2 The Expedition ANTARKTIS XX/2

2. The Expedition ANTARKTIS-XX/2 Cape Town - Cape Town

November 24, 2002 to January 23, 2003

2.1 Summary and itinerary

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The second leg of RV POLARSTERN expedition ANT-XX was devoted to a multi-disciplinary research programme in the eastern Weddell Sea and Riiser Larsen Sea. It focussed on oceanographical, geochemical and sedimentological projects carried out along two transects, from north to south along the Prime Meridian and from south to north along 23° longitude east (Fig. 2.1-1). Apart from the scientific programme, the - as early as possible in the season - supply of Neumayer and Kohnen stations and the logistic support of AWI polar aircrafts as well as research projects at Neumayer played an important role on this leg. Its scheduling was done on site absolutely depending on sea-ice conditions.

A major goal of the hydrographic investigations was the recovery (after two years of deployment) and redeployment of nine mooring systems along the Prime Meridian in the framework of the WECCON project (Weddell Sea convection control) which was started already in 1996. This project was complemented by a complete CTD (conductivity, temperature, depth) and water sampling programme along the Prime Meridian and along 23° longitude east for Carbon dioxide investigations, CFC tracers, naturally radionuclide tracers and chlorophyll and particle flux investigations as well as for a small biological project dealing with virioplankton and oligotrophic bacteria.

The marine geological investigations concentrated mainly to sediment coring and sampling of a channel-levee system on the continental slope of the southern Riiser Larsen Sea (see GeoBox in Fig. 2.1-1). Swath sonar bathymetric measurements with the HYDROSWEEP system planned to contribute to the AWI Bathymetric Chart of the Weddell Sea (BCWS) and subbottom echosounding profiling with the PARASOUND system in support of the sedimentological project were only partially successful due to very specific obligations by the German Federal Office for the Environment (UBA) for operating all hydro acoustic devices, e.g. echosounding systems. However, extensive experience was gathered on the efforts and needs to run a permanent passive acoustic and visual monitoring of marine mammals while doing acoustic profiling (see Chapter 2.4).

RV POLARSTERN set sail in the evening of November 24, 2002 with an international team of 51 scientists and technicians from seven countries, PR China, Germany, Greece, Mexico, The Netherlands, South Africa, United Kingdom, and 43 crew and left the harbour of Cape Town (South Africa) on a south westerly course heading for the Prime Meridian at 51 degree latitude south (Fig. 2.1-1).

Fine weather and calm sea conditions during the first days of the cruise enabled POLARSTERN to make good progress. After leaving the South African EEZ, a continuous en-route bathymetric and acoustic sediment profiling survey was started using the ship‘s swath sounding HYDROSWEEP system and the PARASOUND system, respectively. On November 26, a test station for the CTD/rosette system at 39°33‘S,

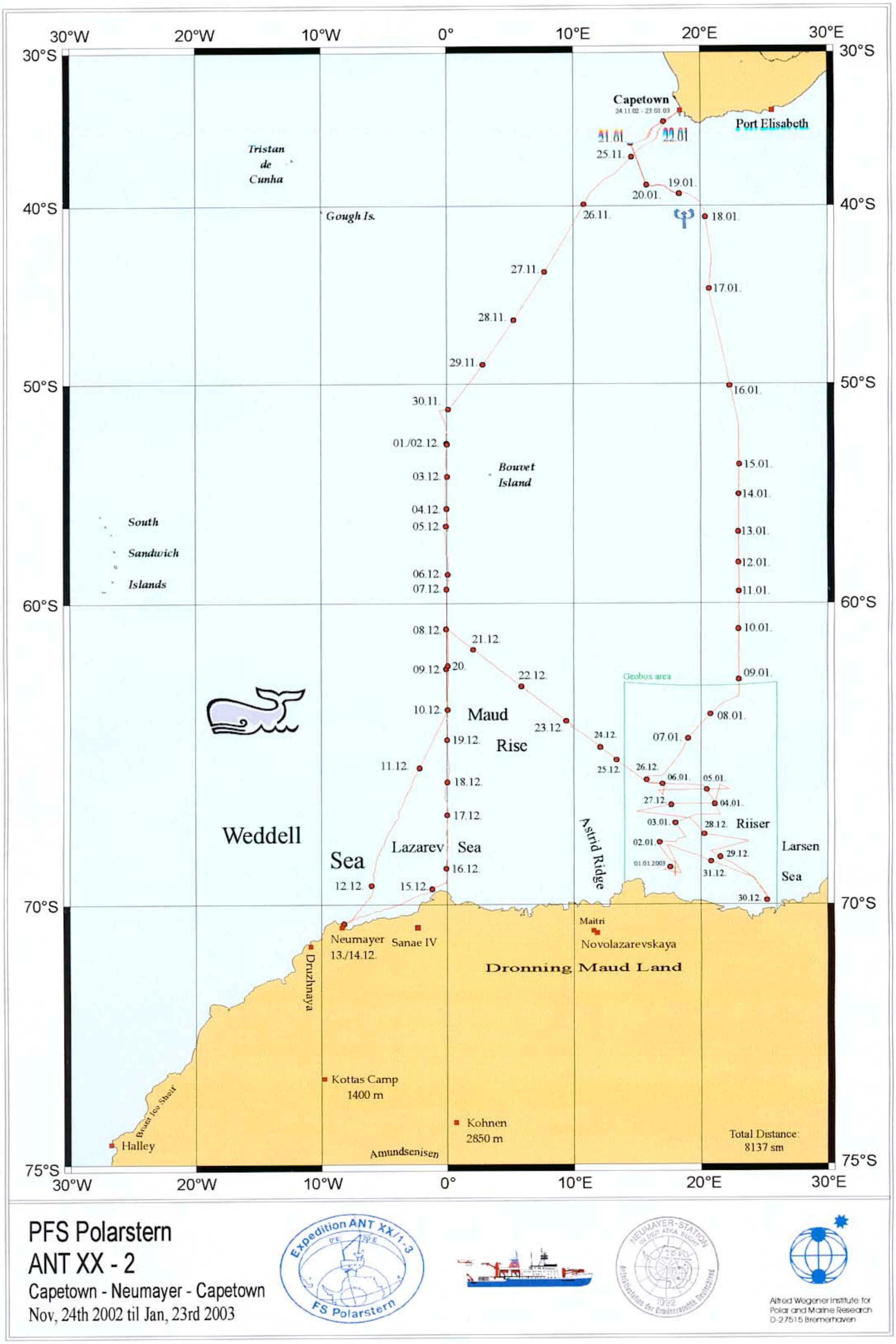

Fig. 2.1-1: Cruise track of RV POLARSTERN during ANT-XX/2

11°05‘E and a towing test at different speed of the hydrophone streamer system for acoustic mammals monitoring were carried out successfully.

Regular hydrographic station work started on November 27, along the TOPEX / POSEIDON ground track #133 along which two pressure inverted echosounders (PIES) were deployed. At regular distance of about 70 nautical miles a CTD (Conductivity, Temperature, Depth) sonde and attached rosette water sampler were used to provide the various projects with hydrographic data and water samples. Strong gale during these days, lasting until December 04, caused difficult working conditions. Two CTD stations had to be cancelled because of heavy sea state.

The Prime Meridian was reached on November 30, to continue CTD and rosette sampling at regular distances of half degree latitude or 30 nautical miles from 50 °S to 69 °S as part of the WECCON (Weddell Sea Convection Control) project. As a major component of WECCON, nine mooring systems deployed two years ago along the Prime Meridian were to be recovered and redeployed. The first mooring system was recovered under extremely difficult sea state conditions on December 01. The first attempt to deploy the new system had to be stopped. It was successfully deployed only later the next day when sea state conditions had improved slightly.

First icebergs were sighted in the morning of December 04, and the ice edge consisting of dense but loosely packed drift-ice was met unexpectedly far north, at about 56°30‘S during the afternoon of the same day. Ice coverage intensified and increased from 5-7 tenths to 8-9 tenths while CTD station work progressively moved south. Wind force decreased, and together with moderately strong coverage of relatively soft and thin one-year ice, working conditions changed considerably to the better.

On December 07, crossing 60° south latitude, POLARSTERN entered the area under the Antarctic Treaty legislation. To perform the special requirements laid down by the German Federal Office of the Environment (UBA) for operating the swath sonar HYDROSWEEP and sediment echosounder PARASOUND systems and all other hydro-acoustic devices scientists set up a passive acoustic as well as a visual monitoring of marine mammals. Once marine mammals, seals or whales, were sighted or recorded, the ship’s sonar systems (HYDROSWEEP swath sounder and PARASOUND subbottom echosounder) had to be shut down for a certain period and reactivated only if no other mammal had been sighted meanwhile. Especially the visual monitoring increased the general watch keeping duties for all scientists tremendously.

CTD station work was continued until December 10, at 64 °S, west of Maud Rise where a mooring system was recovered and deployed before POLARSTERN at almost midnight shaped course for Atka Bay and Neumayer Station. Very convenient ice conditions, 4/10 of ice coverage and wide open water made good headway. Ice conditions changed to the worse during December 11, when thick flows of strongly ridged multi-year ice with a thick snow cover became more and more predominant. Tough ice conditions prevailed until the next morning when the dense pack ice opened slowly and POLARSTERN reached the wide open coastal polynya stretching from 5 °W to 15 °W (see Fig. 2.3-1a).

Late in the evening of December 12, POLARSTERN arrived at Atka Iceport which - according with the early season - was completely covered by acomplete and intact ice cover. By midnight the ship came alongside the exposed “Nordanleger” in the lee of a huge grounded iceberg where the ice-edge reaches a height of approximately 12 m. Cargo operations started early in the morning of December 13, and - meeting fine weather conditions - were finished in the late afternoon of December 14. While the vessel stayed at the “Nordanleger” satellite transmitters were mounted during helicopter flights on three suitable icebergs for tracking them during melting. Supported by helicopter, two hydroacoustic experiments to record seal songs from open leads in the sea ice cover of Atka Bay were carried out as well. Other scientists and crew that had not visited Neumayer Station before took the chance of a helicopter shuttle to the station.

Late in the evening of December 14, POLARSTERN left Atka Bay and steamed through the widely open waters of the polynya on northeasterly course along the ice edge for the Prime Meridian at about 69 °S, slightly north of Trolltunga. Shortly before midnight POLARSTERN met with the Russian research vessel ACADEMIC FEDOROV which passed nearby on her way for Neumayer Station. Between December 15 and 20 intensive CTD station work and sediment sampling along the Prime Meridian from 69°20‘S to 64 °S in the western Lazarev Sea was carried out. Additionally, four mooring systems were recovered and deployed and a 19 m long piston core was recovered at 61 °S. Improving ice conditions changed from heavy pack and 8-10 tenths coverage in the south to almost open water in the north, and made station work increasingly easier. By means of a number of helicopter flights four icebergs between 69 °S and 64 °S were marked by satellite transmitters.

From December 21 through December 26 a transect of hydrographic CTD stations and geological multi-corer stations was sampled at regular distances of 38 nautical miles each, from the Prime Meridian at 61 °S, north of Maud Rise, to 66°26‘S, 15°55‘E east of the Astrid Ridge in the western Riiser Larsen Sea. A sound-source mooring was deployed at 64°31‘S, 09°50‘E and at 64°53‘S, 10°57‘E use of the in-situ pump system was made for sampling large volume samples for natural radionuclide tracers. Regular sampling was interrupted from December 24 to 25 to celebrate the Christmas Eve.

