1 Research Objectives

1.1 Introduction

METEOR-cruise 45 took place in the North Atlantic Ocean with measurements north of 40°N during three legs as well as in the Gulf of Cadiz, around the Azores and the Canary Islands during 2 legs (Fig. 1). The cruise began on 18 May 1999 in Malaga and ended on 4 November 1999 in Las Palmas. METEOR-cruise 45 combined activities of physical oceanography, marine chemistry, meteorological and geological working groups (Table 1).

The research activities during METEOR cruise M45/1 were related to the scientific programs CANIGO/ ESTOC and DOMEST. At the beginning of the cruise the structures of the near-surface sediments, which reflect the effects of paleooceanographic and paleoclimatic variability in the sedimentation processes, has been continuously monitored at high resolution with the PARASOUND echosounder system in the Gulf of Cadiz. Near the Canary Islands, the scientific work was focused on the nationally funded project DOMEST. New devices like the integrated Multi Sensor Device (sediment trap, CTD and micro controller with acoustic underwater communication), the deep sea YoYo profiling vehicle, deep sea winch system and the optical refractometer were tested successfully for their functioning on board and in the deep ocean.

Parallel to the DOMEST activities, scientific work related to the EU funded CANIGO/ESTOC project has been carried out. The ESTOC sediment trap mooring was turned around and the La Palma mooring was recovered without replacement. In addition vertical profiles with the high resolution particle-camera system ParCa were recorded, drifting sediment traps were used twice in the ESTOC region and intense water column sampling and probing with multi-pumps and a rosette watersampler was carried out at ESTOC and DOMEST locations, performed by the marine chemistry working group.

The objectives during the second and the third leg were regional investigations of the thermohaline circulation in the western and eastern basins within the context of the Sonderforschungsbereich SFB 460 "Dynamics of thermohaline circulation variability" at the University of Kiel. The main objectives during the SFB 460 related cruise legs were hydrographic measurements as well as intense mooring work, supplemented with marine chemistry, tracer, meteorological measurements and float deployment.

The subpolar North Atlantic has a significant impact on the moderate climate conditions of Europe. The southward export of North Atlantic Deep Water from this region parallels the export from the continental slope of America. It is the "cold limb" of the global thermohaline circulation cell. North Atlantic Deep Water consists of a blend of overflow waters from the sills between Greenland, Iceland and Scotland. Additional components are Labrador Sea Water and mixing products of Mediterranean Water and Antarctic Bottom Water.

The formation of the Deep Water components and its transports and paths are variable and the different mooring arrays maintained or newly deployed are aimed at investigating the formation process of Labrador Sea Water by the ADCP/CTD and tomography mooring array in the Labrador Sea and to record continously the variability of the Labrador Sea export by the western boundary current mooring array. The hydrographic surveys will allow to investigate the spreading paths and year to year differences of the different water masses. Further, a "float park" releases deep drifters into the mid depth circulation of the eastern basin to determine pathways of the cold water masses.

Besides the hydrographic and mooring work distributions of total dissolved inorganic carbon and total alkalinity were measured at the hydrocast locations of the SFB 460 related cruise legs. Nutrients and dissolved oxygen were determined in parallel. This combined analysis will allow the calculation of the penetration of anthropogenic CO_2 into the water column. Additionally, a system to continously monitor the

CO_2 partial pressure in surface waters and air was operated during the two legs. This will allow calculating the CO_2 flux between atmosphere and ocean.

Cruise leg M45/4 was a contribution to the EC- project VEINS (Variability of exchanges in the Northern Seas). Eighteen countries are contributing to field work and modeling of the transport fluctuations through the major ocean passages between the Arctic Ocean and the Northern North Atlantic. This cruise focussed on the fluxes of water masses in the area from the Denmark Strait to the southern tip of Greenland. It is a repeat of METEOR-cruise M39/5 in 1997 and of Valdivia-cruise 173 in 1998.

For logistical reasons, cruise leg M45/5 was subdivided into two parts, the first covering the sedimentological investigations in the North Sea, Azores frontal system and off NW Africa, the second part focusing on instrument testing and water column investigations. The harbour of Las Palmas was visited in-between the two parts in order to exchange scientists and equipment. The cruise took place with international collaboration of Portuguese and Spanish scientists.

