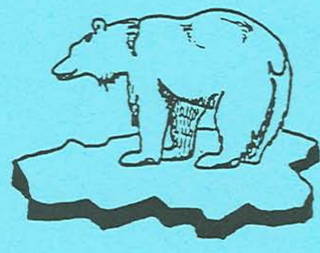
RV "Polarstern"
EXPEDITION PROGRAMME No. 28



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German-Russian Expedition ARCTIC'93

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RV "Polarstern"
ARK-IX/4
Chief Scientist: D. K. Fütterer

jointly with

RV "Ivan Kireyev"
TRANSDRIFT I
Chief Scientist: V. Yu. Karpyi

ALFRED WEGENER INSTITUTE FOR POLAR AND MARINE RESEARCH
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1 Zusammenfassung

Als ein deutliches Zeichen der positiven Entwicklung in der wissenschaftlichen Zusammenarbeit zwischen Rußland und Deutschland wird der vierte Fahrtabschnitt der neunten Reise von FS *Polarstern* in die Arktis (ARK-IX/4) als gemeinsame deutsch-russische Expedition - ARCTIC'93 - zusammen mit dem russischen Schiff FS *Ivan Kireyev* des "Arctic and Antarctic Research Institute" (AARI), St. Petersburg, durchgeführt. Das Zielgebiet für die gemeinsamen Arbeiten ist der Schelf und Kontinentalhang der Laptevsee, einem Zentralbereich des Eurasischen Schelfmeeres. In einer Vorphase wird *Polarstern* Arbeiten in der östlichen Barentssee, nördlich von Franz-Joseph-Land, in einer losen Absprache mit einem weiteren russischen Forschungsschiff, der *Dalnie Zelentsy* des "Murmansk Marine Biological Institute" (MMBI) der Russischen Akademie der Wissenschaften, durchführen.

Die multidisziplinären Forschungsprogramme von *Polarstern* und *Ivan Kireyev* sind eng aufeinander abgestimmt. *Polarstern* wird im Packeis und am Eisrand über dem Kontinentalrand und der Tiefsee des östlichen Nansen-Beckens, in der nördlichen Laptevsee operieren. Die *Ivan Kireyev* wird dagegen im eisfreien Flachwasser des Laptevschelfes zwischen dem Lenadelta und dem Eisrand arbeiten. Deutsche und russische Wissenschaftler werden auf beiden Schiffen an gemeinsamen Forschungsthemen arbeiten.

Polarstern wird am 6. August 1993 von Tromsö (Norwegen) mit Kurs auf Murmansk auslaufen. Während eines kurzen Aufenthaltes in Murmansk werden die russischen Teilnehmer an Bord gehen. Auf der Anreise von Murmansk in das Arbeitsgebiet A nordwestlich Franz-Joseph-Land (Abb. 1) wird Polarstern ozeanographische Jahresverankerungen im Storfjord, südlich Spitzbergen, auslegen. Voraussichtlich am 13./14. August wird das Arbeitsgebiet nördlich Franz-Joseph-Land erreicht werden. In einem etwa 10tägigen multidisziplinären Beprobungs- und Meßprogramm sollen die Stationsprofile A-D (Abb. 1) bis zum 25. August abgearbeitet werden. Gleichzeitig wird die *Dalnie Zelentsy* des MMBI im eisfreien Wasser südlich Franz-Joseph-Land operieren. Während dieser Arbeitsperiode werden auch zwei Überflüge mit einem russischen flugzeuggetragenen Eiserkundungsradar durchgeführt werden.

Etwa vom 25. August bis in die ersten Septembertage wird *Polarstern* eine Transitfahrt vom Arbeitsgebiet nördlich Franz-Joseph-Land entlang der "Northern Searoute" durch die Karasee und die Wilkitski-Straße in die Laptevsee durchführen. Die genaue Fahrtroute ist von den in diesem Bereich häufig sehr schwierigen Eisbedingungen abhängig; dabei wird *Polarstern* von den russischen Eisbrechern der "Northern Searoute"-Verwaltung beraten und unterstützt werden.

Im Verlauf des Septembers wird ein umfangreiches Meß- und Beprobungsprogramm am Eisrand und im Packeis der nördlichen Laptevsee (siehe Abb. 1) durchgeführt werden. Den erwarteten Eisbedingungen folgend werden hier die Arbeiten weit im Osten, in der Nähe der Neusibirischen Inseln, begonnen. Ob das Arbeitsgebiet E, nördlich Severnaya Zemlya (Abb. 1), erreicht werden kann, wird von den Eisbedingungen abhängig gemacht werden müssen. In der Laptevsee ist wenigstens ein direktes Treffen mit *Ivan Kireyev* zur Inter-Kalibrierung der auf beiden Schiffen verwendeten Meßsysteme geplant. Für die Planung und für den Daten-und Informationsaustausch wird zwischen beiden Schiffen eine ständige Funkverbindung bestehen. Auch im Eisrand der Laptevsee werden die Arbeiten durch zwei Überflüge mit dem russischen flugzeuggetragenen Eiserkundungsradar unterstützt werden. Etwa am 25. September werden die Stationsarbeiten in der Laptevsee beendet werden.

Die Rückfahrt der *Polarstern* entlang der "Northern Searoute" wird für einen kurzen Hafenaufenthalt in Murmansk unterbrochen werden, um die russischen Wissenschaftler mit ihrer Ausrüstung an Land zu setzen. Am 5. Oktober 1993 wird *Polarstern* in Bremerhaven zurückerwartet.

Neben Mitarbeitern des AWI und Wissenschaftlern und Technikern weiterer deutscher Forschungsinstitute nehmen auf *Polarstern* vor allem russische Kollegen aber auch Wissenschaftler aus Italien, Schweden und den U.S.A. an der Expedition teil.

Polarstern wird auf dieser Reise ein multidisziplinäres Forschungsprogramm durchgeführen, das seine Schwerpunkte in den Bereichen Ozeanographie, Biologie, Meereisglaziologie und -fernerkundung und Geologie aufweist. Das Beprobungsprogramm ist aufeinander abgestimmt und soll, in Abhängigkeit von der Eislage, dem Schema in Abbildung 1 folgen.

Die o z e a n o g r a p h i s c h e n A r b e i t e n befassen sich mit dem Einfluß des dichten Schelfbodenwassers auf die Erneuerung der Wassermassen und auf die thermohaline Zirkulation im arktischen Ozean. Die Spurenstoffmessungen stehen vor allem in Zusammenhang mit der Untersuchung der Tiefenwasser-Bildungsprozesse. In einer Reihe von Schnitten senkrecht zum Kontinentalhang von der westlichen Barentsee bis zur östlichen Laptevsee soll die Veränderung der Wassermassen im Nansen-Becken auf ihren Zusammenhang mit dem Abfluß von Schelfbodenwasser untersucht werden. Dabei werden Temperatur- und Salzgehaltsmessungen mit einem CTD-System durchgeführt. An Wasserproben aus bis zu 24 Tiefenstufen werden der Gehalt an gelöstem Sauerstoff sowie an Nährstoffen bestimmt.

Die b i o l o g i s c h e n A r b e i t e n werden sich schwerpunktmäßig mit Untersuchungen zur Ökologie und Biogeographie befassen. Im Vordergrund steht dabei die Veränderung des marinen arktischen Ökosystems im Übergang von atlantisch geprägten Strukturen zu den Strukturen des östlichen arktischen Ökosystems. Ein weiteres Hauptziel ist die Erfassung der Quellen und Flüsse der organischen Substanz über dem Kontinentalhang und ein Vergleich zwischen der stark atlantisch geprägten nördlichen Barentssee und der stark kontinental geprägten nördlichen Laptevsee. Entlang verschiedener Profilschnitte vom Schelf bis in die Tiefsee sollen Wassersäule und Meeresboden mit verschiedenen Netzen und Bodengreifern beprobt werden.

Fig. 1: Planned cruise track and sampling stations of RV *Polarstern* along the continental margin of the eastern Barents and Laptev seas.


H
61
60
G
68
53
F
42
52
41
E
34
LAPTEV
SEA
PENINSULA
SEVERNAYA
VOZONIN TROUGH
CENTRAL
KARA RISE
ST. ANNA TROUGH
KARA
SEA
33
D
25
24
C
19
18
10
B
11
A
1
ZEMLYA
FRANTSA
IOSIFA
NOVAYA
ZEMLYA
GYDANSKIY
PENINSULA
Gulf of Ob
TROUGH

Der Schwerpunkt der F e r n e r k u n d u n g d e s M e e r e i s e s liegt auf der Erfassung der Meereiskonzentration durch verschiedene Sensoren und Bewegung auf verschiedenen Skalen. Die Arbeiten umfassen die Nutzung von NOAA-AVHRR-Bildern im infraroten und sichtbaren Spektralbereich, ERS-1-SAR-Daten, den Empfang flugzeuggestützter Radarbilder und den Einsatz einer "line scan camera" vom Hubschrauber aus.

Die p h y s i k a l i s c h e n U n t e r s u c h u n g e n d e s M e e r e i s e s befassen sich mit der Messung Beprobung (Eiskerne) des Fest- und Packeises der östlichen Barentssee und Laptevsee und der Bestimmung der physico-chemischen Eigenschaften (Schnee- und Eisdicke, Temperatur, Dichte, Salzgehalt, stabile Isotope, Nährstoffe).

Die m e e r e i s b i o l o g i s c h e n A r b e i t e n werden sich mit vier Themenschwerpunkten beschäftigen, mit der Biologie der Schmelzwassertümpel, dem biogeographischen Vorkommen von Schneealgen, mit der Biologie und Ökophysilogie der arktischen Meereis- und Untereisfauna und mit dem Einschluß der Organismen bei der Neueisbildung. Das Probenmaterial wird durch das Bohren von Eiskernen gewonnen werden; die Beprobung der Eisunterseite erfolgt durch Pumpen und Netzfänge.

Der Schwerpunkt der m a r i n - g e o l o g i s c h e n A r b e i t e n liegt auf der Gewinnung möglichst langer Sedimentkerne für die Rekonstruktion der paläozeanographischen und paläoklimatischen Entwicklung des Arktischen Ozeans im Quartär. Das Probenmaterial soll auf mehreren Profilschnitten vom Schelf bis in die Tiefsee des Nansen-Beckens mit verschiedenen Kerngeräten und Greifern gewonnen werden.

