods. The following topics will be addressed:

- Biomass development and phytoplankton production in open coastal water and in the adjacent ice covered area will be observed. In case of sea ice melting, liberated microbial organisms may considerably favour the spring bloom of phytoplankton. Shipboard tank experiments will be carried out to yield insight into limiting factors of phytoplankton production, succession of species, grazing and sedimentation influences.
- Sea ice biota will be described quantitatively. Overwintering forms will be specified, and their viability after thawing and their adaptation to a low temperature/high salinity environment will be investigated. Sea ice cores along transects perpendicular to the coast from the fast ice of coastal inlets to open ocean sea ice will be analysed to detect shore effects on the biomass distribution.
- The hibernating zooplankton rises to the surface when spring blooms provide abundant forage. To document the ascent and the triggering factors, samples from various depths will be taken by multiple closing nets. The development of the zooplankton community and its impact on the primary producers will also be studied in tank experiments.
- The hatching of fish larvae takes place in early spring in the polynya. Since the early stages of fish depend on a static stable surface layer and the presence of water mass fronts close to the coast as a lateral barrier, the hatch must be related to such phenomena. Migration of fish larvae from benthic eggs must take place in hydrographically favourable conditions, possibly in areas and at times of small convection. The arrival of larvae in the plankton layer must coincide with the presence of food in form of small zooplankton organisms. Consequently, there should be a time-lag between the onset of the phytoplankton spring bloom and the appearance of fish larvae near the sea surface.
- The biochemical composition of zooplankton and fish larvae at the end of winter provide an indication of the hibernation methods of these species.
- Fish will be caught for investigations on the condition factor, the content of lipids and their composition, and the stage of maturity. Ripe eggs may be obtained for artificial fertilization and experimental hatching of larvae. The buoyancy mechanisms based on lipids of the pelagic fish Pleuragramma antarcticum will be investigated at the end of winter. In relation to lipid deposits which are used as energy source, blood properties and enzymes by overwintering fish will be analysed in shipboard experiments.

- Adaptation of benthic organisms to the seasonally variable sedimentation of food particles will be most pronounced at the end of winter, before the onset of the new production in the water column. Reproduction is probably linked to the new production. Different survival modes will be separated by biochemical analysis.
- Reproduction of Emperor Penguins and Weddell Seals takes place in winter and early spring. Population biology, reproduction and feeding will be investigated from an ice-based station in the Drescher Inlet, near Vestkapp. The observations of individual specimens will yield insight into daily and long-term rhythms of behaviour during the rapidly changing light regime in spring.

2.2.2 Physical and chemical oceanography

The ocean loses a considerable amount of heat to the atmosphere through coastal polynyas. This leads to the generation of sea ice which is transported off the coast by cold continental winds. The resulting thermohaline features and currents will be explored by a close grid of CTD casts and current meter moorings perpendicular to the coast. Ice conditions permitting, an attempt will be made to study the downstream evolution of the slope current.

The chemistry studies on this leg have the same goals as on the previous one. An important extension would be achieved if the source of Weddell Sea Bottom Water could be detected in the southwesterly part of the experimental area. In this case it should be possible to test the hypothesis that bottom water in these coastal regions is generated through mixing of Western Shelf Water and Warm Deep Water.

2.2.3 Meteorology

Antarctic coastal polynyas are generated and maintained primarily by off-shore winds. Sea ice is pushed off-shore by cold air flowing down the ice-covered Antarctic continent and crossing the shore line. On its way over open water, the low level air accumulates a considerable amount of heat extracted from the ocean. Consequently, the surface water is cooled down to the freezing point. The polynya is only maintained as long as the newly formed sea ice is advected off-shore. Thus, the dynamic and thermal interaction between air, ice and water must be rather vigorous. The atmospheric part of these processes will be studied through measurements ashore and over the ocean. The thermodynamic and kinematic characteristics of the continental atmospheric boundary layer will be measured with the aid of two ice shelf stations, one at the ice shelf front and the other about 50 km inland, and also by radiosondes attached to constant level balloons, launched from the inland station. The atmospheric surface field will be derived from a set of eight automatic stations on ice floes, as portrayed in Figure 3. Regular radiosonde ascents from Halley and Georg-von-Neumayer stations and "Polarstern" provide, firstly, the vertical atmospheric structure and, secondly, the large scale tropospheric conditions.