From December 26 to January 06 HYDROSWEEP bathymetric swath sonar profiling for areal mapping of erosional channels and PARASOUND sediment profiling for mapping the thickness of the sedimentary cover and identifying suitable sediment coring sites were carried out in parallel with sediment sampling by gravity corer and multi-corer (MUC) in the so called GeoBox in the southern Riiser Larsen Sea. Regular CTD station work was continued to extend the hydrographic transect started at the Prime Meridian to the southeast as far as to 69°55‘S, 25°30‘E near the ice shelf edge of the Prinsesse Ragnhild Kyst. There, ice surveys by helicopter along the shelf ice edge revealed 8-9 tenths coverage of thick multi-year ice extending far to the west in the direction for the Astrid Ridge. Therefore, it was decided on December 30, not to take direct course to Erskinebukta in the west but to choose a more northerly course where thinner one-year ice eased the ice conditions, as experienced the days before. The New Year’s Eve was celebrated while transiting from the eastern to the western part of Riiser Larsen Sea.

On January 02, 2003 an acoustic experiment to record and distinguish sounds of marine mammals, e.g. seals, without the strong background noise of RV POLARSTERN was carried out using one of POLARSTERN’s life boats in the drift-ice zone of the northern Riiser Larsen Sea. Sediment profiling in the GeoBox in general but specifically in the densely ice covered area of the southern Riiser Larsen Sea near the shelf ice edge was severely hampered by complying with the specific environmental restrictions of the German Federal Environmental Office (UBA) for the use of active acoustical devices.

From January 07 through the afternoon of January 15 intensive hydrographic as well geoscientific sampling was carried out along 23° east longitude. CTD/rosette and fluorimeter casts were taken regularly each half degree latitude or 30 nm in distance. Long piston cores and surface samples by multi-corer were taken on selected sites at 60 to 90 nm distance, precise locations identified from existing HYDROSWEEP and PARASOUND records or from online surveys where available according to environmental injunctions. Station work was generally favoured by calm weather conditions. However, piston coring in greater water depths, deeper than 5000 m, was substantially hampered by high swell during January 10 to 12. HYDROSWEEP swath sounding and PARASOUND sediment profiling was carried out continuously north of 60 °S.

An exceptional event occurred on January 15 when during station work for several hours altogether more than 20 Humpback whales played around the vessel showing not dread of the vessel itself and of ongoing sampling activities or of active sonar systems.

During the night from January 15 to January 16 the hydrographic transect along 23 °E was finished at 53 °S. In the same night a large low pressure system caused fresh gale and heavy sea preventing POLARSTERN from further piston coring. A fundamental decision was required how to spend the remaining station time of the cruise; to wait on site for increasing weather conditions to proceed with piston coring along 23 °E or to escape as fast as possible to the north to sample the Agulhas system around 40 °S with CTD and *in-situ* pumps for a hydrographical-geochemical project and to sample additional piston cores *en route* where feasible. POLARSTERN left the area around 52 °S and sailed north assisted by strong southerly winds and swell astern.

During daytime of January 18 to January 21 the waters of the Agulhas Retroflection and associated gyre system of the Agulhas Rings at 40 to 36 °S and 20 to 14 °E were sampled on four long-lasting stations by *in-situ* pumps and CTD while night-time was used for transit between stations. Refreshing winds and swell and strong currents during January 19 caused difficult working conditions on station, cancellation of CTD casts and delayed beginning of station work on January 20. Bright sunshine and calm sea saw the final station work of this cruise when the last CTD came on board in the late afternoon of January 21. After 60 days at sea and a distance of about 8100 nautical miles, RV POLARSTERN arrived on schedule in Cape Town in the early morning of January 23, 2003.

2.8 Investigations on physical hydrography: Weddell Sea Convection Control - WECCON

Since 1996 moorings were deployed along the Prime Meridian (Fig. 2.8-1) and redeployed every two years, as was done during this cruise. The two southernmost moorings covered the area of the coastal current. Westward of Maud Rise there are three moorings equipped with temperature-conductivity recorders from approximately 250-750 m depth to monitor the change in the stratification. This data are imported to study the possible pre-conditioning for the occurrence of a polynya. The four northern moorings are at the westward flowing branch of the Weddell Gyre and the transition into the Antarctic Circumpolar Current (ACC). This region is characterized by fronts, which also effect the elevation of the sea surface. Thus bottom pressure recorders in the three northernmost moorings are used to record the change of the sea surface elevation and from these records the shift of the ACC can be determined. The sea surface elevation was compared with the satellite sea surface height measurements from TOPEX/Poseidon. The ACC was also described with the full coverage of temperature-conductivity recorders in this region. Inverted echo sounders are placed on top of the six southern moorings to measure the sea-ice draft and the variability of the yearly sea ice coverage. The instrumentation of the deployed moorings (Tab. 2.8-2) has not changed compared to the instrumentation of the recovered moorings (Tab. 2.8-1) but in addition two sound sources have been attached in mooring 229 and 231 at 850 m depth each. A third sound source was deployed as a single sound source mooring near 10 °E

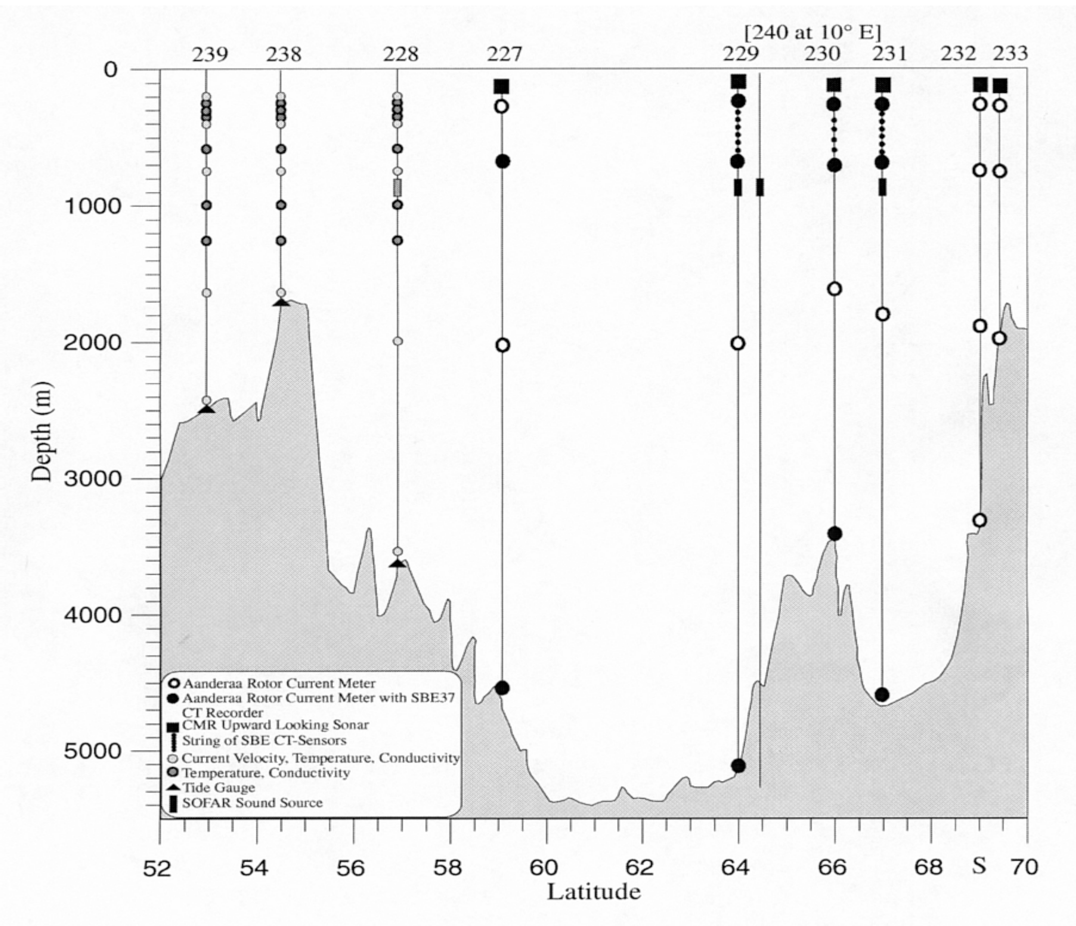

Fig. 2.8-1: Vertical section along the Prime Meridian with the moored instruments. Mooring AWI227 to AWI239 are the moorings which have been replaced. In addition sound sources were attached in moorings AWI229, AWI231, and in AWI240 which is a newly deployed one at 10 °E.

The mooring work started with mooring AWI239 and the first part ends with mooring AWI229 before steaming on direct course to Neumayer Station. After the suply activities the mooring work was continued from the south, starting with mooring AWI233 towards mooring AWI230. The sound source mooring AWI240 was deployed on the south-east transect to the GeoBox (see Fig. 2.1-1). The two northern moorings were replaced in open water. Due to rough weather conditions the deployment of AWI239 was stopped. The next day conditions became slightly better and the deployment could be finished. The sea ice edge was found north of AWI227 and at the mooring position the ice coverage ranged from 8/10 to 9/10. All further moorings were recovered under extremely closed ice cover with only a few small leads. Because the prototype of an acoustic unit (TT801) failed, the POSIDONIA positioning system was used. The successful recovery of all moorings during this cruise suggests that POSIDONIA may warrant a complete recovery even under difficult ice conditions. It was the first successful use of POSIDONIA for mooring recovery, therefore the following section exemplifies the recovery routine of one of our moorings.

2.8.1 Mooring recovery with POSIDONIA

POSIDONIA is an acoustic ultra short baseline positioning system of the IXSEA OCEANO company (France). The transducer array is fixed on a platform to be installed in the ships moon pool. The moon pool is locked when breaking through the ice. Thus the transducer array can only be installed on station and further ice breaking is not possible. Only cautious manoeuvring of the ship within leads is possible once the transducer array is installed. The installation of the transducer array occupies approximately 45 minutes. The POSIDONIA processing unit is connected to the ships navigation system as well to the pitch and roll sensors. The system was operated from a PC with special positioning software. The system is able to track acoustic transponders which can be placed on underwater vehicles or in moorings. These transponders must be POSIDONIA compatible transmitting multi frequency shifted key (MFSK). One of the moorings double releases can transmit MFSK and also one transponder at the moorings top. Thus it was possible to position and track at least one unit. The release command can be generated for POSIDONIA compatible releases. The PC was placed on the bridge and therefore one can directly communicate with the navigation officer during the mooring positioning and release.