2 Research programme of RV *Polarstern*

2.1 General introduction

Encouraged by the successes and experiences gained during the multidisciplinary scientific expeditions of RV *Polarstern* in 1991 - the ARCTIC'91 expedition into the Arctic Ocean proper and to the North Pole in a multi-ship operation jointly with the Swedish icebreaker *Oden* and the US icebreaker *Polarstar* and the EPOS II expedition of *Polarstern* to the northern Barents Sea - the Alfred Wegener Institute for Polar and Marine Research (AWI) started early preparations for a multidisciplinary scientific expedition with its RV *Polarstern* to the Eurasian continental margin of the Barents and Laptev seas for summer 1993.

Because of the rich experience and knowledge of Russian scientists and institutions in Arctic shelf seas research over the past 60 years, and aware of the general difficulties of logistic operations in the pack-ice of the Arctic Ocean and its shelf seas a truly joint cooperative German-Russian approach which would include joint operations of RV *Polarstern* and Russian research vessels seemed to be most promising for a scientifically successful expedition.

Based on the past fruitful cooperation between Arctic and Antarctic Research Institute (AARI) and AWI in the Antarctic and favoured by the new geopolitical conditions, discussions with AARI started in early 1992 in St. Petersburg on a joint scientific operation in the Laptev Sea. During the "International Workshop on Russian-German Cooperation in and around the Laptev Sea" in May 1993 in St. Petersburg, it was agreed upon to carry out a joint international and interdisciplinary marine expedition to the Laptev Sea area in summer 1993 aboard the German icebreaker *Polarstern* and the Russian hydrographic vessel *Ivan Kireyev.* A participation of German and Russian scientists was stipulated on each vessel.

During ARK-IX/4 Polarstern will carry out a multidisciplinary research programme including physical, chemical and tracer oceanography, remote sensing and sampling of sea ice, biological and geological sampling.

2.2 Physical oceanography (AARI, AWI, SAIC, ZMK)

Background

The modification of water masses and the related thermohaline circulation in the central Arctic Ocean are to a large extent controlled by processes on the Eurasian shelves and their slopes. The formation of the Arctic halocline, saline Eurasian Basin Deep Water as well as the dilution of the Atlantic water layer in the Nansen Basin are expected to be related to the outflow of dense Shelf Brine Water (SBW) from the shelves which is formed by brine release during sea ice production in winter. If its production rate and density is high enough, SBW flows along the shelf bottom towards the shelf edge and sinks along the continental slopes into the central basins where it settles at levels that are determined by their relative densities. The role of the individual shelf areas depends on the amount of fresh water supply by rivers, of the contribution of heat and salt by Atlantic Water, the ice formation rate and the depth of the shelves.

The Barents Sea has a direct Atlantic water inflow, a low river water input and is the deepest among the Eurasian shelves while the Laptev Sea is shallower than 100 m, has a large freshwater input and the admixture of marine water is probably related to an estuarine circulation. The characteristics of SBW formed in the two areas are therefore expected to differ considerably. There are indications that SBW from the Barents Sea contributes to the deep water formation of the Nansen Basin. Results from hydrographic sections carried out during Polarstern cruise ARK VIII/2 and from a mooring programme south of Svalbard show that SBW is involved in the dilution of the Atlantic water layer in the Nansen Basin. The characteristics of SBW formed in the Laptev Sea are unknown, however the nutrient distribution of the Arctic halocline in the Nansen Basin indicate that parts of it originate in the Laptev Sea.

Objectives and programme

The aim of the oceanographic programme is to study the interaction of the shelf water masses, specially of SBW, formed in the Barents, the Kara and the Laptev Sea, with the water masses of the Nansen Basin. This will be done by a series of sections with a dense station grid across the continental slope extending from the western Barents Sea to the eastern Laptev Sea. Some sections are positioned downstream of the main outflow troughs of the different shelf areas in order to determine their respective contribution. Temperature and salinity profiles will be measured by a CTD, dissolved oxygen and nutrients will be determined from bottle samples at maximal 24 depths at each station. Despite their use as tracers, the chemical data are also necessary for the ecological work performed by other groups on board. Continuous measurements with an Acoustic Doppler Sonar Profiler will be done along the whole ship track. They will provide information of frontal currents in the upper 300 m.

The mooring programme to study the outflow of SBW from the western Barents Sea will be continued. Two moorings will be deployed at the southern entrance of the Storfjord of Svalbard where earlier measurements revealed a strong outflow of SBW. Two other moorings will be deployed downstream at the western shelf edge of the Barents Sea in order to allow an estimate of the mixing of the SBW plume with ambient water while spreading along the shelf bottom. The moorings will be equipped with current meters, CTDs, thermistor chains, and a sediment trap and will be deployed for one year.

Two moorings with current meters, thermistor chains, and a sediment trap shall be recovered from the continental slope northeast of Svalbard. They were moored in summer 1991 to record the along-slope propagation of Atlantic Water and Eurasian Basin Deep Water and eventually to detect the flow of SBW. Given a successful recover, the moorings will provide the first long time records from the Nansen Basin.

2.3 Tracer oceanography - Measurement of anthropogenic and natural tracers on the Arctic shelf and slope (IUH, L-DEO)

Scientific background

The extensive continental shelves around the Arctic Ocean play an important role in the formation of subsurface water masses in the Arctic Ocean. Extensive sea ice formation occurs over the shelves and brines that form by salt exclusion during the freezing process can accumulate in depressions on the shelves and then flow into the Arctic Basin. Since these brines form from surface water, they are tagged with anthropogenic tracers that have been proven to be very useful for the investigation of ocean water mass formation and circulation and mixing. These tracers include tritium, the helium isotopes ^{3}He and ^{4}He ^{18}O, ^{14}C, ^{85}Kr and the chlorofluorocarbons (CFCs) F-11, F-12 and F-113.

During the past decade, with ships such as the *Polarstern*, high quality hydrographic tracer surveys were made in the Arctic Ocean interior in 1987 and 1991. Beginning with 1984 several surveys were made across and north of the Fram Strait. Most of the tracers listed above were measured on these surveys. They have been used to investigate the ventilation of the Arctic intermediate waters and have revealed that the most recently ventilated deep water is found in deep boundary currents along the continental slopes forming the western and southern margins of the Nansen Basin and along the Gakkel Ridge. However, to use these data to the maximum, it is necessary to establish the input functions to the subsurface water masses. Thus, it is critical to measure these tracers in the waters that form on the continental shelves and in the water flowing off of the shelves into the Arctic Ocean interior.

Research objectives

The overall objectives of our tracer programme are to investigate the input of shelf water from the Barents, Kara, and Laptev seas into the subsurface water masses of the Eurasian Basin and to investigate the circulation of these subsurface water masses in a boundary current that appears to flow in a cyclonic direction along the continental slope of the Barents, Kara, and Laptev seas.

Specific objectives are as follows:

• Determine the locations of shelf water input to the Eurasian Basin along the Barents, Kara, and Laptev seas continental slope. This will be done by comparing the tracer distributions on the sections across the continental slope.

• Investigate the existence of the cyclonic boundary current that is postulated to flow along the continental slope of the Barents, Kara, and Laptev seas and the transport of newly formed subsurface water masses in this current. The existence of the current will be determined from the temperature and salinity distribution measured by other investigators and the tracer data will be used to identify the recently formed water masses within the current.

• Determine the tracer content of brines on the Barents Shelf. Brines appear to flow into the deep Eurasian Basin at various levels and they seem to be an important endmember of several different water masses. Since they form under conditions of extensive ice cover, they may not be in equilibrium with the atmosphere. To determine the tracer input functions of the brine waters it is necessary to know the degree that they are saturated relative to the atmosphere.

• Investigate mixing between shelf waters and the ambient water into which they flow to form the subsurface water masses observed in the Eurasian Basin. This will be done using a combination of hydrographic and tracer data to determine the proportions in which the various water types mix.

• Estimate time scales of water mass formation and assess mean residence times by determining tracer ages for the various water types and mixtures.

The oceanographic use of some of the tracers used in this study

Anthropogenic tritium was mainly released to the atmosphere by the nuclear weapon tests during the 1950s and the 1960s. The maximum input occurred in 1963 and the man made tritium has surpassed the natural signal by several orders of magnitude. In the troposphere tritium is predominant as tritiated water, and with the natural water cycle it subsequently enters the ocean surface water. From there tritium slowly penetrates into the interior of the ocean. For this reason tritium may be used like a dye marking a water mass as it leaves the ocean surface and propagates into the deep sea.

Due to the radioactive nature of tritium, it can be used, together with it's daughter product, for dating of water masses. With a mean lifetime of about 18 years tritium decays to ^3He. At the ocean surface the helium content of a water parcel is set to equilibrium with the atmosphere, and it is also tagged with tritium as described above. Once this water parcel leaves the surface the gas exchange is inhibited and due to tritium decay, ^3He is enriched relative to ^4He, the primary helium isotope in the atmosphere. So the combined measurement of the $^3He/^4He$ ratio and the tritium content of a water parcel allows calculation of a formal tritium/^3He age. If the water parcel was not altered by mixing with other water containing tritium or ^3He this age is identical with the time passed since it has left the surface.

A very similar concept may be applied using several chlorofluorocarbons (CFCs). These substances include F-11, F-12 and F-113. They all have strong anthropogenic sources and they are used in many industrial processes. They enter the ocean surface by gas exchange and most of the ocean surface is apparently in equilibrium with the atmospheric concentrations. Thus, their concentration in the surface ocean as a function of time can be calculated from their (fairly well known) time histories and their solubilities. Opposite to the tritium input, which subsequently has diminished after 1963, the concentration of the CFCs increased continuously since their first occurrence in the 1930s. However, as they have increased at different rates, their ratios vary in a unique way as a function of time. Therefore CFCs may be used, like tritium/^3He, for dating of water masses. The same holds true for a combination of CFC and tritium data. The CFC/tritium ratio is a powerful tool for dating of water masses which have formed during the past decade, and in combination with the respective concentration it particularly allows for studies of the tracer input.

In contradiction to the tracers mentioned above ^{18}O is a natural stable isotope and it's large scale distribution in the ocean is assumed to be constant in time. Whereas the first group of tracers is transient and may be used for water mass dating, ^{18}O is a so-called steady state tracer (like temperature and salinity) and therefore is helpful in assessing mixing ratios between water masses. ^{18}O is incorporated in the water molecule, and like tritium it takes part in the natural water cycle. Each time water changes it's phase (e.g. evaporation, condensation, freezing) because of the different isotopic composition, mass fractionation will occur yielding to a characteristic distribution of ^{18}O in the state considered. For example continental rain is depleted in ^{18}O and therefore river-runoff into the ocean adds a specific tracer signature to the surface water. This signature, together with other properties of river water (e.g. high tritium concentration, low salinity) may be compared to the tracer distribution prominent in the marine environment and used to distinguish between river- runoff and sea ice meltwater contained in the freshwater component of the Arctic halocline.