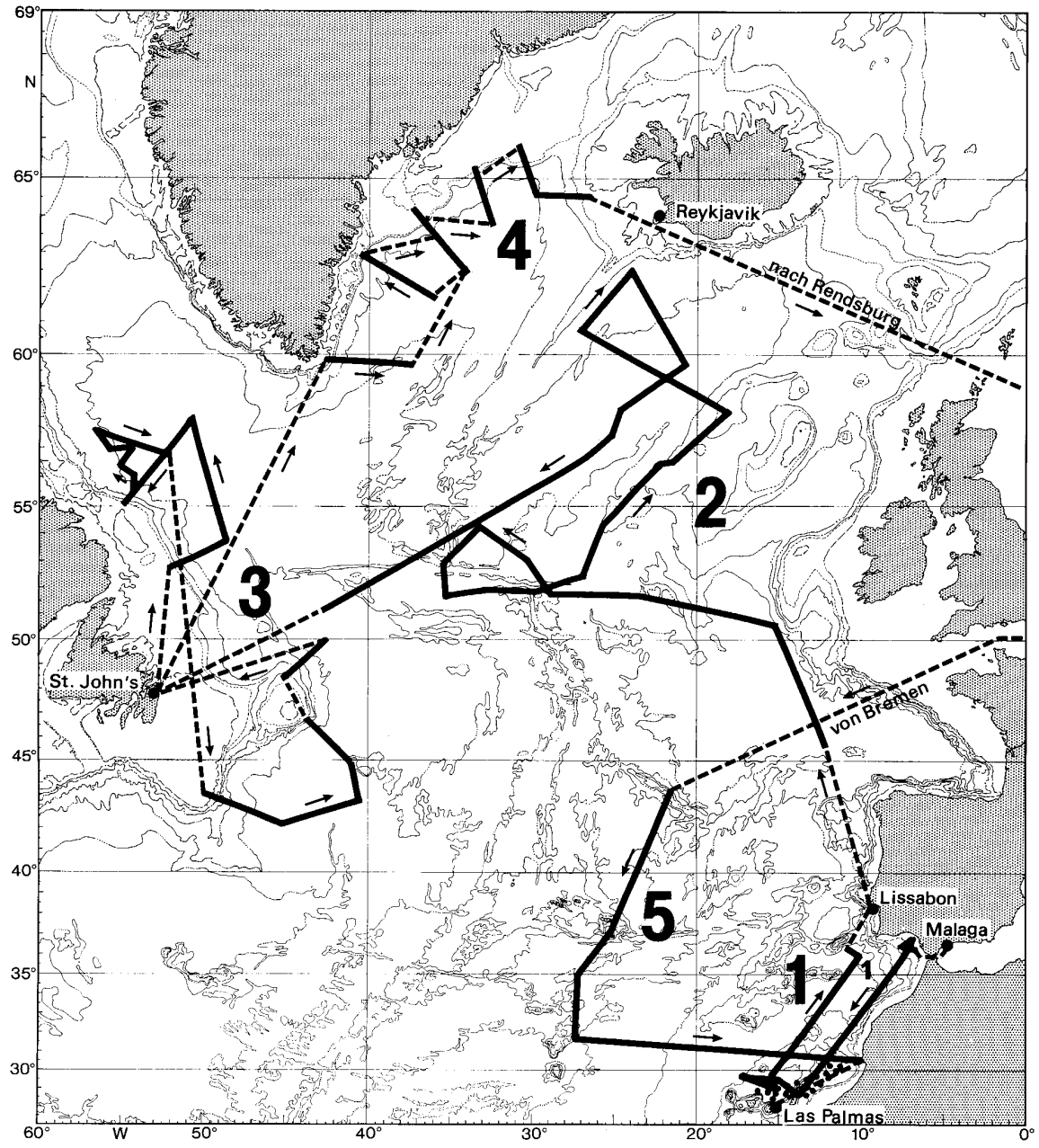

Fig. 1: Cruise track of the 5 legs of METEOR cruise M 45. For details of the work in the Skagerrak and the North Sea see Fig. 8.

Tab.1: Legs and chief scientist of METEOR cruise No. 45.