The transducer array was installed when RV POLARSTERN had reached a lead close to the mooring location. Afterwards the positioning software was started and the transponder/releaser set-ups were loaded into the program from the configuration file, which is needed for POSIDONIA compatible transponders. Before the transponders can reply on their specific interrogate frequency for positioning, an enable command has to be transmitted. When this command is confirmed, the main positioning routine starts. It shows two graphs for plotting the horizontal and vertical distances between the ship and the transponder. Another window displays the calculated transponder position in latitude, longitude and depth in meters. There is also a status window, showing which of the four receivers detected a signal from the transponder. An interrogate signal was transmitted every five seconds. As soon as all four receivers have detected a reply from the transponder, its position is displayed. For moorings that have been deployed with the anchor first, the position measured with POSIDONIA was the same as being noticed after the deployment. For moorings that have been deployed in open water with anchor last, it was found that the position was not very far off the calculated position. Once

POSIDONIA has found the position of the mooring the navigation officer sets a marker from this position on the radar screen, which shows the surrounding sea ice field. If the mooring was in a region of heavy sea-ice coverage the mooring was not released. Instead the ice drift was observed to find a lead passing the mooring. As soon as a lead has reached the mooring position a release command was send. This can be done directly from the POSIDONIA software. After the release positioning was continued and the POSIDONIA PC-display shows decreasing transponder depth. It occurred that the moorings top-floats appeared directly in the assumed 50 m wide lead. Because the mooring will drift with the current, which may set differently than the drifting sea ice, the mooring can miss the lead. In this case the positions from the POSIDONIA system help to fix the region to search for float packages, which may appear between the ice flows.

Even in open water POSIDONIA helps to improve the mooring recovery. It was found that release commands being transmitted with the standard deck units (TT301 and TT801) and the 30 m cable hand-held-transducer failed if the release is placed in very deep water (greater 4000 m). During this cruise it could be verified that the release did not fail if the ship's noise was reduced disconnecting the propellers. But POSIDONIA transmitted release codes are able to release deep moorings even with running propellers or thrusters.

2.8.2 Iceberg tracking

To estimate the fresh water transport by icebergs, 10 satellite tracked transmitters were deployed there upon. These iceberg markers were manufactured by the "Denk Manufaktur" company, Gr. Kneten, Germany. The markers determine their position once per day at noon with a GPS receiver. The positions are transmitted via satellite using the ARGOS system. The ARGOS transmitter is switched on for six hours once a week only, to send the positions from the past seven days. The transmitter's on-time lasts long enough to ensure that all data can be received by CLS in Toulouse, France. This weekly transmission mode was chosen to save CLS service costs. Three markers are equipped additionally with an air pressure sensor. The ARGOS transmitters of these markers are operating in a 90 seconds continuous mode, providing three hourly air pressure data to the GTS. The iceberg markers are designed to operate for up to two years. Due to environmental aspects, the housing is slightly enlarged compared to previous versions. Thus the new markers have positive buoyancy without using additional floats. Markers from melted icebergs are likely to leave the Antarctic Ocean by drifting northwards and being entrained into the Antarctic Circumpolar Current. Tilt sensors are installed to detect when an iceberg begins to capsize. The ARGOS transmitter will switch into a continuous mode as soon as the tilt is excessive.

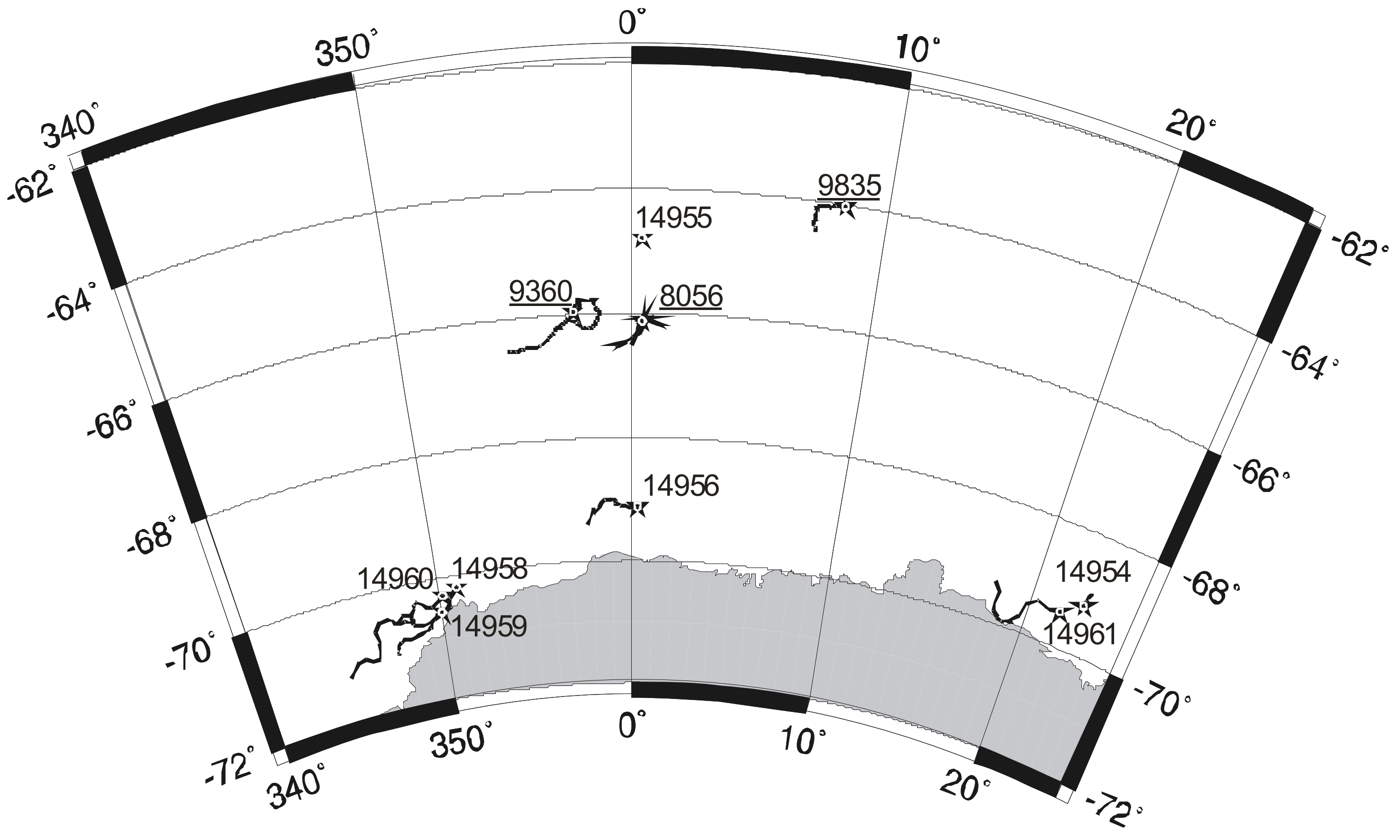

Fig. 2.8-2: Map of the ice bergs with deployed ARGOS transmitters. Numbers are the ARGOS Ids. Underlined Ids indicate the transmitters that are additionally equipped with air pressure sensor. The drift is shown for the period given in Table 2.8-3.

A helicopter was used to deploy markers on icebergs. Figure 2.8-2 shows the locations of the marked icebergs. The icebergs were chosen along the cruise track with a maximum flight distance of 20 nautical miles. Three markers were deployed during the supply activities at Neumayer Station. A digital photograph was taken to describe the shape of the iceberg. The length and width was measured with the GPS, flying along and across the iceberg. The height above sea level is taken from the radar altimeter of the helicopter. Table 2.8-3 gives a summary of all icebergs marked. Snow was sampled for the tracer group from IUPB.

Data collection from CLS via direct computer link and to do the data processing and validation is assigned to OPTIMARE company, Bremerhaven, Germany. Daily updated iceberg tracks are available from Gerd Rohardt (grohardt@awi-bremerhaven.de).

2.8.3 Deployment of pressure inverted echo sounders - PIES

To monitor the Antarctic Circumpolar Current (ACC) transport, two Pressure Inverted Echo Sounders (PIES) were purchased from the University of Rhode Island and deployed across the ACC's. The instruments are located on the TOPEX/Poseidon ground track number 133 (Fig. 2.8-3), complementing a PIES array between the South African coast and about 40 °S, which is currently being deployed by Deidre Byrne, University of Maine along the same satellite ground track.

PIES deliver bottom pressure and travel times of sound signals from the bottom to the sea-surface, effectively providing a measure of average temperatures, bottom pressure variations and sea surface height. After the planned recovery of the instruments in austral summer 2004/2005, the data shall be used to extract baroclinic and possibly barotropic transport variations within the gap spanned by the PIES.

A high resolution bathymetric profile between Cape Town and the two PIES was recorded with the HYDROSWEEP System (Fig. 2.8-4 and Fig. 2.8-5).

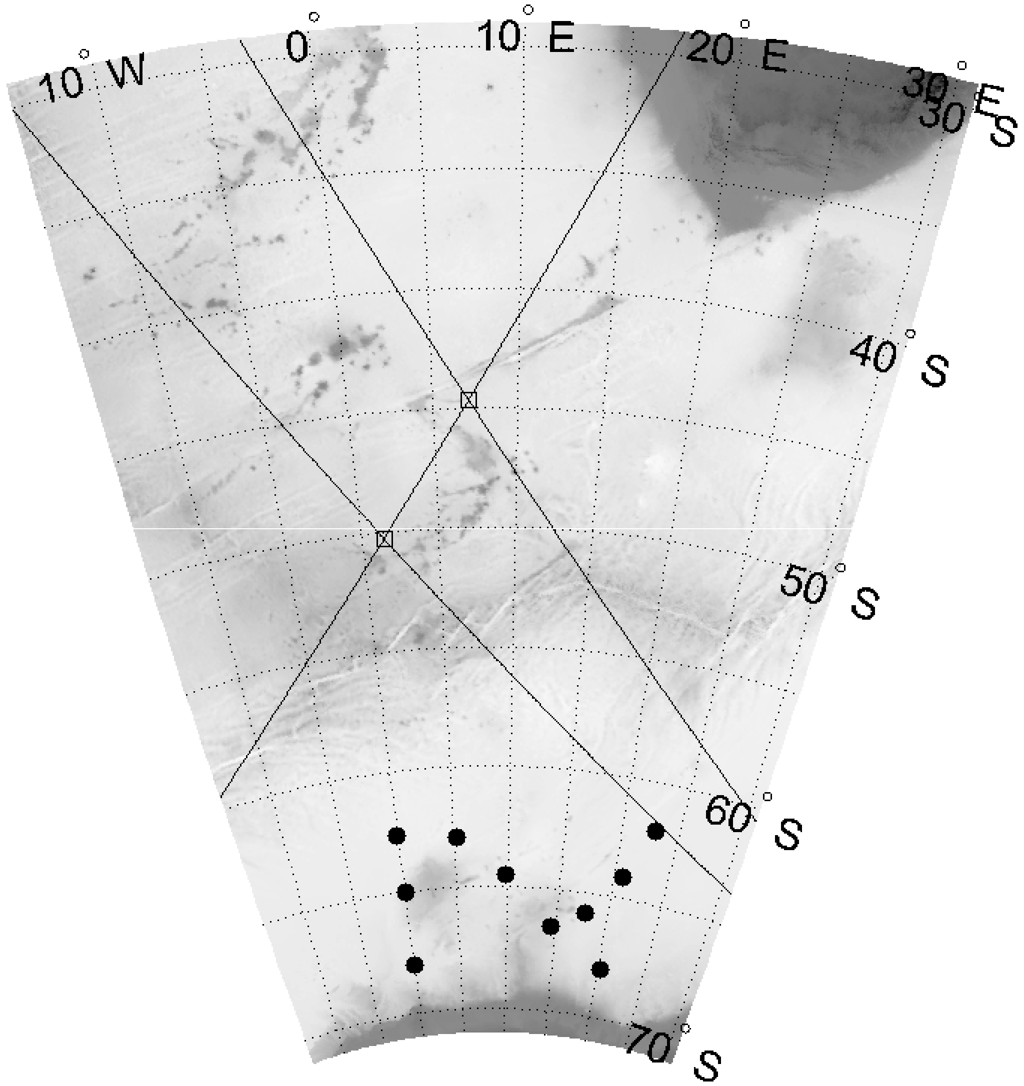

Fig. 2.8-3: Map of Pressure Inverted Echo Sounders (PIES) deployment positions (square boxes near 45° and 50 °S at the crossover points of TOPEX/Poseidon tracks 133, 98 and 48) together with setting positions of ten freely drifting ARGO/APEX floats. Bottom topography from SMITH & SANDWELL.