Concluding, natural or anthropogenic tracers have a specific signature in the water masses under consideration. These tracers may be stable or they may be radioactive. Their input to the ocean may be transient or their distribution in the ocean may be in steady state. They follow the pathways of the circulation without affecting it. In many cases they carry information independent from the hydrographic data and therefore they are a valuable tool to study oceanographic processes and circulation.

Analytical methods

With exception of ^{85}Kr all the tracer samples will be drawn from 12-liter Niskin bottles mounted to a 24 bottles rosette/CTD system. Extreme care has to be taken that the tracer content in the water is not altered by degassing or contamination with ambient air. Recent investigations show the CFCs and the helium isotopes are most sensitive to degassing and atmospheric contamination and therefore should be drawn from the Niskin bottles first.Then the oxygen tritium, ^{18}O and ^{14}C should be sampled. If all the tracers mentioned are sampled 3-4 liters of water will be used.

To avoid any extraordinary contamination of our samples none of the respective trace substances should be released inside the ship. For the CFCs the ships refrigeration system may be a possible source of trouble. The same holds true for prospective experiments using helium from gas cylinders. One source of possible tritium contamination are luminescent watches that might be tagged with tritium. A more serious source of problems is radioactive material used in biological experiments, e.g. tritium and ^{14}C as label substances for biological measurements. Since the activity of the specimen used is enormous compared to the concentration in the sea water extreme care has to be taken that definitively no radioactive material is transferred outside the isotope laboratory and that none of the equipment used in these experiments comes in contact with the Niskin bottles.

Samples for the CFC analyses will be drawn into 100 cm^3 glass syringes. The Niskin bottles will be equipped with Buna-N O-rings that have been baked in a vacuum oven to reduce the halocarbon blank and with epoxy coated stainless steel springs. The samples will be stored in a bath of fresh running surface water until analyses. The measurement will be performed in a gas chromatograph equipped with an ECD detector. The CFC content of the ambient air will be monitored by analyses of air aliquots obtained from inside and from the bow of the ship.

Due to the very low solubility in sea water, helium isotope analyses are very sensitive to any addition of atmospheric helium. For this reason the samples will be transferred from the Niskin bottle into the helium sample container using a flexible plastic tubing made from low helium permeability material. The helium sample container consists of a copper tube which may be pinched-off at both ends with special stainless steel clamps while rinsing the copper tube with sample water. Care has to be taken that no air bubbles are included in the container during this procedure. The closed container may be stored prior to analysis for a long time. In the home laboratory the samples are degassed in a special vacuum extraction system. The extracted gasses are transferred to a special mass spectrometer, where helium is separated from the other gases and both the $^{3}He/^{4}He$ ratio and the ^{4}He concentration are measured subsequently.

Samples for tritium and ^{18}O analyses are taken and stored in 1-liter glass bottles. Tritium is measured on-shore applying the ^{3}He ingrowth method. For this the sample is degassed and sealed off in a glass bulb. During an appropriate time (usually six months) ^{3}He will ingrow from tritium decay. The measurement of this small gas amount is performed on the same mass spectrometer used for the helium isotopes.

^{18}O is determined in a mass spectrometer as well. Preceding the analysis an aliquot of water is set to isotopic equilibrium with carbon dioxide admitted to the sample and the gas is transferred to the analyzer thereafter.

For ^{14}C analyses the water is transferred from the Niskin bottle into an evacuated glass bulb via a flexible tubing. On-shore the total inorganic carbon contained in the bulb is converted to carbon dioxide and the latter is extracted quantitatively. Afterwards carbon is reduced via combustion and pressed inside a so-called target. The carbon isotope ratio of the material derived is determined using accelerator mass spectrometry (co-operation with ETH Zürich, Switzerland).

^{85}Kr will be obtained from 30-liter Niskins or from tripping five or six twelve-liter Niskin bottles at the same depth. Sixty liters of water are required for each sample. The ^{85}Kr activity will be determined on-shore with a gas counter. The gas extraction step required for this procedure will be performed with a special extraction system directly after the sampling.

Planned work

Tracer sampling is planned at nearly all the stations along the seven sections extending from the continental shelf to about the 3000 m isobath between the Barents Sea and the Laptev Sea. Thus shelf water masses, halocline water, Atlantic Water, and the deep and bottom waters of the Eurasian Basin will be sampled. Furthermore the section across the Frants-Victoriya Trough in the Barents Sea is of special interest. This channel leads to depressions on the Barents Shelf deeper than 200 m and will sample outflow of shelf water or brines from these depressions.

For stations deeper than 2000 m, 18-24 tracer samples will be taken. In general for stations less than 2000 m deep, the vertical resolution will be 50-100 m and will be guided by the water mass structure determined from the CTD profiles.

The tracer team will be able to sample and to process a maximum of 48 water samples per day. We anticipate performing 1000-1200 CFC analyses during the cruise, and collecting about 500 samples each for tritium, helium and ^{18}O. About 30 samples each will be collected for ^{14}C and for ^{85}Kr. The ^{14}C sampling will be restricted to particular shelf water masses, and ^{85}Kr will focus on some specific depth levels on the sections directly east and west from the Kara Sea.

2.4 Studies of the carbonate system (AMK)

The Siberian rivers transport a large amount of fresh water to the continental shelves in the Arctic Basins. As a result of biological productivity and decay on the Tundra this river run-off is high in both total carbonate and total organic carbon content. This in turn allows total carbonate to be utilized as a tracer of the river run-off as the fresh water component in the Arctic Ocean.

During the summer period the shelves are ice free allowing high biological primary production which induces uptake of atmospheric carbon dioxide. In the end of the productive season organic matter accumulates at the sediment surface.

Another consequence of the seasonal ice production is that high salinity bottom water formed as brine is rejected from the freezing ice. This process is important in the formation of most water masses in the Arctic Ocean and provides a chemical signal that can be used in modelling work. The fluxes and transformation of carbon within the Arctic Ocean constitute an essential part in the climatic issue i.e. especially the possible respons to a global warming. In oder to obtain a better understanding of the above processes we will study the carbonate system during ARK-IX/4. This will be a follow up on our earlier work during e.g. ARK-IV/3 and Oden-91.

2.5 Plant nutrients and oxygen as indicators of water masses and production processes (AWI, MMBI, ITT)

The plant nutrients silicate, phosphate, nitrate, nitrite and ammonia together with the oxygen saturation in the water are important indicators of production, water masses and their "fate" are to be studied in detail during the planned ecological investigations along the Eurasian continental slopes (measurements in several layers of the water column along the proposed transects). The identification of Atlantic water masses at the margin of the deep Arctic basins and the study of the influences of the large Sibirian rivers are of specific interest. These investigations are a direct continuation of "SEAS" in the Barents Sea (ARK VIII/2, 1991) and therefore patronized by the European Science Foundation.

Ice-ecologists will be supported by nutrient measurements of ice cores.

Methods

Sampling for nutrient measurements will be carried out parallel to physical oceanography sampling and phytoplankton work using Rosette-water sampler and CDT profiling. Nutrients and oxygen will be measured by standard methods (*Chemlab* Continuous Flow Analyser with modified methods according to Grasshoff et al., ammonia after *Catalano*, oxygen according to the Winkler method).

2.6 Meteorology (AARI)

The state of ice cover (concentration, age etc.) is known to determine the character of redistribution within the under-ice layer of short-wave solar radiation penetration through the water surface. The portion of radiation absorbed at different depths in turn crucially influences on the biological activity in the upper layer (e.g., photosynthesis processes). Close to the marginal sea ice zone as well as in local polynyas and leads, there is a specific vertical circulation facilitating the redistribution of biological productivity from surface layers. The relative area of open water as zones of intensive absorbtion of incoming radiation is mainly governed by the surface heat budget and lateral ice melting.

These processes have brobably a pronounced regional character and - taking into account the features of the hydrological regime - are of different intensity in deep and shallow water regions of the Arctic seas.

At the same time, in order to solve problems related to the description of the coupled atmosphere-biosphere-ocean system, a number of unsettled problems related to the prametrization of thermal interaction processes between the atmosphere and hydrosphere in a partially ice covered sea have to be solved.

Taking into account that *Polarstern* will cover a poorly studied region of the Laptev Sea a number of *in situ* observations combining the above aspects and biological problems will be carried out by measuring the following parameters:

- vertical profile of solar radiation penetrating into the water;
- total incoming short-wave radiation;
- albedo and temperature of underlying surface;
- long-wave radiation of the surface and atmospheric counter radiation;
- ultra-violet radiation;
- vertical profile of the atmospheric boundary layer.

These measurements will contribute to:

- quantitative estimates of vertical redistribution of solar radiation penetrating to the open and ice-covered sea;
- integral estimates of heat accumulation; revealing of statistical relations of biological productivity at different water depths;
- surface heat budget calculations;
- estimation of integral characteristics taking into account .the non-uniformity of underlying surfaces (open water, ice, snow);
- modelling of the atmospheric boundary layer over ploynyas, leads and variable ice concentration.

2.7 Marine ecology and biogeography

The presence of the seasonally ice-covered shelves and permanently ice-covered deep basins and the transition from Atlantic to Arctic water determine the structure of the eastern Arctic marine ecosystems. Previous western investigations concentrated on the marginal seas, the Barents and Greenland Seas, all showing a considerable Atlantic influence. The proposed study will give the opportunity to extend our knowledge of the Arctic Ocean proper, and forms a logical follow-up to the 1991 cruises ARK-VIII/2 ("SEAS" of ESF: Northwestern Barents Sea) and ARK-VIII/3 (ARCTIC'91, deep Arctic basins).

During ARK-IX/4 various environments will be sampled along transects from the shelf down to the deep-sea plains. The data gathered will provide baselines for further Arctic studies in cooperation with Russian scientists and other counterparts.

A main goal is to compare and understand the sources, fluxes and effects of organic matter in the transition zones down the continental slopes of the highly atlantically influenced northern Barents Sea and the northern Laptev Sea, which is under strong continental influence. Moreover, by providing data about the biogeography in these very different environments, a basis for the understanding of ecological alterations related to climatic change will be provided.

2.7.1 Phytoplankton development, sedimentation processes and microbial degradation of organic matter on the sea floor (AWI, ZISP)

The main topic of the programme is the investigation of the development of phytoplankton under the specific hydrographical, chemical and other environmental conditions on the Eurasian shelves, which are strongly related to the amount of terrestrial freshwater input, to exchange processes with the sea floor on the shelf, to ice dynamics and to zooplankton and microbial activities.