Leg M45/1
18.05.-09.06.1999, Malaga, Spain - Lisbon, Portugal
Chief scientist : Dr. G. Meinecke

Leg M45/2
10.06.-09.07.1999, Lisbon, Portugal - St. John's, Canada
Chief scientist : Dr. W. Zenk

Leg M45/3
10.07.-11.08.1999, St. John's, Canada - St. John's, Canada
Chief scientist : Prof. Dr. F. Schott

Leg M45/4
12.08.-31.08.1999, St. John's, Canada - Rendsburg, Germany
Chief scientist : Prof. Dr. J. Meincke

Werft/Ship yard
01.09.-29.09.1999
30.09.1999, Transfer to Bremen

Leg M45/5a
01.10.-25.10.1999, Bremen, Germany - Las Palmas, Canary Islands, Spain
Chief scientist : Frau Dr. S. Neuer

Leg M45/5b
26.10.-4.11.1999, Las Palmas, Canary Islands, Spain - Las Palmas, Canary Islands, Spain
Chief scientist : Frau Dr. S. Neuer

Coordination: Prof. Dr. F. Schott

Masters: Captain S. Bülow
Captain M. Kull

1.2 Projects

The Sonderforschungsbereich SFB 460 "Dynamics of thermohaline circulation variability" started in 1996 at Kiel University. Main objective of the SFB 460 is to investigate the variability of the watermass formation and transport processes in the subpolar North Atlantic and to gain an understanding of its role in the dynamics of the thermohaline circulation and the ocean uptake of anthropogenic CO_2. The variability of circulation and water mass distribution are closely related with climate changes in northern Europe through the North Atlantic Oscillation (NAO). These connections were a central issue of the SFB research during cruise M45. The interaction of the measuring and the modelling groups within the SFB 460 will allow improved interpretation of the measured data.

A wide range of hydrographic, tracer and current measurement techniques were applied to investigate the variability of the circulation of the subpolar North Atlantic. A new component of the second funding phase of the SFB 460 (1999-2002) is to extend the major measurement area from the subpolar gyre measuring the deep water export towards the subtropical Atlantic. Part of the measurements during M45 were designated to investigate the western boundary deep water export from the subpolar to the subtropical gyre.

VEINS (Variability of Exchanges in the Northern Seas) is an EU-MAST Project focussing on the variability of oceanic fluxes between the Arctic Ocean and the Northern North Atlantic for a period of three years. Its objective is to develop a cost-efficient array for the long-term monitoring of the polar and subpolar contributions to the decadal climate variability. VEINS aims at a synoptic coverage of fluxes through Fram Straits, the Western Barents Shelf, the Iceland-Scotland Ridge and the Denmark Straits, including the continental slope of SE-Greenland.

The goal of CANIGO (Canary Islands Azores Gibraltar Observations) Subproject 3 is to quantitatively determine the influence of coastal upwelling and Saharan dust on the magnitude and composition of particle flux in the Canary region, and to investigate how this influence varied through the last glacial and interglacial period. The main aim of the first work package „Flux of dissolved and particulate matter in the water column" is to quantify particle flux and to determine its composition on seasonal and interannual time scales along a zonal transect at 29°N to be able to discern autochtonous export production from the eolian input and deep and shallow sources of advected particulate matter. The main goal of the second work package „Flux variability through the last glacial-interglacial cycle" is to study the variability of accumulation rates of environmentally sensitive parameters and atmospheric dust through the last glacial-interglacial cycle across an upwelling margin.

The aim of the project DOMEST (Data transfer in the ocean and technology to record participle transport into the deep ocean) is the development of a moored sensor network in the deep sea. The advanced sensors will provide high-resolution data on particle fluxes and element concentrations in the open ocean and can be accessed from land via satellite and acoustic transmission. Communication under water will be performed through a bidirectional acoustic high-speed telemetry. Above water, a low-earth-orbit (leo) satellite network will establish the data transport between the moored system and a landbased ground station. The system will be deployed at 4000 m water depth over a maximum duration of one year.

2 Participants

Tab.2: Participants of METEOR cruise no. 45

Leg M45/1

Name	Speciality	Institute
1. Meinecke, Gerrit, Dr.	Chief Scientist	GeoB
2. Bergenthal, Markus	DOMEST	GeoB
3. Deeken, Aloys	Chemistry Marine	UBMCh
4. Drünert, Frank	DOMEST	OHB
5. Langer, Jens	Marine Geology	GeoB
6. Metzler, Wolfgang	DOMEST	GeoB
7. Meyer, Birgit	GeoB	GeoB
8. Nowald, Nicolas	DOMEST	GeoB
9. Oppen, Caroline von	Marine Chemistry	UBMCh
10. Ratmeyer, Volker, Dr	DOMEST	GeoB
11. Rosiak, Uwe	DOMEST	GeoB
12. Ruhland, Götz	DOMEST	GeoB
13. Waldmann, Ch., Dr.	DOMEST	GeoB
14. Morisse, Ole	Marine Chemistry	UBMCh
15. Stregel, Sven	Marine Geology	GeoB
16. Kaufeld, Lothar, Dr.	Meteorology	DWD
17. Ochsenhirt, Wolf-Th.	Meteorology	DWD