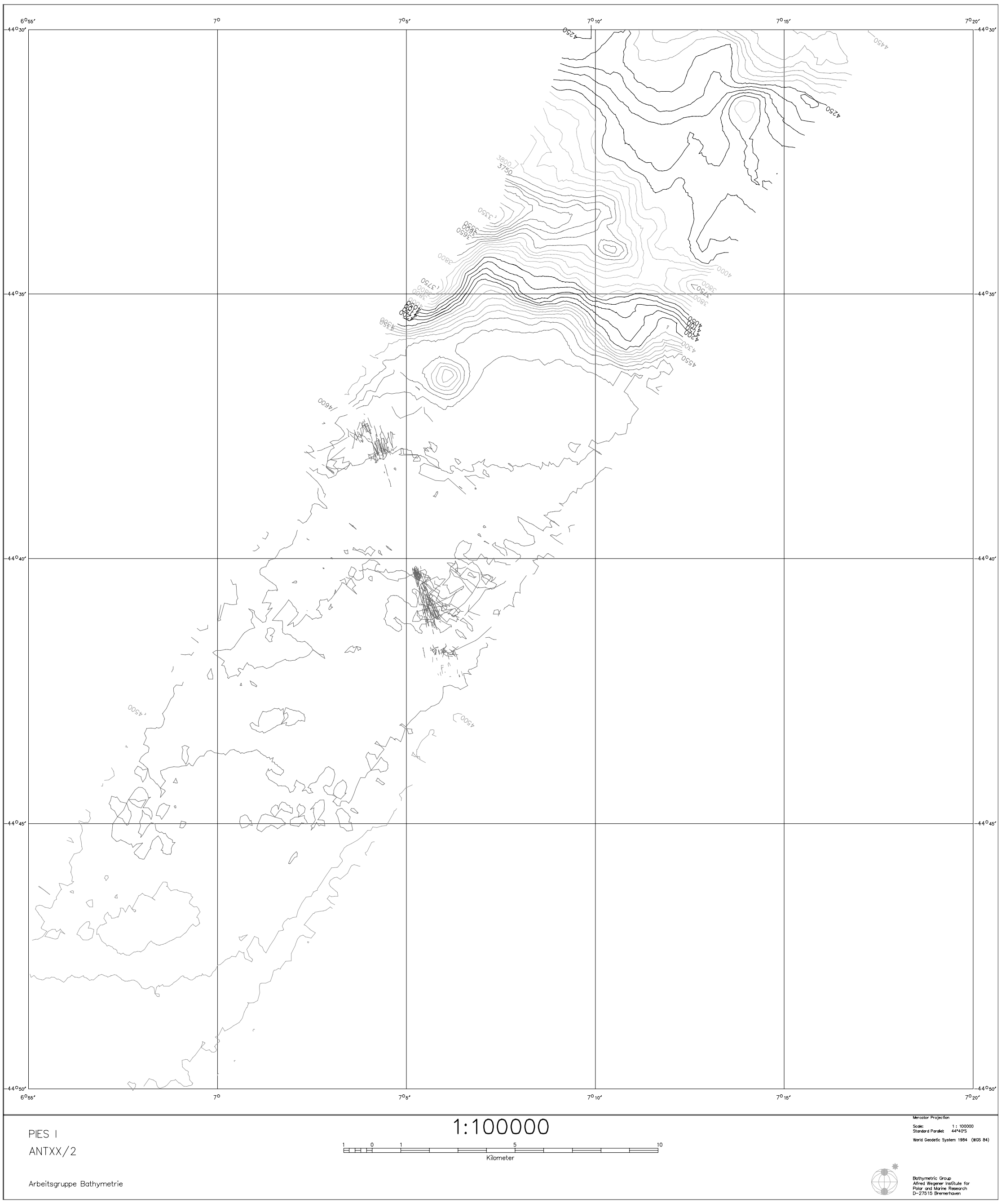

Fig. 2.8-4: Bathymetry around deployment position of PIES-1 at 44°39.75'S, 7°05.03'E. The bathymetry was recorded by HYDROSWEEP during cruise ANT-XX/2. Isobaths are spaced by 50 m.

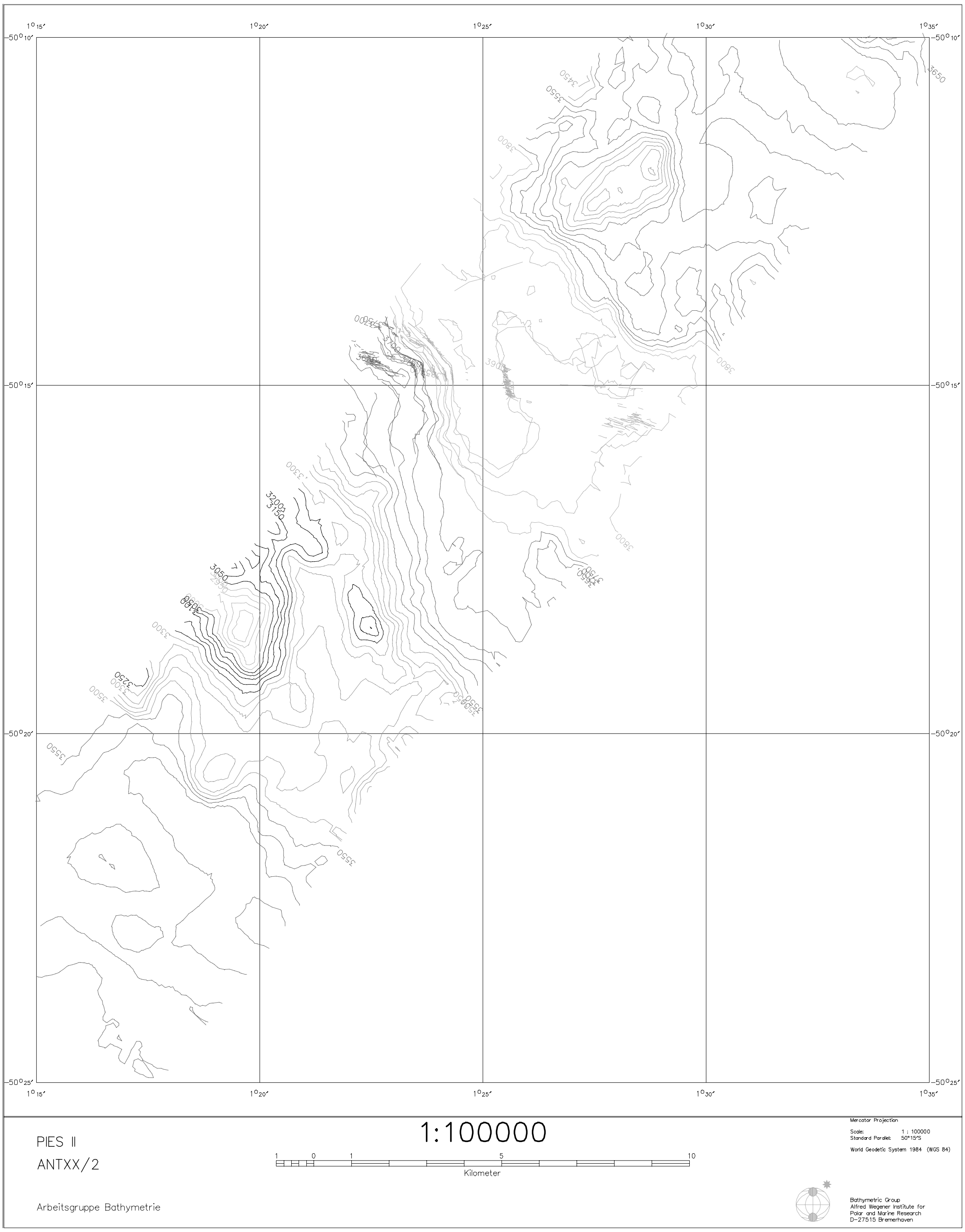

Fig. 2.8-5: Bathymetry around deployment position of PIES-1 at 50°15.01'S, 1°25.00'E. The bathymetry was recorded by HYDROSWEEP during cruise ANT-XX/2. Isobaths are spaced by 50 m.

2.8.4 Deployment of ARGO/APEX floats

The international ARGO (Array of Real Time Global Oceanography) project aims to set on the order of 3000 profiling floats into the world ocean to establish a real-time operational data stream of upper (<2000 m) ocean temperature and salinity profiles. Since 2001 the AWI contributes to this program with nine APEX floats, roving primarily between 50-60 °S, which cycle every seven days between the sea surface and their drift depth near 800 m. This year the fleet that was augmented by another ten floats, set south of 60 °S and cycling at ten days intervals (Fig. 2.8-3).

2.8.5 Deployment of RAFOS floats and sound source moorings at Maud Rise

The Ranging and Fixing of Sound (RAFOS) technology has been used widely in moderate latitudes to provide high-resolution trajectories of neutrally buoyant floats by means of underwater acoustics. It is based on travel time measurements of a coded sound signal between a moored sound source and the moving float. However, at high latitudes, this technique is expected to work at considerable shorter ranges only, and the Maud Rise RAFOS Experiment (MARE) is designed as a first test to explore the ranges to be expected, while simultaneously trying to unveil the mesoscale circulation patterns around Maud Rise. To this end, three sound sources were moored and nine floats were launched in the vicinity of Maud Rise (Fig. 2.8-6, Tab. 2.8-6 and Tab. 2.8-7).