Measurements in the plankton will concentrate on the determination of chlorophyll-a, particulate organic carbon and nitrogen, microscopic identifications and counts of phytoplankton species and supplementary laboratory experiments.

Additionally, investigations of the sedimentation of organic matter to the sea floor and its microbial degradation in the sediment on transects down the continental shelf slopes in different sedimentation zones will be carried out. This will be accomplished by studies of the material gathered by short-time deployments of sediment traps, by determination of bacterial biomass in the sediments (microscopy, phospholipid analyses) and by measurement of the activity of different bacterial extracellular enzymes. In feeding experiments the reaction of sediment bacteria to food inputs will be studied.

Methods

Sampling of pelagic material will mainly be done by Rosette water bottles (combined with CTD) at most of the oceanographic stations (at 10 depths, taking 6-8 l of water). Surface phytoplankton may be sampled with a small hand net.

Bottom sediments will be obtained by multicorer in cooperation with the geology and zoobenthos groups on all downslope transects (about five casts on each transect).

Particle flux material will be sampled on a few locations by short-term moorings of sediment traps (up to 3 days; they may be attached to ice floes); and one trap will be moored in the Laptev Sea for a fortnight.

2.7.2 Distribution of zooplankton and its role in the transformation of organic matter (AWI, IORAS, MMBI)

According to our knowledge there is a strong gradient in the zooplankton fauna between the western Barents Sea and the eastern Laptev Sea. The advection of Atlantic elements into the Arctic Ocean via Fram Strait and Barents Sea is to be considered one main factor controlling this distribution. This is not only relevant for the shelf and slope plankton, but also for the deep-sea fauna of the Eurasian basins. This deep-sea fauna is expected to be closely related to that of the Greenland Sea, with which it is connected via the Fram Strait.

In earlier studies a strong gradient of zooplankton biomass from the Barents shelf to the deep Nansen Basin has been found, which was closely related to the inflow of Atlantic Water north of Svalbard. It is insufficiently known, how far this advection is relevant along the Sibirian shelves. Distribution of zooplankton species (including meroplankton) and biomass will accordingly be studied in deep stratified samples along transects across the outer shelves and down the slopes of the northern parts of the Barents and Laptev seas.

To understand the role of zooplankton in the transformation of organic matter in the Arctic Ocean, two approaches will be used:

- The direct measurement of grazing in the euphotic zone, determined by the gut pigment method. These measurements will be supported by the laboratory method of egg production counts and estimations of the amount of fecal pellets produced,
- to use the deep-sea zooplankton fauna as an indicator of the trophic conditions in the overlaying euphotic zone. Assuming the food chain being based on primary production in this overlaying zone, the biomass and trophic structure of the deep living zooplankton community should provide valuable information on the amount of particulate organic matter which is settling out of the euphotic layer during the year. In other words: low sedimentation rates should support only a poor deep-sea fauna. The deep sea-fauna is expected to be closely related to the Greenland Sea zooplankton, which has been studied before and will be used as a reference.

Methods

Zooplankton will be collected by a multiple closing net (multinet) and a bongo net. The multinet (150µm mesh) will provide stratified samples down to 3000 m to study species composition, biomass, abundances and large-scale as well as vertical distribution patterns. The catches of the bongo nets (200 and 500 µm meshes) from the upper 100 m will be split. One part will be frozen on filters for dry weight, protein and lipid measurements, from the other part live animals will be sorted for laboratory determinations of grazing, egg production and defecation. In addition, the state of gonadal development of dominant copepod species will be examined.

2.7.3 Zoobenthos as an indicator of productivity, sedimentation and water circulation in the Arctic Ocean - (AWI, BIO, IPÖ, MMBI, IORAS, ZISP)

A number of main ecological gradients are known from the Eurasian shelves and their continental slopes, exercising great influences on the benthic communities:

- a decreasing Atlantic influence related with a decline in biodiversity and
- a progressing influence of freshwater input, from west to east;
- gradients in productivity and biomass depending on the food input (by direct sedimentation and advection of organic matter), related to water depth, stratification, sea ice cover, water circulation and bottom topography.

From this baseline knowledge the following biogeographical and ecological questions arise and will be tackled during the cruise:

- To which degree can the above mentioned gradients be identified and quantified?
- How are they related to processes in the water column?
- To which degree are the expected large scale gradients super-imposed and, may-be, veiled by small scale environmental variations?
- Which major pathways of energy flow exist in the benthic system and how far do they mirror processes occurring in the water column?

In combination with the deep sea samples of the 1991 cruises, a step forward in the understanding of the differences of community structures of the high Arctic Ocean is expected. A main question will be, how the different shelves (Barents - Laptev) are supporting the deep-sea fauna and whether the relative importance of meiofauna and famine-adapted other animals will increase with depth.

Methods

Sampling of epibenthos will be carried out by dredging with an Agassiz trawl at different depths down the continental slopes. This material will be used for providing a faunistic inventory and elaborations of zoogeographical conclusions, for descriptions of benthic communities and their distributions, and for autecological laboratory studies as well as for studies of chemical contaminations on selected (key) species.

The endobenthos will be obtained at about five depths per slope transect by multicorer, minicorer, and (multi-)box corer parallelly with geological and microbiological sampling. These samples will be used for community analyses and quantitative estimates of macro- and meio-endofauna densities as well as for correlation analyses with sedimentological and other biological (microbial) parameters.

Benthos will also be sampled on board the cooperating Russian vessel *Ivan Kireyev* which is planned to operate predominantly in the ice-free waters of the southern Laptev Sea. This will allow to better understand large-scale distribution patterns in the shelf seas proper and to trace ecological gradients from inshore waters across the shelf down into the deep basins, especially in the Laptev Sea (from the Lena delta to the Amundsen and Nansen Basins). It is also intended to join the RV *Mendeleev* cruise of SIOM to the Kara Sea to get a quasi-synoptic coverage of the whole area from Barents via Kara to Laptev Sea.

2.7.4 Investigation of fish fauna (ZISP, AWI)

The fish fauna along the continental slopes of the Eurasian shelfe seas is insufficiently known. The species composition along the slopes of the Barents and Laptev seas will be compared to work out, whether these areas are as different as the inshore waters of both seas.

All Agassiz trawl catches will therefore be analyzed with regard to fish species and their distribution patterns. If catches are sufficient, material will also be used for experimental work, stomach content (food) studies and analyses of organic contaminants.

2.8 Sea ice remote sensing (AARI, AWI, INTAARI)

Since the launch of SEASAT in 1978 radar techniques have been used to obtain all weather information on the state of the sea ice cover. Especially sea ice motion and concentration have been determined from SAR (synthetic apertur radar) images. Together with visible, infrared and passive microwave observations radar data are utilized to provide data sets which are required for optimization and verification of sea ice models used in climate research. In addition, other sea ice characteristics like surface roughness have been investigated using radar information. With the launch of the european ERS-1 and the Japanese JERS-1 two SAR-sensors are presently available for sea ice research. Although, there is a great potential of the synthetic apertur radar for sea ice research, there are still problems in the interpretation of SAR images, especially the distinction between open water and thin ice is often difficult. Therefore, a small number of aircraft missions with a SAR have been undertaken to help improving the interpretation of ERS-1 SAR data.

For this expedition it is planned to use the INTAARI airborne RADAR system to obtain X-band RADAR images and laser altimeter data during four missions. At the same time visible and infrared data will be taken with the AVHRR-receiving station on *Polarstern*. Furthermore, the optical line scan camera mounted on a helicopter will be used from *Polarstern* to map the small scale sea ice concentration on a quadratic flight pattern of 10nm length. These optical data may then be compared to both the aircraft and satellite Radar images to get an improved interpretation. A coordination of the INTAARI missions and the line scan helicopter flights with ERS-1 overflights is, therefore, necessary. INTAARI missions which do not overlap with ERS-1 overflights are of lesser use.

In addition to remote sensing observations ground truth data on the sea ice floes will be taken by the sea ice/biology group. This includes ice and snow thickness, temperature, salinity and density profiles within the ice, and ice texture.

The main focus of the remote sensing project is to obtain improved information on sea ice concentration from different sensors. On the other hand, it is also planned to retrieve information on sea ice surface roughness from the radar images. In this regard the INTAARI laser altimeter data represents a valuable additional data set. Surface roughness data (statistics of pressure ridges) provides information on sea ice deformation which can be used together with other data to optimize dynamic-thermodynamic sea ice models.

The remote sensing activities, therefore, include:

- Estimation of sea ice type and concentration from a helicopter-borne line scan camera (horizontal resolution 1 m) which will be used to verify satellite observations from ERS-1 SAR and low altitude aircraft measurements obtained by the SLAR system.
- Coordination of the INTAARI radar measurements which are also received on *Polarstern* and ERS-1 overflights. Comparison of aircraft radar images with ERS-1 SAR observations concerning sea ice type and concentration.
- Estimation of sea ice concentration using the NOAA-AVHRR data (visible and infrared) received on *Polarstern* and comparison to radar results.
- Determination of sea ice motion on smaller scales (≈100 km) from radar images and on larger scales (≈1000 km) using AVHRR observations.

2.9 Sea ice studies

The sea ice of the Arctic Ocean covers between 7 (summer) to 14 Mio km^2. It consists mainly of multi-year ice floes with more than 2 m in thickness. Beside its enormous effects on physical processes like radiative and conductive heat transfer between ocean and atmosphere, the ice itself is a unique habitat for Arctic organisms. Recent estimates have demonstrated that the ice algae can contribute up to 35% of the total Arctic Ocean primary production. In shelf areas, planktonic organisms like herbivorous copepods use the high standing stocks of ice algae to survive the Arctic winter. Furthermore, sea ice constitutes a geological agent of prime importance, with the ice acting as a conveyor belt transporting sediment from the shelves to the main ablation areas.

The Laptev Sea plays a significant role concerning the ice drift in the Arctic Ocean. It is the root area for the so-called Transpolar Drift, where in autumn and winter new pack ice is formed and introduced into the Transpolar Drift. Thus the Laptev Sea is an ideal region for sampling of young Arctic pack ice to get insights into both physical and biological processes dealing with the formation of Arctic sea ice and following successive processes.