Leg M45/2

Name	Speciality	Institute
1. Zenk, Walter, Dr.	Chief scientist	IfMK
2. Becker, Sylvia	Marine Physics	IfMK
3. Böhme, Lars	Marine Physics	IfMK
4. Carlsen, Dieter	Marine Physics	IfMK
5. Csernok, Tiberiu	Marine Physics	IfMK
6. Dankert, Jutta	Tracer Oceanography	IOW
7. Dietze, Heiner	Marine Physics	IfMK
8. Elbrächter, Martina	Tracer Oceanography	IfMK
9. Fietzke, Jan	Geochemistry	IfG
10. Frenzke, Hanna	Marine Chemistry	IfMK
11. Friis, Karsten	Marine Chemistry	IfMK
12. Johannsen, Hergen	Marine Chemistry	IfMK
13. Johnson, Kenneth M., Dr. h.c.	Marine Chemistry	IfMK
14. Kahl, Gerhard	Meteorology	DWD
15. Kieke, Dagmar	Tracer Oceanography	IfMK
16. Körner, Sven	Meteorology	DWD
17. Meyer, Peter	Marine Physics	IfMK
18. Müller, Thomas, Dr.	Marine Physics	IfMK
19. Ochsenhirt, Wolf-Thilo	Meteorology	DWD
20. Pinck, Andreas	Marine Physics	IfMK
21. Reich, Michael	Marine Physics	IfMK
22. Wild, Christian	Tracer Physics	UB

Tab.2: continued

Leg M45/3

Name	Speciality	Institute
1. Schott, Friedrich, Prof., Dr.	Chief Scientist	IfMK
2. Badewien, Thomas	CFC	IOW
3. Begler, Christian	CTD/mooring	IfMK
4. Brandt, Peter, Dr.	CTD/Pegasus	IfMK
5. Coatelan, Stephane	Tomography	ORCA
6. Coldewey, Melanie	Meteorology	IfMK
7. Dombrowsky, Uwe	CTD	IfMK
8. Elbrächter, Martina	CFC	IfMK
9. Fischer, Jürgen, Dr.	ADCP/moorings	IfMK
10. Friis, Karsten	CO_2-system	IfMK
11. Helmbrecht, Lutz	CTD	IfMK
12. Hohmann, Roland, Dr.	Tracer	LDEO
13. Johnson, Kenneth	CO_2-system	IfMK
14. Kahl, Gerhard	Meteorology	DWD
15. Kindler, Detlef	Tomography	IfMK
16. Link, Rudolf	CTD/moorings	IfMK
17. Malien, Frank	Nutients, O_2	IfMK
18. Mertens, Christian	Pegasus, CTD	IfMK
19. Morsdorf, Felix	ADCP/CTD	IfMK
20. Müller, Mario	ADCP, moorings	IfMK
21. Ochsenhirt, Wolf-Thilo	Meteorology	DWD
22. Papenburg, Uwe	ADCP/moorings	IfMK
23. Rhein, Monika, Prof. Dr.	CFC	IOW
24. Steinhoff, Tobias	CO_2-system	IfMK
25. Stramma, Lothar, Dr.	CTD	IfMK
26. Strümpel, Sebastian	CFC	IfMK
27. Terre, Thierry	Tomography	IFRB

Tab.2: continued

Leg M45/4

Name	Speciality	Institute
1. Meincke, Jens	Chief Scientist	IfMH
2. Bassek,Dieter	Meteorology	DWD
3. Bulsiewicz, Klaus	Tracer	UBL
4. Classen, Nikolaus	Oceanography	IfMH
5. Hargreaves, Geoffrey	Moorings	POL
6. Holfort, Jürgen	Oceanography	IfMH
7. Kahl, Gerhard	Meteorology	DWD
8. Knuth, Edmund	Meteorology	DWD
9. Nerger, Wolf-Christian	Oceanography	IfMH
10. Plähn, Olaf	Tracer	IOW
11. Rabe, Berit	Oceanography	IfMH
12. Read, John	Moorings	CEFAS
13. Rinas, Knud	Oceanography	IfMH
14. Rudels, Bert	Oceanography	FIMR
15. Schlimme, Ingo	Tracer	IfMK
16. Schulze, Klaus	Oceanography	IfMH
17. Verch, Norbert	Oceanography	IfMH
18. Wüllner, Helmut	Moorings	IfMH