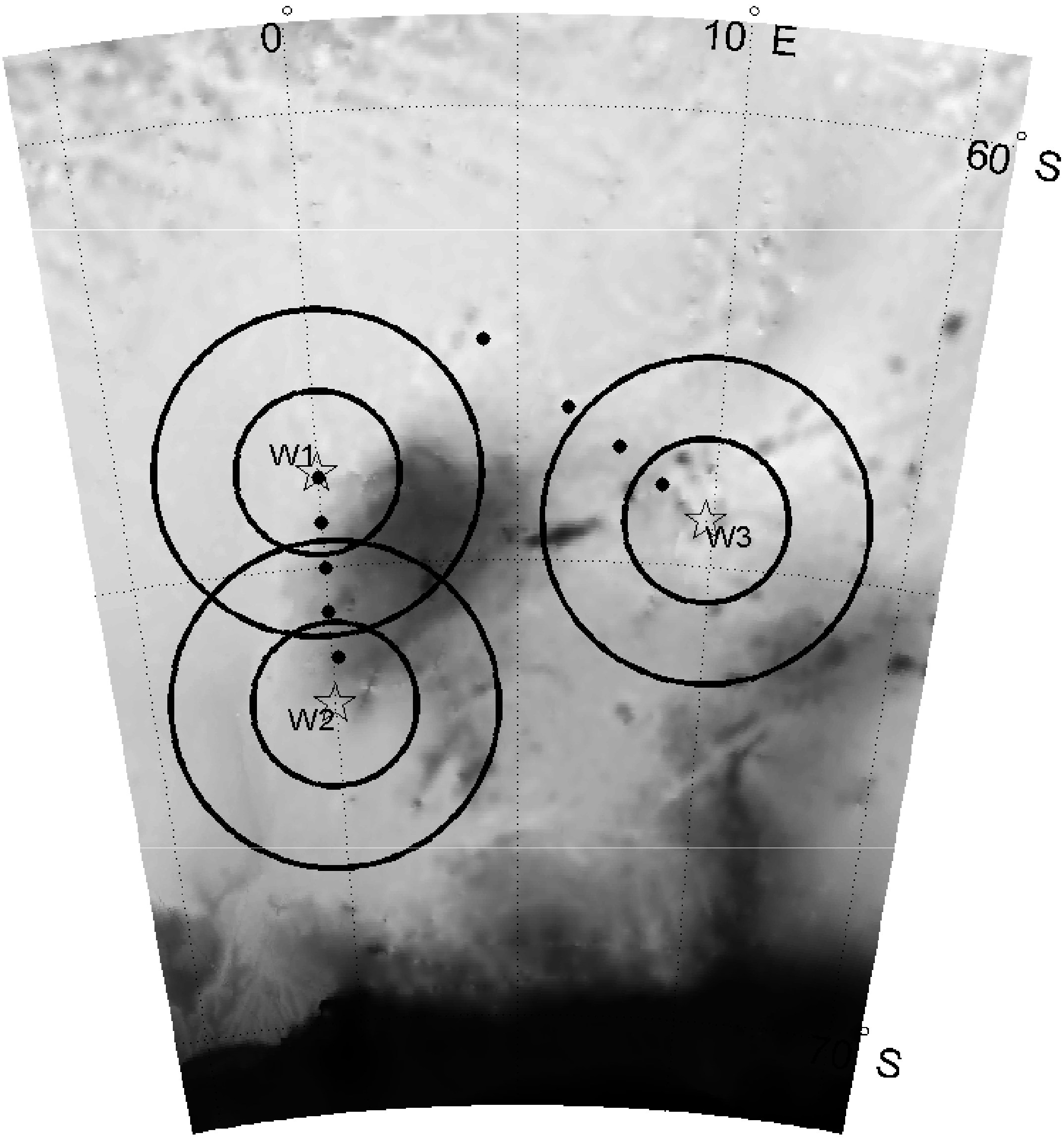

Fig. 2.8-6: Map of Sound Source moorings and RAFOS float deployment sites around Maud Rise. Asterisks mark the sound source mooring positions, with circles indicating 100 and 200 km ranges. Dots mark the setting positions of nine RAFOS (Ranging and Fixing of Sound) floats. Bathymetry according to SMITH & SANDWELL.

The sources are refurbished sources, with some major problems that could only provisionally be fixed in Bremerhaven before shipment. Sound source 21 showed signs of previous leakage at the high voltage feed-through, which was provisionally fixed with Scotch Fill. Sound source 19 and 21 could only be addressed through the internal interface and hence could not be vacuum checked before deployment. Sound source 49/14 had the high voltage feed-through replaced and spliced to the external cable leading to the transducer.

2.8.6 Measurements with the vessel mounted acoustic Doppler current profiler - VM-ADCP

AWI, OPTIMARE

A 150 kHz ADCP is mounted in the ship's hull and monitors continuously the velocity profile in the upper water column. Navigation is provided by the Marine Inertial Navigation System (MINS).

Due to problems with one of the four transducers the ADCP was run in the 3-beam-solution mode for the whole cruise up to January 3, 2003, when it was switched off for repair. The decision to switch the VM-ADCP off that early, was made to take the opportunity to demount the instrument in calm weather conditions near the ice edge.

The instrument will be sent to the manufacturer RD Instruments for repair after the cruise. A preliminary scan through the data indicates no problems. The final processing will be done with the CODAS software at home.

Mooring	Latitude Longitude	Water depth (m)	Date time of 1st record	Instrument type	Serial number	Instrument depth (m)	Record length (days)
AWI233-5	69°23.73'S 00°04.04'W	1916	20-12-00 16:00	ULS ACM AVT ACM-CTD	42 1569A 9186 1387A	191 220 717 1873	725 (1) 725 725
AWI232-5	68°59.49'S 00°02.18'W	3337	21-12-00 16:00	ULS ACM AVTPC AVT ACM-CTD	46 1565A 9214 9182 1447A	166 225 732 1778 3284	724 (1) 5(2) 724 724
AWI231-4	66°30.00S 00°01.80'W	4515	23-12-00 10:00	ULS ACM-CTD CT CT CT CTD CT CT CT-P CTD CT-P ACM-CT AVT ACM-CTD	47 1456A 237 238 239 245 240 435 1231 247 1232 1442A 10003 1472A	179 198 250 300 350 400 450 500 550 600 650 705 1811 4472	724 (1) 724 724 724 724 724 724 (3) 724 724 724 724 (1)
AWI230-3	66°00.34'S 00°10.38'E	3447	23-12-00 20:00	ULS ADCP	36 1600	170 187	724 (4)

Mooring	Latitude Longitude	Water depth (m)	Date time of 1st record	Instrument type	Serial number	Instrument depth (m)	Record length (days)
				AVTP	9204	195	724
				CT	236	295	724
				CTD	243	395	724
				CTD	244	495	724
				CT-P	1230	595	724
				ACM-CTD	1474A	705	724
				AVT	9785	1598	724
				ACM-CTD	1470A	3404	(1)
AWI229-4	63°57.86'S 00°02.40'E	5167	26-12-00 18:00	ULS	24	127	713
				ACM-CTD	1450A	170	(1)
				CT	228	220	713
				CT	230	270	713
				CT	232	320	713
				CTD	241	370	713
				CT	233	420	713
				CT	235	470	713
				CT-P	1288	520	713
				CTD	242	570	713
				CT-P	1229	620	713
				ACM-CTD	1443A	677	713
				AVT	9391	1973	74(2
				ACM-CTD	1451	5117	(1)
AWI227-7	59°04.20'S 00°04.40'E	4620	29-12-00 14:00	ULS	08	148	(4)
				AVTPC	9194	252	707
				AVTPC	9998	679	707
				SBE16	2422	680	637
				AVT	9179	1986	707
				AVT	9211	4596	707
				SBE16	631	4597	(4)
AWI228-5	56°57.61'S 00°01.40'E	3712	30-12-00 16:00	ACM	1553A	205	(1)
				SBE16	2416	206	551
				Micro-J	1324F	256	411
				CT-P	1235	306	704
				CT	224	356	704
				AVTP	10541	413	704
				SBE16	630	414	(4)
				SBE16	319	575	(4)
				AVT	9180	741	704
				CT	229	742	704
				CT-P	1603	992	704
				CT-P	1604	1242	704
				AVT	9190	1948	704
				RCM11	20	3649	704
				SBE26	227	3712	(4)
AWI238-3	54°30.60'S 00°01.70'E	1700	31-12-00 16:00	ACM	1567A	176	701
				SBE16	2415	187	625
				CT	231	227	701
				CT-P	1234	327	701
				AVTP	9193	383	701
				SBE16	1167	384	701
				CT-P	1237	550	701
				AVTP	10926	730	701
				SBE16	1979	731	697
				CT-P	1605	981	701
				CT-P	1606	1231	701
				RCM11	25	1610	701
				SBE26	228	1700	(4)
AWI239-2	52°00.66'E	2460	03-01-01	ACM	1558A	218	697

Mooring	Latitude Longitude	Water depth (m)	Date time of 1st record	Instrument type	Serial number	Instrument depth (m)	Record length (days)
	00°00.93'E		02:00	SBE16	2414	219	496
				CT-P	1233	269	697
				CT	216	319	697
				CT	225	369	697
				AVTP	10927	426	697
				SBE16	1977	427	566
				CT-P	1236	597	697
				AVTP	10928	773	697
				SBE16	1978	774	584
				CT-P	1607	1024	697
				CT	269	1274	697
				AVTP	12325	1780	697
				CT	227	1781	697
				RCM11	26	2407	697
				SBE26	276	2460	697

Tab. 2.8-1: Moorings recovered at the Prime Meridian. ADCP = RDI Inc. self contained acoustic doppler current profiler. ACM-CTD = Falmouth Scientific Inc. three-dimensional acoustic current meter with CTD head (CTD = Conductivity, Temperature, Depth). AVTCP = Aanderaa current meter with temperature-, conductivity-, and pressure sensor. AVTP = Aanderaa current meter with temperature and pressure sensor. AVT = Aanderaa current meter with temperature sensor. RCM 11 = Aanderaa Doppler current meter. SBE16 = Seabird Electronics SBE16 recording temperature, conductivity, and pressure. ULS = Christian Michelsen Research Inc. upward looking sonar to measure the sea ice draft. SBE26 = Seabird Electronics SBE26 bottom pressure recorder. CT = Seabird Electronics SBE37 recording temperature and conductivity. CT-P = Seabird Electronics SBE37 recording temperature, conductivity, and pressure.

Remarks: Instrument failure = no data recorded; Instrument flooded = data lost; Instrument lost during recovery; Memory download failed, has to be done by manufacturer.