2.9.1 Sea ice physics (AWI, USGS/GEOMAR)

General characterization of sea ice properties

The thickness, structure and properties of the Arctic sea-ice cover constitute important variables in the global climate system. Numerical model experiments and previous expeditions, including the ARK-VIII/3-cruise into the central Arctic Basin in 1991, have indicated that the thickness distribution and the characteristics of the multi-year ice cover are very sensitive to processes occurring during the melt season. As of yet, these processes are poorly understood, with a distinct lack of field data to assess the validity of modelling approaches. This regards the thickness evolution of multi-year ice through thermodynamic growth and the effects of climatic change as well as the transport of particulate and dissolved matter from the shelves to the deep sea. Of particular interest in this context are modification and thickness changes induced in sea ice formed on the Eurasian shelves and subsequently introduced into the Transpolar Drift Stream. The expedition ARK IX/4 represents an excellent opportunity to study the transition of first- to multi-year in the source areas. Furthermore, ice-core studies allow us to draw conclusions about the evolution of the ice cover on the shelf along the cruise track. The studies to be undertaken during the expedition tie in closely with the programmes of the other sea ice groups (remote sensing, meteorology, biology, sedimentology) and are a direct continuation of the work carried out in 1991 in the central Arctic.

During the expedition, it is planned to keep a continuous log of ice conditions through hourly observations and photo- and video-documentation from the ship's bridge. During ice stations, thickness drilling will be carried out in level ice (Fig. 2). At selected sites these will be compared to indirect measurements employing an electromagnetic, active-inductive technique which has been used successfully on a previous cruise. Based on the thickness profile, ice cores will be obtained. In a cold lab on board the ship, cores will be sectioned for stratigraphic analysis of ice texture and subsequent sampling for measurements of temperature, density, and salinity, with further analyses, including stable-isotope measurements, carried out at the Alfred-Wegener-Institut. Detailed analysis of the ice microstructure will provide information on dynamic and thermodynamic growth processes and their importance for ice growth. Furthermore, sampling of melt ponds for stable isotope-analysis will allow estimates of redistribution of meltwater and its contribution to level-ice thickness (Fig. 2).

Owing to the importance of solar radiation in determining ablation during the summer months and as ground-truth information for satellite remote sensing, measurements of the spectral albedo of different ice surfaces (bare ice, melt ponds, dirty ice, brown ice) will be carried out. In particular, the relation between ice microstructure and impurity content on the one hand, and spectral albedo on the other will be looked at through detailed ice-core analysis. These spot measurements will be augmented by helicopter surveys using line-scan and video cameras (in collaboration with remote-sensing group) to allow quantitative estimates on the regional distribution of different ice surfaces.

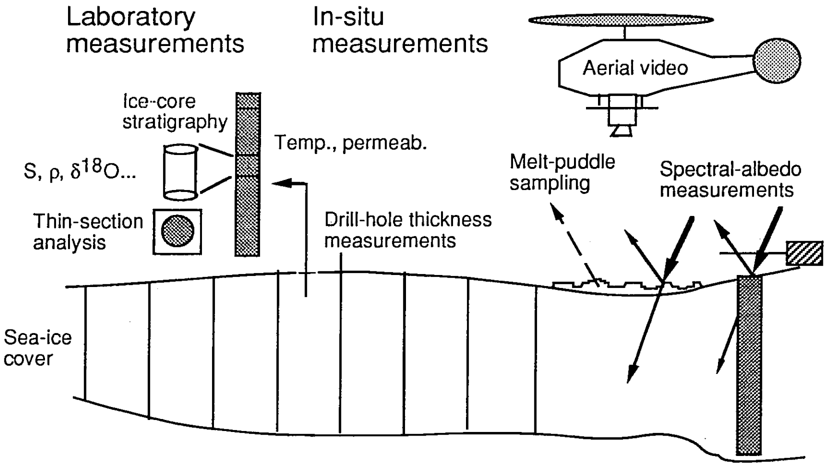

Fig. 2: Overview of *in situ* and laboratory measurements planned as part of the sea-ice physics programme during ARK-IX/4.

2.9.2 Sea ice biology (AWI, IPÖ)

General

Recent investigations have shown considerable differences in both total biomass and community structure between pack ice samples from shelf areas and samples from the central Arctic Ocean. Our main aim during this expedition will be to characterize the sea ice community of diffe rent types of sea ice in its main formation area in relation to the phy sical properties of their habitat.

The main objectives of the biological studies are:

- To generally characterize sea ice properties such as ice coverage, ice types, snow cover, temperature, and total salinity.
- To characterize environmental conditions inside the brine channels (shape, volume, nutrients, salinity)
- To investigate biomass and diversity of the sea ice community including bacteria, algae, protozoa and metazoa.
- To investigate migration of sea ice organisms.
- To investigate cryopelagic coupling between the sea ice and the pelagial by under-ice fauna.
- To characterize communities of melt water ponds.

Conditions inside the brine channels

A special technique for the investigation of the brine channel system was developed for Antarctic sea ice. During this cruise, it will be used for the first time for Arctic sea ice. The interstitial system of brine channels and pockets contains the habitats of sea ice organisms. The frequencies of brine channels and pockets per unit of volume of sea ice, their dimension, and degrees of ramification in different ice types will be investigated using a cast technique. After removal of brine by centrifugation at *in situ* temperatures, a water soluble resin will be deployed to penetrate drained brine channels of ice. Because of the toxicity of the resin, this work has to be done at the AWI. After polimerization of the resin the hardened casts can be mounted for microscopical analysis. This was also done with sea ice from the Antarctic and the results will be compared.

In order to gain a more realistic picture of chemical status in sea ice, we will determine the nutrients and the salinity in melted ice core sections, in extracted brine and in surface water. We will carry out these measurements with both, new formed sea ice and older ice flows in this region. These results will be compared with data from the Weddell Sea too, which were obtained by the same methods.

Biomass and diversity of sea ice communities

Organisms found inside Arctic sea ice cover a wide range of sizes (from 0.2 μm up to 1000 μm) and abundances (from concentrations <1 l^{-1} up to concentrations of 10^7 ml^{-1}). Thus different techniques have to be used to obtain total biomass estimates. The smallest and most abundant organisms (bacteria, auto- and heterotrophic flagellates) will be counted using the fluorescence microscopy technique directly on bord. Larger organism like ciliates and metazoans (mainly nematods, turbellarians, copepods) will be life counted under a dissecting microscope on board. Special fixation techniques (like e.g., Bouin fixation) will be used to obtain samples for subsequent taxonomical studies.

Autecological investigtions will start on board *Polarstern* during the cruise and will continue in the cold laboratory of IPÖ Kiel. Here life observations of the metazoans, studies of their behaviour, their adaption to changing temperature and salinity regimes and their reproduction cylce will be main topics of interest.

Migration of sea ice organisms

Sea ice is pervaded by an highly branched brine-channel system which connects different horizons in an ice flow together. Sea ice organisms possibly migrate along these channels. We intend to observe this migration with a video system mounted on a L-shaped frame in the under ice layer and in the ice with an endoscope.

Cryopelagic coupling

Investigations in the Arctic and Antarctic have demonstrated that a variety of pelagic organisms is able to use the ice algal biomass as temporary food source. Our interest focuses on the mesoplankton organisms dominated by crustaceans, mainly copepods. Samples will be taken by an under-ice pumping system and in addition an under-ice net. Specimens of the obtained material are used for studies of the gut content via gut fluorescence analysis. Video systems will be used to study the distribution and the behaviour of these organisms in their natural habitat. Parallel to the ice sampling, the pelagic community structure will be studied using Bongo nets and multinets from the upper 100 and 500 m, respectively.

Melt pond communities

During summer more than 60% of the sea ice surface are covered with melt ponds of different salinities. Samples will be taken from melt ponds for the analysis of physical, chemical and biological parameters to get insights into the dynamics of biological changes in this habitat.

Sampling of sea ice

Samples will be obtained by various sampling strategies:

- by direct sampling of melt water ponds and snow;
- by ice coring with a 3" and 4" CRRELL-type ice auger;
- by under-ice sampling through drilled ice holes by a pump system and under-ice net;
- by optical investigations using an under-water video system and endoscopes.

Sampling and investigation strategies for ice works are shown in Figure 3. To compare the results of each ice core we will auging the ice cores as close as possible. The ice cores will be treated according to the diagramm shown in Figure 4.

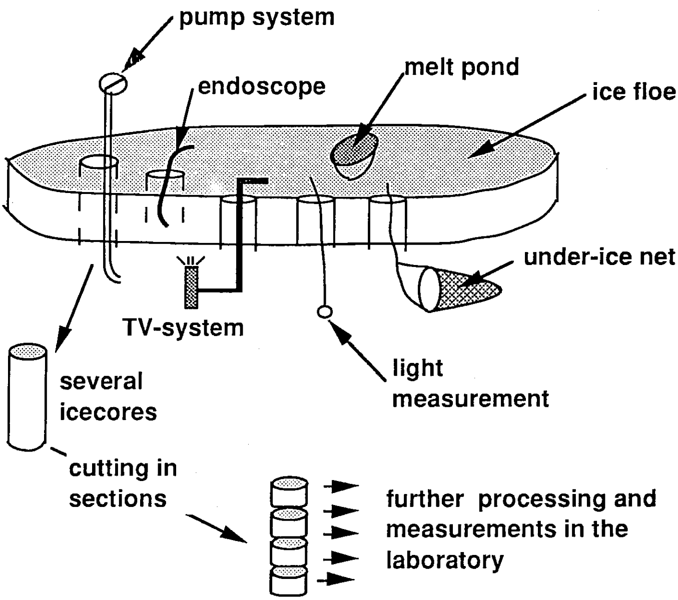

Fig. 3: Sampling scheme for sea ice investigations

Number	processing	measured parameters
1	storage at -30°C	file copy
2	direct melting of ice sections after stratification cutting	texture,volume, salinity, chlorophyll-a, phaeopigments, nutrients, DOC (disolved organic carbon)
3	brine extraction and melting	brine: salinity, volume, chlorophyll-a, phaeopigments, nutrients, DOC. brine-free core sections: shape and structure of brine channels (cast technique, Weissenberger et al. 1992), salinity, volume, chlorophyll-a, phaeopigments, DOC.
4	melting in filtered seawater	abundances of sea ice organisms (algae, protozoans and metazoans)
5 and more		for special purposes

Fig 4: Diagram for processing ice cores

2.9.3 Sediments in Siberian pack ice (USGS/GEOMAR)

Observations and measurements of sediments in pack ice, and of their mode of occurrence, will be made both during transit and at all stations within the pack ice. Considering the overall ice motions in the Transpolar Drift, this planned work gains special significance since it will expand our knowledge from ablation areas right to the heart of Siberian ice production regions. Two years downdrift, where most shipboard observations so far were made, most sediments are found concentrated on the ice surface in form of wind-ablatian patches, snow drifts, general melt - ablation horizons, meltwater ponds, in drainage channels, or in cryoconite holes. This mode of sediment occurrence, a result of aging and ice/sediment metamorphism, tends to mask evidence for the original sediment entrainment mechanisms and sediment sources. Even shallow-water, benthic, calcareous microfossils seem to dissappear from slightly acidic conditions on wet sea ice sufaces. Past observations of surface concentrations of fine sediment therefore have led to possibly erroneous speculations of wind transport from the Siberian continent onto the seasonal fast bordering the continent.