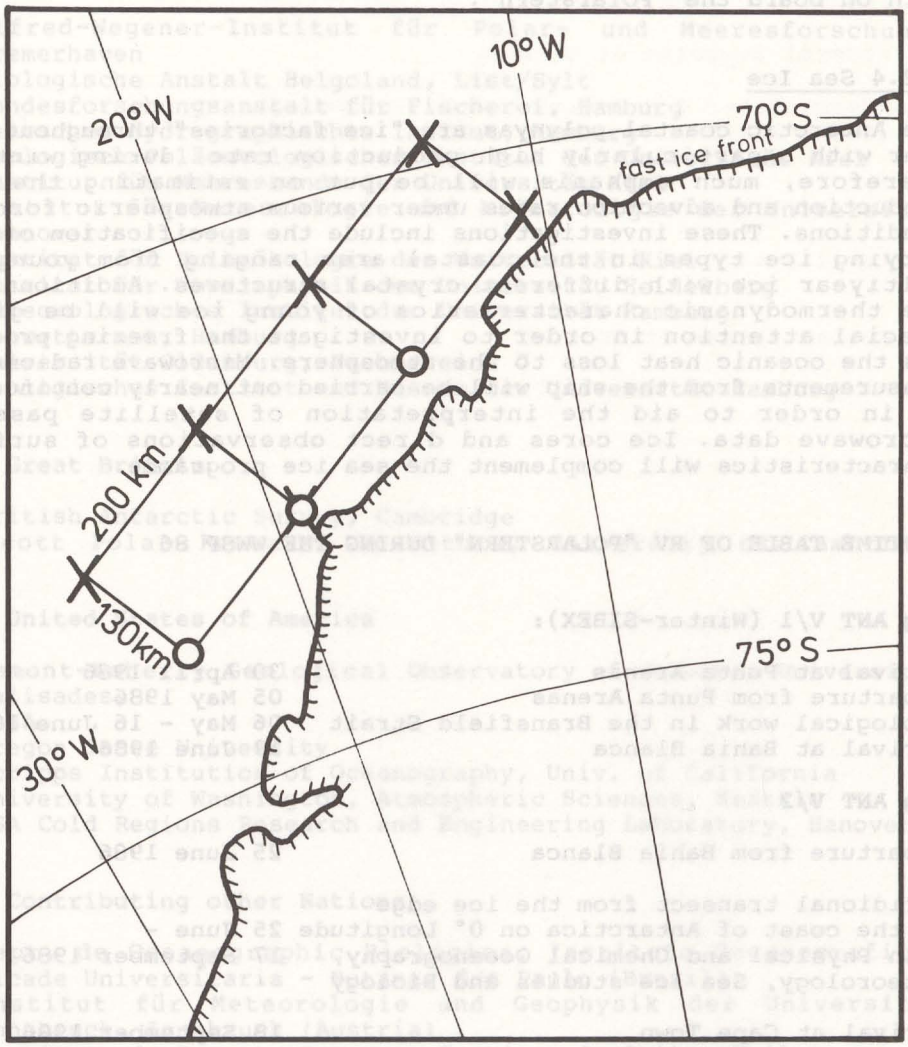

Figure 3 ARGOS-station grid at the Antarctic coast during ANT V/3. Crosses indicate systems with pressure and temperature sensors only, at open circle positions wind speed and direction sensors are added and at the position with a crossed open circle wind speed and direction and the ocean currents will be measured.

The detailed low level vertical wind velocity profile is obtained from a Doppler SODAR and the turbulent heat and momentum fluxes will be computed from measurements with a sonic device, both on board the "Polarstern".