Mooring	Latitude Longitude	Water Depth (m)	Date / time of 1st record	Instrument type	Serial number	Instrument depth
AWI233-6	69°23.66'S	1948	15-12-02	ULS	49	165
	00°03.98'W		22:48	AVTP	8367	237
				AVTPC	8395	738
				SBE37	1604	1891
				AVT	10499	1892
AWI232-6	68°59.87'S	3369	16-12-02	ULS	50	175
	00°00.32'E		14:46	AVTP	11887	252
				AVTPV	8396	765
				AVT	10498	1809
				SBE37	1605	3314
				RCM11	127	3315
AWI231-5	66°30.56'S	4552	18-12-02	ULS	39	178
	00°02.03'W		10:55	AVTPC	8400	220
				SBE37	2609	220
				SBE37	211	270
				SBE37	2610	320
				SBE37	214	370
				SBE37	215	420
				SBE37Pup3	2392	470
				SBE37	220	520
				SBE37	222	570
				SBE37	223	620
				SBE37	2234	670
				SBE37Pu	2382	720
				AVTPC	9215	731

Mooring	Latitude Longitude	Water Depth (m)	Date / time of 1st record	Instrument type	Serial number	Instrument depth
				SQ	18/W2	882
				AVT	9768	1837
				SBE37Pu	2383	4492
				RCM11	133	4498
AWI230-4	66°00.30'S	3477	18-12-02	ULS	38	177
	00°10.29'E		20:53	AVTPC	8401	220
				SBE37Pu	2384	220
				SBE37Pu	2385	320
				SBE37P3	249	420
				SBE37	445	520
				SBE37	446	620
				SBE37Pu	2386	720
				AVTPC	9995	731
				RCM11	134	1627
				SBE37Pu	2087	3427
				RCM11	135	3433
AWI227-8	59°04.20'S	4566	07-12-02	ULS	41	162
	00°04.47'E		09:01	AVTPC	10004	274
				AVT	3570	704
				SBE37PuP3	2395	705
				AVT	10503	2011
				SBE37Pu	2091	4616
				RCM11	146	4622
AWI229-5	63°57.23'S	5200	10-12-02	ULS	38	147
	00°00.21'W		18:45	AVTP	8402	193
				SBE37P3	2387	200
				SBE37	250	250
				SBE37	448	300
				SBE37	449	350
				SBE37Pu	2086	400
				SBE37PuP3	2393	450
				SBE37Pu	2088	500
				SBE37Pu	2089	550
				SBE37Pu	2090	600
				SBE37	2611	700
				SBE37PuP7	1564	750
				AVTP	9783	704
				SQ	14/W1	859
				RCM11	144	2005
				SBE37Pu	2388	5150
				RCM11	145	5156
AWI228-6	56°57.64'S	3699	04-12-02	AVTPC	8405	190
	00°01.62'E		23:00	SBE16P1	19783	191
				SBE37PuP3	2235	241
				SBE37Pu	2092	291
				SBE37Pu	2093	341
				AVTPC	9201	402
				SBE37Pu	2391	403
				SBE37PuP3	2396666	562
				AVT	9389	728
				SBE37Pu	2094	729
				SBE37Pu	2095	979
				SBE37PaP7	1565	1227
				RCM11	100	1934
				RCM11	101	3635
				SBE37Pu	2389	3636
				SBE26	276	3699
AWI238-4	54°30.63'S	1718	03-12-02	AVTP	11892	187
	00°01.81'E		14:20	SBE16P3	2420	188

Mooring	Latitude Longitude	Water Depth (m)	Date / time of 1st record	Instrument type	Serial number	Instrument depth
				SBE37Pu	2096	238
				SBE37Pu	2097	288
				SBE37Pu	2098	338
				AVTP	10491	399
				SBE37PuP3	2236	400
				SBE37Pu	2099	570
				AVT	9390	745
				SBE37PuP3	2237	746
				SBE37Pu	2100	1000
				SBE37Pu	2101	1250
				RCM11	102	1651
				SBE37Pu	2390	1652
				SBE26	257	1718
Mooring	Latitude Longitude	Water depth (m)	Date / time of 1st record	Instrument type	Serial number	Instrument depth
AWI239-3	53°00.49'S 00°01.96'E	2483	02-12-02 18:03	AVTPC	8419	240
				SBE37Pu	2231	241
				SBE37Pu	2102	291
				SBE37Pu	2103	341
				SBE37Pu	2104	391
				AVT	9401	441
				SBE37PuP3	2394	442
				SBE37Pu	2105	613
				AVT	9458	797
				SBE37PuP3	2238	798
				SBE37Pu	2233	1043
				SBE37PuP7	1566	1293
				RCM11	103	1793
				SBE37	2232	1804
				RCM11	104	2429
				SBE26	261	2483
AWI240-1	64°30.00'S 10°00.00'E	5200		SQ	new	856

Tab. 2.8-2: Moorings deployed at the Prime Meridian and sound source mooring northeast of Maud Rise. AVTCP = Aanderaa current meter with temperature, conductivity, and pressure sensor; AVTP = Aanderaa current meter with temperature and pressure sensor; AVT = Aanderaa current meter with temperature sensor; RCM 11 = Aanderaa Doppler current meter; SBE16P# = Seabird Electronics SBE16 recording temperature, conductivity, and pressure; here P# indicates the pressure range e.g. P1 for 1000 psi; ULS = Christian Michelsen Research Inc. upward looking sonar to measure the sea ice draft; SBE26 = Seabird Electronics SBE26 bottom pressure recorder; SBE37-Seabird Electronics SBE37 recording temperature and conductivity, SBE37Pu = Seabird Electronics SBE37 recording temperature and conductivity with external pump; SBE37PuP# = Seabird Electronics SBE37 recording temperature, conductivity, and pressure with external pump; here P# indicates the pressure range e.g. P1 for 1000 psi; SQ-Sound source for SOFAR-Drifters.

ARGOS identification	Date and time of - deployment - last position	Latitude Longitude	Iceberg dimension L - W - H (m)	Remarks	Digital photo (JPG)
9360	11-12-02 / 11:36 13-01-03 / 12:00	65°57.15'S 02°28.89'W	200 - 200 - 26	inclusive air pressure sensor	EB1
14959	13-12-02 / 15:09 10-01-03 / 12:00	70°20.88'S 08°20.44'W	1600 - 750 -40	tritium snow sample taken	EB2
14958	13-12-02 / 15:30 10-01-03 / 12:00	70°13.61'S 07°57.00'W	380 - 380 - 25	tritium snow sample taken	EB3
14960	14-12-02 / 12:54 11-01-03 / 12:00	70°16.63'S 09°39.85'W	380 - 380 - 40	tritium snow sample taken	EB4
14956	16-12-02 / 13:25 12-01-03 / 12:00	69°06.05'S 00°29.81'E	380 - 380 - 20	tritium snow sample taken	EB5a EB5b
8056	18-12-02 / 13:56 13-01-03 / 12:00	66°07.24'S 00°24.79'E	180 - 180 - 10	inclusive air pressure sensor	EB6a EB6b
14955	19-12-02 / 09:30 22-12-02 / 12:00	64°52.09'S 00°16.97'E	180 - 180 - 50	tritium snow sample taken	EB7
9835	23-12-02 / 09:00 10-01-03 / 12:00	64°01.33'S 08°17.02'E	200 - 100 - 15	inclusive air pressure sensor capsized	EB8a EB8b EB8c
14954	29-12-02 / 15:25 12-01-03 / 12:00	69°10.98'S 22°32.06'E	100 - 300 - 30	tritium snow sample taken	EB9a EB9b
14961	29-12-02 / 16:09 12-01-03	69°24.07'S 21°34.69'E	300 - 300 - 35	Tritium snow sample taken	

Tab. 2.8-3: Deployment of ARGOS transmitters on icebergs.

Identifiers AWI project URI SN.	Start -date (DMY) -time (GPS	Auto release - date - time	Launch wt. Depth (m) - HYDROSWE. - PODAS	Latitude Longitude	Date / Time (UTC)	Speed (km/h)
PIES-1 67	26-11-02 18:46:37	26-12-06 20:00	4610 4613	44°39.75'S 07°05.03'E	27-11-02 16:42	1.9
PIES-2 69	28-11-02 16:09:55	25-12-06 20:00	3879 3930	50°15.01'S 01°25.00'E	29-11-02 21:56	2.5

Tab.: 2.8-4: PIES mooring positions. Times are set according to GPS time, which was 14 s late (GPS = UTC + 14 s) relative to UTC during this period.

Float number				Start		Launch				
AWI	ARG HEX	ARG DEC	Webb Res. SN	Date-GPS Time-UCT	Wt. Depth (m)	Latitude Longitude	Date Time (UTC)	Wave height	Wind (m/s)	Ice cov
40	90C64	25649	673	0912-02 09:04:08	5337	62°37.84'S 00°05.81'W	09-12-02 15:32	0	13	5
41	9F3F1	26575	680	16-12-02 16:33:12	4512	68°00.28'S 00°03.49'W	17-12-02 03.44	0	2	5
42	A1965	26725	681	18-12-02 22:48:06	3757	65°00.32'S 00°00.41'W	19-12-02 11:13	0	5	4
43	A9096	10818	655	21-12-02 08:26.04	5172	62°57.27'S 05°16.46'E	22-12-02 09:54	1	5	0
44	90C91	25650	674	23-12-02 08:31:53	5214	64°29.48'S 09°49.45'E	23-12-02 15:43	0	9	1
45	91DC7	25719	675	25-12-02 14:59:45	3424	66°03.46'S 14°32.98'E	25-12-02 23:07	0	2	3
46	93890	25826	676	27-12-02 16:26:23	4045	67°59.98'S 20°13.58'E	28-12-02 13:33	0	5	2
47	95178	25925	677	06-01-03 18:02:00	4899	65°49.57'S 17°45.57'E	06-01-03 20:12	0	2	0
48	9F3A2	26574	679	08-01-03 10:18:32	5055	64°07.90'S 20°45.40'E	08-01-03 13:23	0	4	0
49	9518D	25926	678	09-01-03 19:30:00	5160	61°59.96'S 22°58.95'E	09-01-03 22:45	0	4	0

Tab. 2.8-5: ARGOS/APEX profiling float setting positions during ANT-XX/2. All floats feature an ice avoidance software feature, based on measurement of the median temperature between 50 and 20 m water depth. Float times are set according GPS time which was 14 s late (GPS = UTC + 14 s) relative to UTC during this period.

Float No.				Start			Launch	
AWI	ARGO HEX	ARGO DEC	Sea scan	Start date time GPS	Dive start Expected surf.date	Water depth	Latitude Longitude	Date (UTC) Time (UTC) Wave height Wind (m/s) Ice coverage
01	4938F	4684	262	17-12-02 14:52	18-12-02 16-02-04	3497	66°00.27'S 00°10.30'E	18-12-02 20:28 0 0 7
02	49755	4701	263	17-12-02 14:38	18-12-02 16-02-04	3960	65°29.90'S 00°00.10'E	19-12-02 04:34 0 0 5

Float No.				Start			Launch	
03	5F0EB	6083	270	16-12-02 18:50	17-12-02 17-02-04	3758	65°00.31'S 00°00.36'E	19-12-02 11:13 0 5 4
04	498F0	4707	264	17-12-02 18:31	18-12-02 16-02-04	4670	64°30.36'S 00°00.40'E	20-12-02 00:04 0 4 4
05	49E14	4728	265	17-12-02 18:21	18-12-02 16-02-04	5200	64°00.18'S 00°00.30'E	20-12-02 03:04 0 6 0
06	49E47	4729	266	20-12-02 18:12	21-12-02 17-02-04	5414	62°33.87'S 04°11.42'E	22-12-02 03:22 2 8 0
07	49EE1	4731	268	21-12-02 10:13	22-12-02 16-02-04	5383	63°17.97'S 06°15.10'E	22-12-02 18:43 1 3 0
08	5F101	6084	271	21-12-02 15:37	22-12-02 16-02-04	4926	63°43.23'S 07°32.18'E	23-12-02 02:05 0 5 3
09	49F0B	4732	269	22-12-02 08:42	23-12-02 17-02-04	5028	64°07.30'S 08°38.93'E	23-12-02 09:22 0 8 2

Tab. 2.8-6: RAFOS float setting positions. Float times are set according to GPS time, which was 14 s late (GPS + 14 s) relative to UTC during this period.