Studies in North American ice source regions, however, suggest that most sediment contained in sea ice was entrained from shallow (<30 m) shelf surfaces, in a process called suspension freezing. Near source regions and before metamorphosis, the mechanism can still be recognized by the occurrence of turbid ice. Turbid ice contains evenly disseminated, mainly fine sediments in a substantial layer of granular first-year ice. We expect to encounter younger, and more turbid ice in the 1993 operations area than in any of the past study areas farther downdrift.

During ARK-IX/4, the ice will not only be studied for any clues as to entrainment mechanisms and sediment sources, but also with the goal to quantify sediment load per unit area and volume of ice. This is to be done not only locally for each station, but will be extrapolated to large regions between stations through shipboard and aircraft observations. The total spectrum of reflected visible light will be measured at sites where the sediment content in ice and snow has been quantified in ppm/L of meltwater. The purpose of combined sediment load and spectral radiation measurements is to attempt tracking regions of dirty ice via remote sensing throughout the entire Transpolar Drift from source to ablation area. The results will also be used to calculate changes in the heat budget of sea ice as a function of sediment load.

Close collaboration is planned between parallel studies of ice physical and structural properties, and of biological ice communities. This collaboration will be through the sharing of logistics and work on stations, but also through joint interpretation of data. We anticipate that our collaborative ice studies can be integrated with aircraft radar imagery to be recorded by Russian colleagues.

For sampling of "dirty" sea ice, ice coring and surface sampling of floes is planned at all stations in the northern Barents Sea and the Laptev Sea. Helicopter support is necessary to cover broad areas of the Arctic pack ice. Ice coring equipment provided by GEOMAR and AWI will be applied. 4" ice cores and snow samples will be melted aboard *Polarstern* in order to derive sediment concentrations by vacuum filtering the ice samples and calculating the weight of sediment per litre ice. Observations on the distribution of "dirty" ice patches will be conducted along route.

2.10 Marine geology (AWI, AWI-P, GEOMAR, MMBI)

Main research interest focusses on a high resolution study of changes in paleoclimate, paleoceanic circulation, paleoproductivity, and sea ice distribution at the Eurasian continental margin during Late Quaternary times.

The Arctic Ocean is of outstanding interest for geosciences, which will investigate the Arctic Ocean's influence on changes in global climate and oceanography. During this year's expedition, the marine geology programme will focus on the investigation of sediments from the Eurasian continental margin area.

Because of generally high sedimentation rates typical for the shelf/slope environment (especially in the Laptev Sea area), high-resolution studies of Quaternary climatic and oceanographic variations in the Arctic Ocean and their relationship to global climate change will be possible. Main research objectives will focus on the reconstruction of the depositional environment along the Eurasian continental margin and its change through time. Here, the evolution and spatial variability of an Arctic sea-ice cover during glacial/interglacial cycles will be studied in detail.

The inflow of relatively warm North Atlantic water masses via the Fram Strait to the Arctic Ocean has a severe impact on sedimentation, productivity and ice distribution. When this inflow started, whether it spatially and temporally varied, how far it can be traced along the Eurasian continental margin and how it influenced the glacial/interglacial evolution is one main subject of our studies. For the reconstruction of depositional environment, paleoceanography and paleoclimate, various sedimentological, stratigraphical, mineralogical and geochemical methods will be applied (Fig. 5).

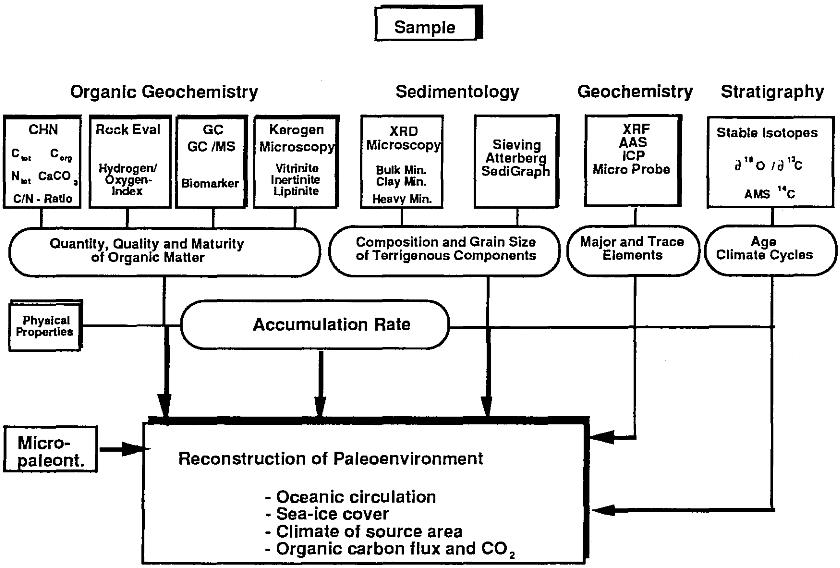

Fig. 5: Methods, which will be applied for the reconstruction of depositional environment, paleoceanography and paleoclimate

2.10.1 Stratigraphical investigations (AWI, GEOMAR)

As a basis for all further reconstructions of paleoenvironmental change, a high-resolution stratigraphic framework for the Eurasian continental margin area has to be established. The Arctic Ocean's relative poverty in microfossils requires a combination of different stratigraphic tools: oxygen and carbon stable isotopes, absolute age dating, biostratigraphy, magnetic susceptibility, and correlation to other existing (dated) Arctic Ocean records. Narrow sampling of the upper sedimentary column will provide a high-resolution stratigraphy, which will elucidate short and long-term variations in the Arctic depositional environment.

2.10.2 Paleontological investigations (AWI, GEOMAR)

The modern distribution of foraminifers and other microfossils (i.e., calcareous and siliceous nannofossils) in relation to the modern Arctic environment (bathymetry, watermass properties, sea ice distribution, availability of nutrients, etc.) will be precisely described. Based on these results, an actualistic model can be derived which will subsequently be applied to the fossil record and allow to reconstruct paleoenvironmental changes (such as watermass properties, surface water productivity etc.) during late Cenozoic glacial/interglacial cycles.

Main interest focusses on the distribution of benthic and planktic foraminifers in marine sediments, which is significantly influenced by oceanographic (inflow of Atlantic Water masses) and environmental factors (e.g. bathymetry and availability of nutrients) and therefore, is commonly used as a proxy for environmental changes. Especially shallow water benthic foraminiferal tests found in Central Arctic Ocean deep-sea sediments may serve as indicators for sea ice transport and will be investigated in Eurasian shelf and slope sediments.

2.10.3 Organic and inorganic-geochemical investigations (AWI, AWI-P, GEOMAR)

Mechanisms controlling the organic carbon budget such as surface water productivity may affect the concentration of atmospheric CO_2 (i.e., during times of increased phytoplankton productivity the ocean may act as a sink for CO_2) and thus, may serve as important controlling factors for the global climate. Since no such data are available to us from the Eurasian continental shelf and slope areas, where presumably large amounts of organic carbon are stored, detailed organic-geochemical studies will be performed in order to reconstruct long-term as well as short-term (Milankovitch-type) changes in these paleoceanographic variables. Corresponding results are absolutely necessary for quantitatively modelling climate change on a global scale.

Main emphasis will be laid on the quantification of the marine and terrigenous organic carbon flux (accumulation rates) in the Eurasian shelf, slope and deep-sea environments. Its spatial and temporal change and its relationship to changes in sea ice distribution, river run-off and paleoclimate is of fundamental importance for paleoenvironmental reconstructions. The amount, composition, and maturity of the organic carbon fraction (i.e. (sub-) recent marine and terrigenous organic carbon, reworked fossil material like coal) will be determined.

Furtheron, an attempt will be made to characterize the mechanisms controlling organic carbon deposition such as surface water productivity caused by fluvial nutrient supply and ice edge blooms, and/or fluvial supply of terrigenous material. Modern water mass properties as well as estimations of the paleo-productivity will be derived from organic carbon data.

Inorganic geochemical tracer (e.g., barium in sediments) and $\partial^{13}C$-measurements within the organic material as well as in benthic foraminifers will support the attempt to reconstruct paleo-productivity. Paleo-water temperatures will be reconstructed from both inorganic (e.g., magnesium in foraminiferal tests) and organic (e.g., ketones) geochemical tracers. Main, minor and trace element analyses of bulk sediments focus on the characterization of sediments. The geochemical comparison of shelf and slope sediments with deep-sea deposits is applied to inform about transport mechanisms and source areas for pelagic sediments.

Heavy metal distribution patterns in sediments from shelf, slope and deep sea areas will indicate recent environmental pollution and oceanic circulation patterns. In this line, pore waters (pH-measurements, concentration profiles of oxygen, nitrate, sulfate, phosphate, ammonium, sulphide, iron, manganese, silica, calcium, magnesium, strontium, barium) will be investigated to study early diagenetic processes within the sediments and to quantify a number of early diagenetical fluxes. The degradation of organic matter creates numerous secondary reactions influencing the biogeochemical cycle of nutrients and elements and the development of new minerals. Solid phases (heavy metals), thus, will also be investigated geochemically within the sediment columns.

Methods to be applied are elemental (CHN) analysis, Rock Eval pyrolysis, carbon stable isotopes of organic matter, kerogen/coal petrography, and gas chromatography. For barium and heavy metal determination, X-ray fluorescence analysis and atomic absorption analysis (AAS, ICP) is planned. Magnesium analyses in foraminiferal tests will be performed by electron-microprobe-analysis.

2.10.4 Sedimentological and mineralogical investigations (AWI, GEOMAR, MMBI)

The terrigenous sediment supply from the Eurasian Continent to the marine realm, its transfer from the shelf via slope to the deep-sea, and its variation between glacial and interglacial times is main topic of the sedimentological working-group. The Laptev Sea is believed to be the source area for the main portion of sediments entrained into sea ice and transported via sea ice (e.g., Transpolar Drift) across the Arctic Ocean. The river Lena is one of the most important contributors for the siliciclastic sediment budget in the entire eastern Arctic Ocean. The distinct glacial-interglacial changes in siliciclastic/fluvial sediment supply have to be quantified (flux rates), qualified, and correlated with the deep-sea records. The correlation between data derived from shelf and upper slope areas close to the river mouth with data from the pelagic central Arctic Ocean area may provide information about the evolution of paleoceanographic circulation patterns, extent of sea ice (and icebergs), and the paleoclimate of Eurasia.