Leg M45/5a

Name	Speciality	Institute
1. Neuer, Susanne, Dr.	Chief Scientist	GeoB
2. Diekamp, Volker	Marine Geology	GeoB
3. Grimm, Guido	Marine Geology	UT
4. Hayn, Christina	Marine Geology	GeoB
5. Hebbeln, Dierk, Dr.	Marine Geology	GeoB
6. Huebner, Hagen	Marine Geology	UG
7. Kahl, Gerhard	Meteorology	DWD
8. Köster, Jana	Marine Geology	GeoB
9. Langer, Jens	Marine Geology	GeoB
10. Meggers, Helge, Dr.	Marine Geology	GeoB
11. Nave, Silvia, MS	Marine Geology	GeoB
12. Ochsenhirt, Wolf-Thilo	Meteorology	DWD
13. Rosiak, Uwe	Marine Geology	GeoB
14. Schiebel, Ralf, Dr.	Marine Geology	UT
15. Struck, Ulrich, Dr.	Marine Geology	UT
16. Themann, Sören	Marine Geology	UT

Tab.2: continued

Leg M45/5b

Name	Speciality	Institute
1. Neuer, Susanne, Dr.	Chief scientist	GeoB
2. Alfke, Rolf Fritz Wilhelm	Engineering	STN
3. Bergenthal, Markus	DOMEST	Marum
4. Bittkau, Axel	DOMEST	OHB
5. Böhme, Lars	Physical Oceanography	IfMK
6. Bothmer, Hartmut	DOMEST	OHB
7. Cianca, Andrés	Marine Chemistry	ICCM
8. Freudenthal, Tim	Marine Chemistry	GeoB
9. Gerdes, Albert	Media	Marum
10. Godoy, Joana	Marine Chemistry	ICCM
11. Hayn, Christina	Marine Geology	GeoB
12. Kahl, Gerhard	Meteorology	DWD
13. Klein, Thorsten	DOMEST	Marum
14. Laglera, Luis	Marine Chemistry	ULPGC
15. Langer, Jens	Marine Geology	GeoB
16. Lenz, Bernd	Physical Oceanography	IfMK
17. Meinceke, Gerrit, Dr.	DOMEST	Marum
18. Metzler, Wolfgang	DOMEST	Marum
19. Moroto, Lleire	Marine Chemistry	ICCM
20. Ochsenhirt, Wolf-Thilo	Meteorology	DWD
21. Ratmeyer, Volker, Dr.	DOMEST	GeoB
22. Rosiak, Uwe	DOMEST	GeoB
23. Rueda, Maria-José, Dr.	Marine Chemistry	ICCM
24. Ruhland, Goetz	DOMEST	Marum
25. Schüßler, Uwe, Dr.	Marine Chemistry	UBMch
26. Villagarcia, Marimar, Dr.	Marine Chemistry	ICCM
27. von Oppen, Caroline	Marine Chemistry	UBMCh
28. Waldmann, Christoph, Dr.	DOMEST	GeoB

Tab. 3: Participating Institutions

BSH	Bundesamt für Seeschiffahrt und Hydrographie Bernhard-Nocht-Str. 78 20597 Hamburg — Germany
CEFAS	Centre for Environment Fisheries & Aquaculture Science Lowestoft Laboratory Lowestoft, Suffolk NR33 0HT — England
CSIC	Unidad de Gestión de Buques Oceanográficos Instituto de Ciencias del Mar CSIC Paseo Juan de Borbon s/n 08039 Barcelona — Spain
DWD	Deutscher Wetterdienst Geschäftsfeld Seeschiffahrt Bernhard-Nocht-Str. 76 20359 Hamburg — Germany
FIMR	Finnish Institute for Marine Research P.O. Box 33 Lyypekinkuja 3a 00931 Helsinki — Finland
GEO	Geomar Forschungszentrum für Marine Geowissenschaften Universität Kiel Wischhofstr. 1-3 24148 Kiel — Germany
GeoB	Universität Bremen Fachbereich 5, Geowissenschaften Klagenfurter Str. 28359 Bremen — Germany
ICCM	Instituto Canario de Ciencias Marinas Dirección General de Universidades e Investigación Consejeria de Educacion 35200 Telde, Canary Islands — Spain