2.2.4 Sea Ice

The Antarctic coastal polynyas are "ice factories" throughout the year with a particularly high production rate during winter. Therefore, much emphasis will be put on estimating the ice production and advection rates under various atmospheric forcing conditions. These investigations include the specification of the varying ice types in the coastal area ranging from young to multiyear ice with different crystal structures. Additionally, the thermodynamic characteristics of young ice will be given special attention in order to investigate the freezing process and the oceanic heat loss to the atmosphere. Microwave radiometer measurements from the ship will be carried out nearly continuously in order to aid the interpretation of satellite passive microwave data. Ice cores and direct observations of surface characteristics will complement the sea ice programme.

3. TIME TABLE OF RV "POLARSTERN" DURING THE WWSP 86

Leg ANT V/1 (Winter-SIBEX):

Arrival at Punta Arenas	30 April 1986
Departure from Punta Arenas	05 May 1986
Biological work in the Bransfield Strait	06 May - 16 June 1986
Arrival at Bahia Blanca	19 June 1986

Leg ANT V/2

Departure from Bahia Blanca	25 June 1986
Meridional transect from the ice edge to the coast of Antarctica on 0° Longitude with Physical and Chemical Oceanography, Meteorology, Sea Ice studies and Biology	25 June - 17 September 1986
Arrival at Cape Town	18 September 1986

Leg ANT V/3

Departure from Cape Town	26 September 1986
Biology, Physical and Chemical Oceanography, Meteorology and Sea Ice studies in a coastal polynya of the eastern Weddell Sea	05 October - 14 December 1986
Arrival at Cape Town	15 December 1986

4. PARTICIPATING INSTITUTIONS

4.1 Federal Republic of Germany

- Alfred-Wegener-Institut für Polar- und Meeresforschung, Bremerhaven
- Biologische Anstalt Helgoland, List/Sylt
- Bundesforschungsanstalt für Fischerei, Hamburg
- Deutsches Hydrographisches Intitut, Hamburg
- Geologisch-Paläontologisches Institut der Universität Kiel
- Institut für Meereskunde der Universität Kiel
- Institut für Meteorologie und Klimatologie der Universität Hannover
- Institut für Polarökologie der Universität Kiel
- Institut für Umweltphysik der Universität Heidelberg
- Meteorologisches Institut der Universität Hamburg
- Seewetteramt, Hamburg
- Universität Oldenburg, Fachbereich 7
- Zoologisches Institut und Museum der Universität Hamburg

4.2 Great Britain

- British Antarctic Survey, Cambridge
- Scott Polar Research Institute, University of Cambridge

4.3 United States of America

- Lamont-Doherty Geological Observatory of Columbia University, Palisades,
- NASA
- Oregon State University
- Scripps Institution of Oceanography, Univ. of California
- University of Washington, Atmospheric Sciences, Seattle
- USA Cold Regions Research and Engineering Laboratory, Hanover

4.4 Contributing other Nations

- Dept. de Oceanographic Biologica, Instituto Oceanografico, Cicade Universitaria - Butana, Sao Paulo (Brazil)
- Institut für Meteorologie und Geophysik der Universität Innsbruck, Innsbruck (Austria)
- Instituto de Fomento Pesquero Santiago de Chile (Chile)
- Netherlands Institute for Sea Research, (Netherlands)
- Prey Identification Service, Port Elisabeth Museum, Humewood (South Africa)
- Universidad de la Republica, Dept. de Biologia Marina y Pesquera, Montevideo (Uruguay)
- Physikalisches Institut der Universität Bern (Switzerland)
- Dept. de Oceanographic biologica, Instituto Oceanografico, Cidade Universitaria - Butana, Sao Paulo (Brazil)

5. SPONSORSHIP

Besides the participating institutions the WWSP 86 research work is financially supported by:

5.1 Federal Republic of Germany

- Bundesminister für Forschung und Technologie
- Deutsche Forschungsgemeinschaft

5.2 Great Britain

- Natural Environment Research Council

5.3 United States of America

- National Science Foundation