Identifiers				Start	Deployments				
AWI project	Sound source SN.	Electr. SN.	AWI mooring	Ping time (GPS)	Water Depth (m)	Latitude Longitude	Date UTC Time UTC	Wave height (m)	Wind (m/s)
W1	49	14	229-5	00:35	5200	63°57.23'S 00°00.21'W	10-12-02 18:45	0	13
W2	19	19	231-5	01:05	4542	66°30.56'S 00°02.03'W	18-12-02 10:41	0	5
W3	21	21	240-1	01:35	5173	64°29.49'S 09°49.53'W	23.-12-02 15:40	0	9

Tab. 2.8-7: Position of sound source moorings.

2.9 Tracer measurements

Hendrik Sander and Martha Schattenhofer

CFCs and Tritium are transient tracers of anthropogenic origin. Measured distributions of these tracers provide information on the renewal of subsurface water from the ocean surface layer on decadal time scales. Sections on the Greenwich Meridian investigated during ANT-X/4 (1992), ANT-XIII/4 (1996) and ANT-XV/4 (1998) were repeated to evaluate the increase of the tracer concentrations in time. The comparison between the atmospheric and the *in-situ* increase will be used to study transport processes. In addition new sections in the east will provide information of the inflow from the east into the Weddell Sea.

All samples taken during the cruise will be analysed in the laboratory after the cruise. The waters samples for CFCs were taken from the rosette water sampler and were stored in flame-sealed ampoules for later analysis. Along the Greenwich Meridian 36 stations were sampled, along the section between 0° and the GeoBox thirteen stations, in the GeoBox six stations and along 23 °E 14 stations. Overall 1007 water samples for CFCs were taken. They will be extracted after the cruise and analysed with a mass spectrometer.

Snow samples for tritium measurements were taken at 25 locations along the entire cruise. This includes eight samples from icebergs, four samples from the shelf-ice and thirteen samples from ice floes. All gases will be extracted from the Tritium samples which will then be stored for half a year. After this time a sufficient amount of Tritium will have decayed to ^3He and can be measured by the mass spectrometer. This will help to improve the global Tritium input function and give more details about the local precipitation.

2.10 Naturally occurring radionuclides as tracers for water mass characterisation

Claudia Hanfland, Walter Geibert, Ingrid Vöge and Olaf Boebel

Natural radioactivity in the oceans originates mainly from three sources: cosmogenic nuclides, ^{40}K and decay products of the naturally occurring decay chains ^{238}U, ^{235}U and ^{232}Th. Especially isotopes of the latter find a wealth of applications in the study of oceanic reaction and transport processes taking place on time scales from hours and days to years. According to their geochemical behaviour in sea water, the radionuclides can be grouped after their respective particle-reactivity. For example, given, radium and actinium tend to stay in solution while thorium or protactinium are quickly scavenged by particles and subsequently transported to the seafloor. Disequilibria between parent and daughter nuclides are the consequence of this partitioning. While particle transport processes are investigated by means of adsorption-prone isotopes, water mass studies rely on elements having a soluble behaviour. The supply of the rather mobile elements to the water column is mostly by diffusion from sediments through decay from a particle-reactive parent while their distribution in the water column is governed by their respective half-lives.

During expedition ANT-XX/2, ^{234}Th, ^{226}Ra, ^{228}Ra and ^{227}Ac have been sampled in surface waters and on selected vertical profiles. ^{234}Th has been measured in order to estimate the export production from the upper water column into deeper water layers and will be presented in further detail in the chapter 2.11.5. SYNPART Project.

^{226}Ra and ^{228}Ra sampling program

Both ^{226}Ra and ^{228}Ra (half-lives 1600 yrs and 5.8 yrs, respectively) are released to the water column from the sediment through decay of thorium isotopes, but in consequence of a difference in parent distribution and half-life, the release of ^{226}Ra is strongest from deep-sea sediments while ^{228}Ra accumulates to high activities in shallow water regions.

Sampling for ^{226}Ra has been carried out with regard to two objectives:
(1) the quantitative determination of ^{226}Ra provides a simple means to convert $^{226}Ra/^{228}Ra$ activity ratios into absolute ^{228}Ra activities (see below).
(2) It is the most abundant of the radium isotopes in open ocean waters and is best suited to study the biogeochemistry of radium in the marine environment, i.e. its behaviour as a biointermediate element.

Radium has been considered as a water mass tracer with a nutrient-like distribution (Broecker et al. 1967). Based on the similarity of vertical water column profiles of ^{226}Ra and Si, it was hypothesised that siliceous tests act as a main carrier phase for ^{226}Ra (Ku et al. 1970, Ku & Lin 1976). Given the predominance of diatoms over other phytoplankton species in the Southern Ocean, the relation should hold especially in circumpolar waters. However, results from previous cruises have indicated that the uptake of ^{226}Ra continues north of the Polar Front after the near depletion of Si, pointing to a decoupling of both parameters.

Besides the subsampling necessary for the ^{228}Ra analysis, ^{226}Ra was sampled on three selected vertical water column profiles (Fig. 2.10-1) in conjunction with nutrient

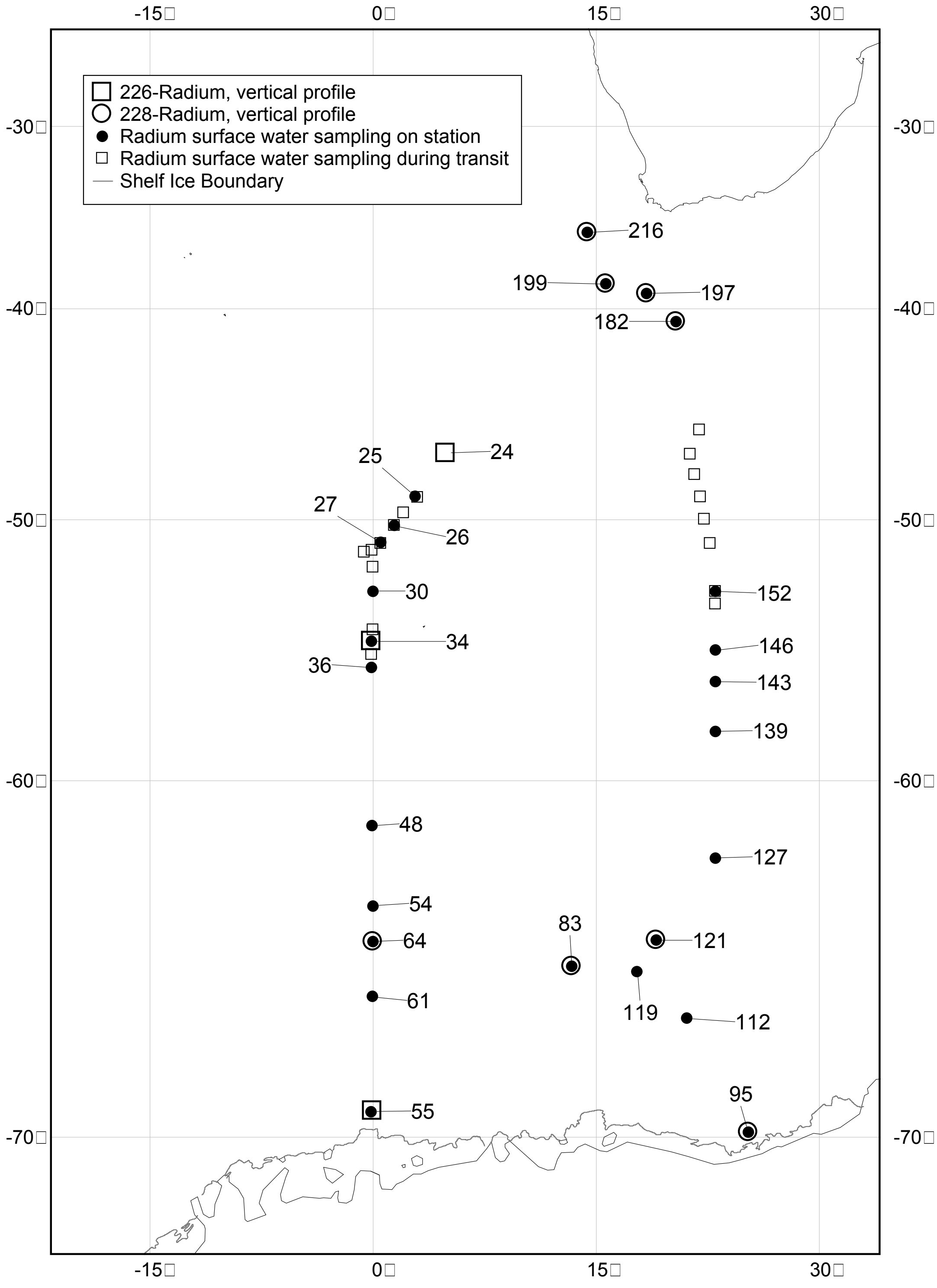

Fig. 2.10-1: Sampling chart for radium and actinium during ANT-XX/2. Numbers refer to official stations, full labelling should read: PS63-xxx.

analysis in order to get a better idea of the biogeochemical processes governing the distribution of ^{226}Ra in southern circumpolar waters.

^{228}Ra has been used widely (e.g. KAUFMANN et al. 1973, REID et al. 1979, MOORE et al. 1986, RUTGERS VAN DER LOEFF et al. 1995) as a tracer for prolonged contact of water masses with continental shelf areas. It is a daughter product of ^{232}Th, which is common in most sediment types but nearly absent in sea water due to its particle reactive behaviour. In contrast, radium is soluble in sea water and can accumulate to high activities over fine-grained sediment. According to its half-life of 5.8 years, the activity of ^{228}Ra will decrease with distance from the source and is extremely low in the open ocean.

Dependant on the geographic region, the sampling for ^{228}Ra during ANT-XX/2 was performed under different aspects (Fig. 2-10-1):

Polar Frontal Region

In the context of iron as a growth-limiting factor for the primary productivity of the Southern Ocean, the oceanic fronts within the Antarctic Circumpolar Current (ACC) and especially the Polar Front have been suggested as effective transport mechanisms for iron released from continental shelf sediments and transported eastwards with ACC (DE BAAR et al. 1995, LÖSCHER at al. 1997). If the shelf areas represent indeed important source areas of iron for the open South Atlantic, this should be mirrored by increased ^{228}Ra activities. Results from previous cruises indicate an ambiguous picture, pointing to rather sporadic inputs that are highly variable in both space and time. Hence, high resolution sampling of the Polar Frontal Region along 0° and 23 °E was done in order to get a better picture of the variability of possible shallow water inputs with the Polar Front.

South-Eastern Weddell Gyre

Inflow of North Atlantic Deep Water into the Weddell Gyre takes place in its south-eastern corner (ORSI et al. 1993), a region where currently only very few natural radionuclide data are available for (GEIBERT et al. 2002, HANFLAND 2002). The determination of ^{228}Ra will help to demarcate the extension of coastal waters into the Weddell Gyre.

Agulhas (Return) Current

Intense mixing of subtropical and subantarctic water masses takes place in the region south of South Africa. Occlusion of the retroflecting Agulhas Current generates rings that move northwestwards into the Atlantic while perturbations in the flow of the Agulhas Current lead to the spawning of both cyclonic and anticyclonic eddies (LUTJEHARMS 1996, BOEBEL et al. 2003). The mixing waters carry very distinct ^{228}Ra signals, a feature that should help especially in a better distinction of the origin of cyclonic eddies. While waters moving north from the Antarctic zone are typically low in ^{228}Ra, cyclones developing along the South African coast in the course of a Natal Pulse can be expected to carry a strong coastal signal.