The inflow of North Atlantic water masses via Fram Strait along the Eurasian continental margin is presumably reflected in mineralogical and sedimentological parameters (e.g., clay mineralogy, coarse fraction) and can subsequently be temporally and spatially reconstructed with sedimentological methods.

Sedimentological and mineralogical investigations will include analyses of sedimentary structures (X-ray radiographs), grain-size distribution, qualitative and quantitative sediment composition (e.g., X-ray diffractometry, light microscopy, coarse fraction analysis). Systematic studies on the mineralogical composition (e.g., heavy minerals, clay minerals) of shelf, slope, deep-sea and sea ice sediments may provide evidence for active entrainment of terrigenous material into the Arctic sea ice cover, its transport (oceanic currents, gravity flow, sea ice transport), and release. The river run-off from the Asian continent and corresponding surface-water salinity changes in space and time will be reconstructed from the stable oxygen and carbon isotope record.

2.10.5 Physical properties (AWI, GEOMAR)

Physical properties in Arctic Ocean sediments (e.g., wet/dry bulk density, water content, porosity) are basic parameters, which will be performed routinely aboard. These parameters can be significantly influenced by oceanographic changes, as could be shown for Arctic Ocean deep-sea sediments. Here, drastic and abrupt climatic changes (e.g., deglaciations) are reflected in pronounced variations of physical properties.

Magnetic susceptibility is routinely measured on whole cores but can also be determined on single subsamples from box samplers aboard *Polarstern* and/or in the home laboratory. The susceptibility is a measure of the amount of magnetizable compounds in the sediments. Generally, the downcore variation of amplitudes is used as an indicator for the variation of biogenic versus terrigenic compounds. Susceptibility logs may provide excellent tools for lateral core correlation and can also be used for stratigraphic interpretations.

Measurements will be performed to determine sediment accumulation rates, to elucidate relationships between physical properties and paleoceanographic processes, and to correlate physical properties to high-resolution seismic records (PARASOUND).

2.10.6 PARASOUND-sediment echography (AWI)

The ship-mounted PARASOUND sediment echosounder will be in operation along all cruise tracks. The system generates two primary frequencies between 18 and 23.2 kHz transmitting simultaneously in a narrow beam of 4° (NBS-signal). As a result of interaction of the primary frequencies in the water column, a secondary parametric frequency between 2.5 and 5.5 kHz is created. The latter is suitable for subbottom profiling of the upper tens of metres of the sediment column with a vertical resolution of 5-10 cm whereas reflections from the NBS signals allow a precise survey of the sea surface morphology up to 10,000 m water depth.

The geometry of subbottom reflectors provides important information for the selection of sediment sampling sites. Reflection data recorded by PARASOUND is simultanously digitized by the PARADIGMA system and stored on tape for later seismic processing. The interpretation of subbottom profiles recorded along tracks parallel and perpendicular to the Sibirian shelf edge, will give a 3-dimensional view of the topmost sediment cover which provides an important stratigraphic framework for lateral linking of sedimentary data from cores. This will then allow a characterization of the physical boundary conditions affecting sedimentation and erosion along the Eurasian continental margin and their variation in space and time. In particular in the Laptev Sea, relatively large amounts of continentally derived particles are transported from the river Lena over the continental shelf into the deep sea. The distribution pattern, and thus the subbottom geometry, are expected to be the result of interfingering of processes such as formation and drift of sediment laden sea ice, currents along the sea floor as well as neotectonic faulting of the

Laptev shelf. The latter is related to the extension of the active North American - Eurasian plate boundary from the Gakkel Ridge into the Lena delta area, wheras the former is strongly dependent on climatic and subsequently sea-level conditions.

2.10.7 Sediment sampling procedure

In order to reach the major objectives of the marine geology programme, undisturbed sediment surface and subsurface samples as well as long, undisturbed sediment cores will be obtained along profiles perpendicular to the Eurasian continental margin from the shelf edge and upper slope down to the deep sea. Coring activities will concentrate on the northern Barents Sea and Laptev Sea continental margins. In the Laptev Sea area, a complementary marine geology programme will be performed on the shelf itself using the Russian RV *Ivan Kireyev*. Coring positions have to be selected carefully in order to avoid areas of sediment redeposition (turbidites, slumps) and erosion. Site selection will be supported by detailed bathymetric and shallow sub-bottom profiling systems. Aboard *Polarstern*, multicorer, giant box corer, kastenlot corer, gravity correr and/or piston corer will be applied. The data from this expedition will be compared with already existing data sets from the Arctic Ocean (ARK-IV/3, ARCTIC'91).

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Lagerhalter	K. Müller
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Stewardess	M. Hoppe
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2. Steward	Ch. L. Yu
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The Laptev Sea Expedition:

Transdrift I

on board RV "IVAN KIREYEV

3 Research programme of RV *Ivan Kireyev*

3.1 Introduction

Main interest of the scientific investigation in the Laptev Sea is
- to understand the recent and past sedimentary environment of this shallow and wide Siberian shelf sea, and
- to understand the modern oceanographic regime and its related biologic processes.

A recurring polynya and its specific geological and biological features make the Laptev Sea one of the most interesting areas for marine research. It is assumed that during winter the Laptev Sea polynya is one of the most important source areas for the sea ice of the Siberian branch of the Transpolar Drift. Hence, this Siberian epi-continental sea is a key region for the understanding of the global climatic system.

In the course of a two-ship expediton of the research vessels *Polarstern* and *Ivan Kireyev,* detailed investigations will be carried out including oceanography, biology, marine geology, and organic/anorganic tracer geochemistry. The target area of the Transdrift I expedition aboard the Russian vessel *Ivan Kireyev* is the seasonally ice-free southern Laptev Sea that will be investigated following the stations of the Russian oceanographic monitoring programme with some additional geological key stations (Fig. 6).Transdrift I will start in Arkhangel'sk on August 1, 1993. Passing the Northern Sea Route, we expect to reach the survey area on August 12, 1993. Work in the Laptev Sea will take 45 days followed by a 12-day-passage back to Arkangel'sk. The time schedule depends extremely on the ice conditions. The joint expedition programme will be carried out in close cooperation with:
- Arctic and Antarctic Research Institute (AARI), St. Petersburg
- All-Russian Research Institute for Geology and Mineral Resources of the World Ocean VNIIOCEANLOGICA, St. Petersburg
- GEOMAR Research Center for Marine Geosciences, Kiel
- Alfred Wegener Institute for Polar and Marine Research (AWI), Bremerhaven and Potsdam.
- Institute for Marine Science (IFM), Kiel
- Institute for Polar Ecology (IPÖ), Kiel

3.2 Oceanographic and Hydrochemical Investigations (AARI)

S c i e n t i f i c b a c k g r o u n d

The Laptev Sea has its characteristic oceanographic features by which it contrasts with other seas of the Arctic region. Water structures in the eastern part of the Laptev Sea are quite different from those observed in its western part. In the latter the Arctic surface and Atlantic deep-water prevail in contrast to the eastern part were the continental water discharge plays a major role in the formation of the hydrological regime. The presence of an extensive area of river water occupying the largest part of the sea area together with the presence of a more or less stationarily extensive polynya in the north-eastern part of the sea present a unique situation which makes the Laptev Sea one of the most interesting environments to study.

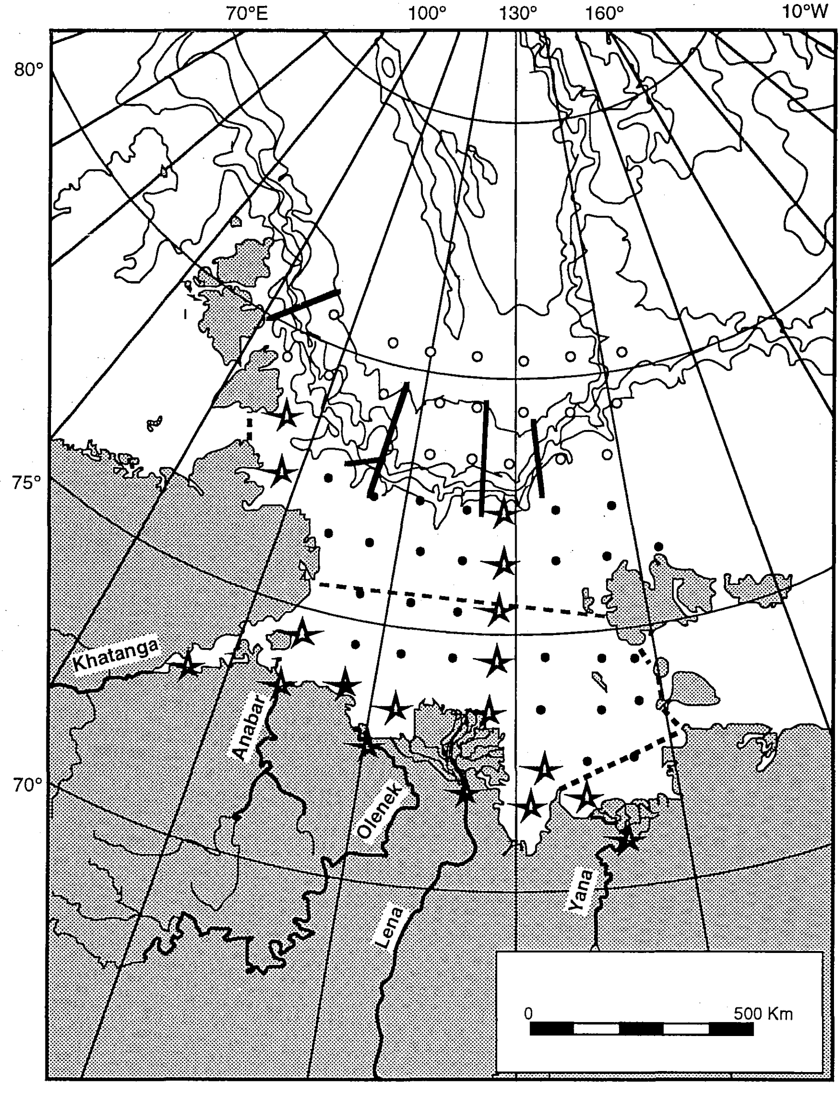

Fig. 6: Working area of Transdrift I expedition with the *RV Ivan Kireyev*

▬▬▬ Planned sampling sections of *FS Polarstern* ARK IX/ 4	O AARI long-term monitoring stations
▪▪▪▪ Oceanographic profiles AARI	• planned coring stations *Ivan Kireyev* TRANSDRIFT I
	★ planned key stations *Ivan Kireyev* TRANSDRIFT I

Main field methods for the investigation of the oceanographic regime are annual large-scale sea surveys with the deployment of buoy observation stations. The presence of extensive transformation zones of the water masses of different origin, significantly varying in their characteristics, require to conduct special field experiments in the frontal zones.

The data on the hydrological regime of the Laptev Sea have been recorded by Russian scientists since the 30s, which resulted in an extensive hydrometeorological data base.

Working programme
All observations will be made by means of sounding instruments of the CTD type down to the bottom. In conjunction with the hydrographic investigations, a profiling transmissiometer will be mounted on the CTD to determine the relationship between suspended particulate matter and the various water masses. In the southern part of the sea (south of 75° 30' N) the distance between the stations is about 30 nautical miles, in the northern part 60 nautical miles. In case of a favourable ice situation the oceanographic survey of the western part of the East-Siberian Sea will be made. In the vicinity of the ice edge zone, the spacing between hydrological stations will be closer.

During the survey the oxygen and silica content will be determined at the standard levels at each oceanographic station of the section. At the stations near the ice edge the oxygen and phosphate concentrations are measured at 0.5 and 10 m water depth. The determination of phosphates, nitrates and nitrites is carried out at the standard levels at these oceanographic stations at which the hydrobiological observations will be made. The observation of the radionuclide level in sea water (^{137}Cs and ^{90}Cr) is also made.

3.3 Weather observations (AARI)

A number of standard hydrometeorological observations and actinometric observations will be carried out during the expedition in accordance with the "Methodical instructions of MGO".

Also, additional meteorological observations will be carried out:
- of the penetrating short-wave radiation
- of the long-wave reverse radiation of the atmosphere;
- of the underlying surface temperatures;

All kinds of additional observations are carried out during the work at all sections, networks and micropoligons.

3.4 Biological investigations (IPÖ)

Background
The large and shallow shelf region of the Laptev Sea is supposed to be characterized by a distinct coupling between the sea ice biota, pelagic zone, and the benthos. On this cruise a first faunistic inventory of all three compartments is

planned. Furthermore, the faunal zonation as well as the distribution and composition of specific species associations in relation to environmental parameters will be investigated. Reproductional, feeding-ecological and ecophysiological studies of dominant species will help to discuss the adaptations of the organisms to the typical environmental characteristics of the Laptev Sea.

Phytoplankton

In order to estimate phytoplankton biomass and to relate biological and hydrographical measurements, vertical profiles of size fractionated Chlorophyll a will be obtained by samples with a Nansen water sampler. Quantitative analysis of the phytoplankton populations in the Laptev Sea will be carried out using the "Utermöhl" method. Additional phytoplankton samples for qualitative species composition will be taken with a hand net (mesh size 20 µm).

Zooplankton

Biomass and species distribution of zooplankton will be determined from Bongo net samples. At selected stations, especially in the region of the fresh water plume of the Lena river, the vertical distribution will be studied in detail using a multinet for stratified sampling. For the determination of the grazing activity of herbivorous zooplankton (e.g. copepods), subsamples will be frozen at -80°C for gut contents and gut fluorescence investigations, respectively. Other samples will be collected for lipid analysis to assess the physiological condition and the nutritional history of the animals.

Experiments will be performed with dominant copepod species in order to investigate the reproductive and feeding biology (egg production, gut contents) under various food and salinity conditions.

Benthos

For the determination of the macro and megabenthos various sampling gears will be used. A small Agassiz trawl (1m opening) and a box corer will catch the material for the determination of the faunistic inventory of the benthic communities. Underwater photography will give *in situ* images of the undisturbed epibenthic habitats. In combination with the corer and the trawl catches, the photographs will provide some information on absolute abundances of epibenthic species as well as their small scale dispersion patterns.

The second focus will be placed on autecological studies of selected key species. The investigated species will comprise different life styles and feeding guilds and will consist of dominant species. Growth and production will be interpreted in combination with the measurements of metabolic performances and will give information of the energetics of polar organisms. Analyses of stable isotopes ($\partial^{13}C$, $\partial^{15}N$) of the digestive system of benthic and pelagic organisms will give information about the trophic relationships of the benthic compartments and between benthos, and pelagic zone as well as sea-ice biota.

3.5 Geological Investigations

3.5.1 The Role of River Run-Off for the Sedimentary Environment of the Laptev Sea (GEOMAR, IFM)

Background

Previous studies have shown that large ice areas of the Transpolar Drift transport significant loads of marine sediments originating from surrounding shallow Siberian shelf regions. Sedimentological and ice-drift data underline the role of the Laptev Sea as a key region for the origin of sedimentary inclusions. Even though, the important regions within the Laptev Sea for the entrainment of sediments into the ice of the Transpolar Drift are still unknown. However, it is reasonable that river run-off from the Asian continent plays a major role. Beside the study of the modern sedimentary environment, emphasis of research activities will be laid on investigations of the paleoenvironment to evaluate the influence and feedback of this region in changes of the global climatic and oceanographic system.

A new approach to the investigation of sea ice sediments and their origin is a detailed sedimentological and geochemical characterization of sediments from all main river systems that flow into the Laptev Sea. We assume that large portions of the fresh-deposited river sediments are resuspended during autumn and winter storms and incorporated into the newly formed ice. Due to that mechanism, not only sediments but also anthropogenic pollutants like PCB's and heavy metals might be brought to the ice. Beside the sedimentological tracers like clay mineral assemblages and geochemical composition, the source localization of these different groups of pollutants in the inner Laptev Sea might be a good working tool for a more focussed investigation of sea ice formation and its pathways through the Arctic.

Working programme

Gravity cores and box cores will be taken systematically from selected sites in the Laptev Sea (Fig. 6). Additional sampling of water and suspended particulate matter will be carried out. Water sampling for multielement analysis, PCB's and tracer oceanography will fulfil the high demand for contamination-free sampling. During the *Ivan Kireyev* expedition samples for detailed sedimentological, stratigraphical and geochemical investigations including:

- clay mineralogy, grain size distribution, content of organic and anorganic carbon, heavy mineral assemblages, physical properties,
- micropaleontology, sediment accumulation rates,
- multi-element trace-analysis and PCB determination in the water and sediments, will be carried out

3.5.2 The Laptev Sea polynya and its effects on sedimentation (GEOMAR).

Scientific programme

The winter ice cover of the Laptev Sea is characterized by the occurrence of an approximately 1800 km long, narrow zone of open water (polynya) on the shelf. During winter polynyas are areas of intensive ice formation, salinity increase and convection within the water column. The polynya is maintained open by off-shore winds that carry away recently formed ice. Suspension freezing within the water column beneath the polynya and subsequent incorporation of the particulate matter into the ice is also an important entrainment mechanism for sediments in sea-ice. From there, the Laptev Sea polynya and the sea ice are significant geological features that control recent sediment dynamics on the shelf. The geological key questions are:

- Does the polynya have an effect on the sedimentary environment ?
- To what extent are bottom water temperature and salinity influenced by the occurrence of the polynya?

Working programme

In addition to the sedimentological sampling programme outlined above, it is planned to map the horizontal and vertical distribution of the young sediment cover by means of side scan sonar and subbottom profiling (3.5 khz). These investigations will be completed by the deployment of three moorings combined with small sediment traps along the polynya to record the particle flux, salinity, and temperature during one year.

3.5.3 Pore water gradients, early diagenetic zones and the material fluxes through the sediment bottom water interface in different subregions of the Laptev Sea shelf (AWI-P)

Scientific Background

The extensive continental shelf around the Arctic Ocean plays an important role in the cycle of nutrients and should be considered as a contribution to the general oceanic material flux and budget. Reaction rates during the degradation of organic substances influence the material fluxes through the sediment/bottom water interface in the same way as the early diagenetic zones in sediments. The primary diagenetic processes of dissolution and precipitation creates numerous secondary reactions, which are indicated by the development of new minerals. Related questions are the ability to preserve paleosignals for the reconstruction of paleoclimate.

Pore waters recovered from sediment cores from various subregions (river mouth of Lena and other Siberian rivers, shelf regions with a large freshwater input, shelf regions where the river run-off is modified by mixing with saline waters and shelf regions which are influenced by brine water during the freezing period) will be investigated geochemically.

Working programme

Objectives will include the measurement of concentration profiles of nitrate, sulphate, sulphide, ammonium, phosphate, manganese, iron, calcium, silicium. The fluxes will be derived from gradients of concentration profiles in connection with parameters of physical properties. The early diagenetic zones in sediments will be investigated in relation to different environments of sedimentation in the subregions of the shelf.

3.5.4 Organic carbon flux in the Laptev shelf area: productivity vs. terrigenous input (AWI)

Scientific background

Mechanisms such as surface-water productivity may affect the concentration of atmospheric CO_2 (i.e., during times of increased phytoplankton productivity the ocean may act as a sink for CO_2) and thus, may be an important factor controlling the global climate. No such data are available from the Eurasian continental shelf and Slope areas in which large amounts of organic carbon might be stored. Thus, one of the major goals of the Laptev Sea expeditions is to quantify the flux of organic carbon on the shelf as well as the slope and deep sea and to characterize the mechanisms controlling organic carbon deposition (i.e., surface-water productivity vs. terrigenous input).

Major objectives are:

- To determine the amount, composition, and maturity of the organic carbon fraction, i.e., (sub-) recent marine and terrigenous organic carbon, reworked fossil material (coals).
- To quantify the flux of marine and terrigenous organic carbon (accumulation rates), its change through space and time, and its relationship to changes in sea-ice distribution, run-off, and paleoclimate.
- To produce distribution maps of organic carbon parameters in order to distinguish between the different factors controlling organic carbon deposition (high productivity caused by fluvial nutrient supply; ice-edge blooms; fluvial supply of terrigenous material).
- To estimate the (paleo-) productivity from organic carbon data (i.e., marine organic carbon flux, biomarker) and geochemical tracer (e.g., Ba).

Working programme

While the slope and deep-sea environments will be sampled by *Polarstern*, the *Ivan Kireyev* sampling will concentrate on the Laptev Sea shelf. In the latter area, transects from the inner and outer Lena delta area to the open shelf are of special interest. The study should include detailed organic geochemical investigations of surface sediments and material from undisturbed box corer sequences.

Laboratory methods to be used to determine the amount, composition, and maturity of the organic matter are elemental (CHN) analysis, Rock Eval pyrolysis, carbon stable isotopes of organic matter, kerogen/coal petrography, and gas chromatography. For Barium determination, RFA and AAS will be used.

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