Four stations had been sampled for ^{228}Ra within the Agulhas Retroflection Area (Fig. 2-10-2):

PS 63-182:	cyclonic eddy	PS 63-197:	Agulhas Retroflection
PS 63-199:	cyclonic eddy	PS 63-216:	Agulhas ring

A highly variable, mesoscale flow field dominates the Agulhas Region. To obtain samples as close as possible to the end-members of each regime, an identification of these mesoscale features during the cruise was mandatory. Using steric sea-surface height anomalies (SSH data) from MODAS (Modular Ocean Data Assimilation System), the location of cyclones and anticyclones was achieved in real-time. Daily MODAS SSH fields were uploaded to RV POLARSTERN by the Stennis Space Center at the Naval Research Lab, Mississippi in real time. MODAS-SSH data have recently been shown to provide a highly reliable view of the overall distribution of the mesoscale flow field (BOEBEL & BARRON 2003) in this region. Modulations in the SSH field are directly related to ocean currents, which flow along SSH isolines with higher SSH values to their left when looking downstream (Fig. 2.10-2).

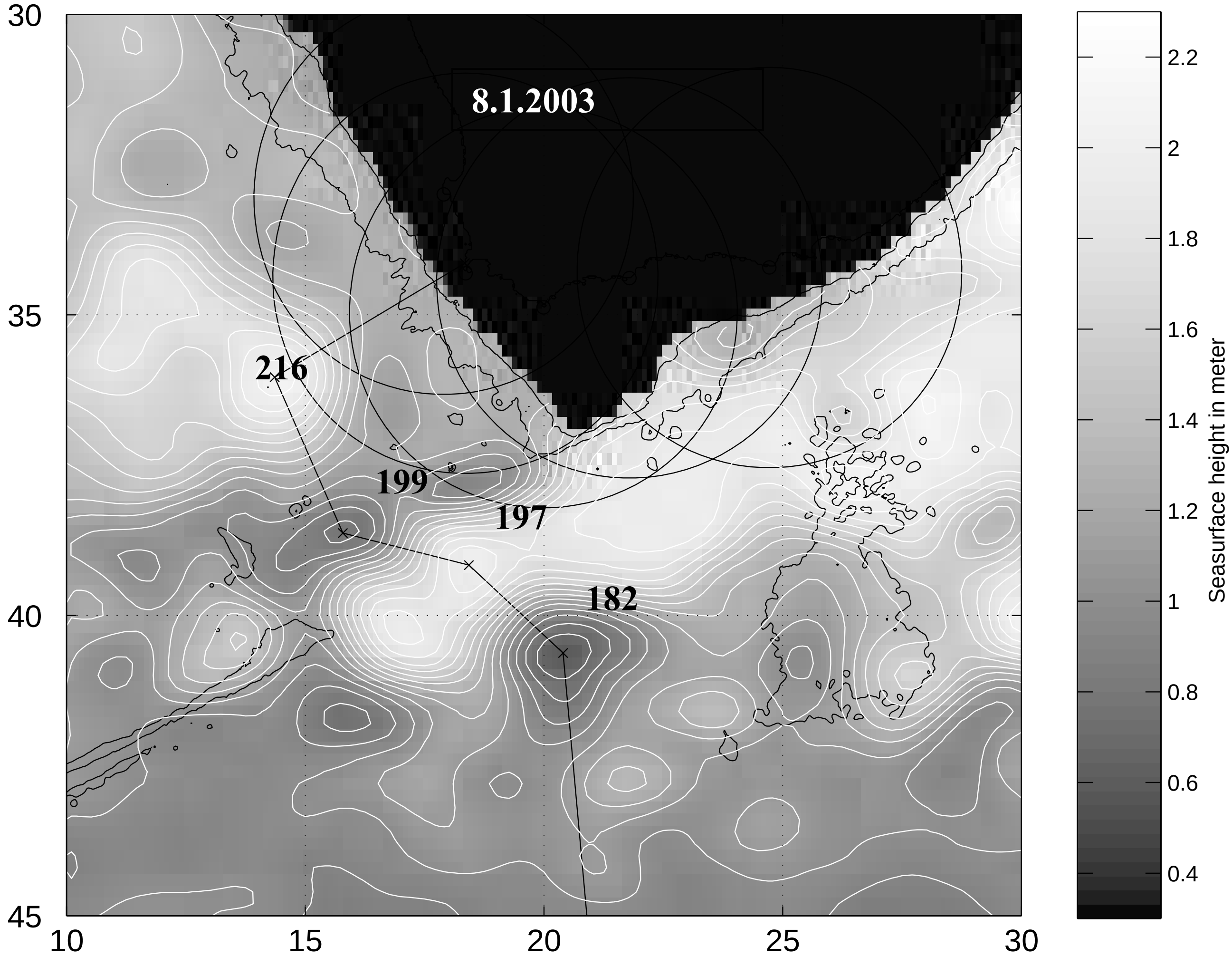

Fig. 2.10-2: Steric sea-surface height (SSH) from MODAS from January 18, 2003. Similar plots were produced for each day and the cruise track adjusted as to sample the water in each features' centre.

The reliability of the actual MODAS SSH fields was tested during the cruise by monitoring the depth of the 10 °C isotherm. The latter should be located at depths around 800 m when an anticyclone is traversed, or alternatively, at 300-500 m when encountering cyclones. This was indeed the case when XBT casts succeeded, though between PS63-197 and PS63-199 only few XBT profiles were collected due to bad weather.

Figure 2-10-2 shows the situation on January 18, 2003. The first eddy sampled near 40°37'S (PS63-182) shows a local SSH minimum and hence represents a cyclonic circulation pattern, which we traced back in time to a subantarctic origin. PS63-197 on the other hand is located at the local SSH maximum indicative of the Agulhas Retroflection proper.

A cyclone north of the Agulhas Retroflection might have subantarctic (Atlantic) or subtropical/Indian origin (a Natal Pulse) or might have been formed locally (BOEBEL et al. 2003). One such cyclone has been probed during PS63-199. In contrast to the previous two locations, this feature is not expected to display end-members but a mix of Indian and Atlantic water types.

The same holds true for the last station in a matured Agulhas Ring (anticyclone) sampled during PS63-216. While travelling north, these features have been shown to entrain surrounding waters, which could be of subantarctic and/or subtropical origin.

^{227}Ac sampling program

^{227}Ac (half-life 21 yrs) is almost exclusively released from deep-sea sediments into bottom waters. Any excess activity over its parent nuclide ^{231}Pa in the upper water column indicates rapid upwelling of deeper water masses (GEIBERT et al. 2002). Sampling for ^{227}Ac at the sea surface follows the same procedure as described for ^{228}Ra (see below). Determination of the ^{227}Ac activity will be done on all surface water samples in the Weddell Gyre and on the vertical stations PS63-64, PS63-83 and PS63-121. The combined analysis of ^{227}Ac and ^{228}Ra will allow a better distinction of deep upwelling versus lateral input of water masses in the southeastern Weddell Gyre.

Additional sampling

Samples for the determination of ^{231}Pa and ^{230}Th in the water column were taken on three selected vertical profiles. These samples will be analysed by the University of Kiel (group Scholten/Fietzke).

Additionally, three samples of Weddell Sea Deep Water were taken for the analysis of the isotopic composition of Cadmium (analysis by Rehkamper, ETH Zürich).

Methods

^{226}Ra

20 l of sea water were taken either directly from the ship's sea water supply or sampled from the CTD. Surface water samples were run through a 1µm-prefilter to remove particulate matter. Particle concentrations from samples taken below the mixed layer

were so low that filtering was not necessary. The samples were then weighed to determine the sample size. Even in rough seas, this is accurate to at least 100 g which equals an error of 0.5 % for 20 kg. A pre-weighed aliquot (100 ml) of a $BaCl_2$-solution that had been prepared before the cruise was added under constant stirring to every 20 l water sample to precipitate radium as $Ba(Ra)SO_4$, making use of the natural sulfate content in sea water. After at least one hour of further mixing on the magnetic stirrer, the crystals were recovered by decantation and centrifugation and washed several times to remove any interfering ions.

At home, the dried and weighed precipitates will be filled in plastic tubes, sealed and set aside for about three weeks to allow the short-lived daughters ^{214}Pb and ^{214}Bi to grow into equilibrium with their parent ^{226}Ra. After establishment of a secular equilibrium, the sample will be counted by γ-spectrometry.

^{228}Ra and ^{227}Ac

Sampling was performed with MnO_2-coated cartridges that had been prepared before the cruise by immersion overnight at 70 °C in a bath of a saturated $KMnO_4$ solution. The radionuclides get adsorbed on the MnO_2-coating. For surface water samples, a filter system was connected to the ship's sea water supply. The water sample was run through an uncoated cartridge (1 µm) for removing particulate matter, two MnO_2-coated cartridges put in series and a flowmeter for recording the sample volume. Typical sample volumes were between 1 and 3 m^3. Sampling on vertical water profiles was performed with six time-programmed pumping units, equally loaded with a prefilter and two coated cartridges. The pumps were let on depth for 2.5 hrs and filtered about 1 m^3 of sea water.

In the home lab, the coated cartridges will be rinsed with deionised water and dried. Further processing of the samples involves acid-leaching of the cartridges, separation of the different isotope fractions by repeated precipitation and ion-exchange chromatography and determination of the respective activities by alpha- or gamma-spectrometry. Due to their extremely low activities, ^{228}Ra and ^{227}Ac will be analysed via their daughter-nuclides ^{228}Th and ^{227}Th, respectively (MOORE 1972, LI et al. 1980, GEIBERT 2002).

As the adsorption of radionuclides on cartridges is seldom quantitaive, the results must be corrected for their efficiency (*E*). For ^{228}Ra, the cartridges yield $^{228}Ra/^{226}Ra$ activity ratios that are converted to absolute ^{228}Ra activities by means of the ^{226}Ra subsamples. ^{227}Ac is determined by using the cartridge formula: E = 1-B/A, where A and B are the two cartridges put in line (RUTGERS VAN DER LOEFF & MOORE 1999).

For the determination of ^{227}Ac activities on depth profiles, it was planned to use a delayed coincidence counter system (MOORE & ARNOLD 1996). However, when in operation on board, the counting unit proved to have several substantial problems. First, the manganese adsorbers dried within about half an hour, with the effect of large changes in counting efficiency. The counting of test samples showed additionally intervals of increased background activity. These intervals were irregular in time, and the activity too variable to allow reliable counting of the samples. Therefore, a different method of sampling was applied. To the water samples (12-60 l) NH_4OH, $KMnO_4$, and $MnCl_2$ were added in small amounts to produce a MnO_2 precipitation that adsorbs ^{227}Ac

quantitatively. Later, the precipitate was filtered onto 142 mm diameter polycarbonate filters with 1 µm pore size. ^{234}Th was counted on the filters as a yield tracer for the MnO_2. Back in the home lab, the samples containing the ^{227}Ac will be dissolved, purified and counted via the more sensitive □-spectrometric method.

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