Tab. 3: continued

IfG	Institut für Geowissenschaften Abteilung Geologie-Paläontologie und Museum Ludewig-Heyn-Str. 10 24118 Kiel — Germany
IfMH	Institut für Meereskunde an der Universität Hamburg Tropolowitzstr. 7 22529 Hamburg — Germany
IfMK	Institut für Meereskunde an der Universität Kiel Düsternbrooker Weg 20 24105 Kiel — Germany
IFRB	IFREMER Brest Institut Francais de Recherche pour l'Exploitation de la Mer B.P. 70, Pointe de diable 29280 Plouzané (Brest) — France
IGM	Instituto Geológico e Mineiro Rua Academia das Ciências, 19-2° 1200 Lisboa-Portugal
IOW	Institut für Ostseeforschung Warnemünde Seestraße 15 18119 Rostock-Warnemünde — Germany
LDEO	Lamont-Doherty Earth Observatory of Columbia University N.Y. 61 Route 9W Palisades N.Y. 70964 — USA
Marum	Zentrum für Marine Umweltwissenschaften Universität Bremen Klagenfurter Str. 28359 Bremen — Germany
OHB	Raumfahrt + Umwelttechnik OHB-System-GmbH Universitätsallee 27-29 28359 Bremen — Germany

Tab. 3: continued

ORCA	ORCA Instrumentation 5, Rue Pierre Rivoalon 29200 Brest — France
POL	Proudman Oceanographic Laboratory Bidston Observatory Birkenhead, Merseyside L43 7RA — England
RF	R/F Reedereigemeinschaft Forschungsfahrt GmbH Haferwende 3 28357 Bremen — Germany
STN	Atlas Seebaldsbrücker Heerstrasse 235 28305 Bremen Germany
UB	Universität Bremen Institut für Umweltphysik, Abt. Tracer-Ozeanographie Bibliotheksstraße 28359 Bremen — Germany
UBMCh	Universität Bremen Fachbereich 2 - Biologie/Chemie, Meereschemie Leobener Straße 28359 Bremen
UBU	Universität Bremen Institut für Umweltphysik, Abt. Tracer-Oceanographie Bibliotheksstraße 28359 Bremen — Germany
UG	Universität Göttingen Institut und Museum für Geologie und Paläontologie Georg-August-Universität Göttingen Goldschmidtstr. 3 37077 Göttingen - Germany

Tab. 3: continued

ULPGC	Universidad de Las Palmas de Gran Canaria Edificio de Ciencias Básicas Campus Universitario Tarifa 35017 Las Palmas de Gran Canaria, Canary Islands — Spain
UT	Universität Tübingen Geologisch- und Paläontologisches Institut Sigwartstr. 10 72076 Tübingen — Germany

3 Research Program

3.1 Sonderforschungsbereich (SFB) 460

The research program of the SFB is based on a combination of physical-oceanographic, marine chemistry and meteorological observation programs, which work in close interaction with a system of numerical models of moderate (50 km), high (15 km) and very high resolution (5 km), allowing simulations of current structures and variability over a wide range of space and time scales. The main interests at the end of the first SFB phase are, first, the water mass formation processes and the circulation of deep water in the subpolar North Atlantic, their interaction and integral effects, especially with regard to the uptake of anthropogenic CO_2. Second, the variability of the ocean - atmosphere interaction is investigated, and modelling investigations of large-scale aspects and causes of this variability are supplemented by the analysis of fluxes from different meteorological standard models in comparison with observations, with emphasis on the fresh water exchange.

The observations during leg M45/2 continued the series of hydrographic and tracer measurements in the eastern North Atlantic. The data will be used for exploring mixing time scales and contribution of Iceland Scotland Overflow Water (ISOW) to the formation of North Atlantic Deep Water (NADW). The investigation focussed on the NADW fraction which remains in the eastern North Atlantic and on Labrador Sea Water (LSW). Leg M45/2 in the Iceland Basin allowed determining the overflow characteristics and served as a northern boundary condition for overflow studies „downstream“ in the deep circulation. The determination of hydrographic conditions and of tracer concentrations of the water flowing through the Charlie Gibbs Fracture Zone was an additional focus of the research program.

Furthermore, chemical observations were carried out during the cruise. The goal remains to collect and interpret especially the effect of changes in thermohaline circulation on the uptake and distribution of anthropogenic CO_2 in the North Atlantic Ocean. With this knowledge predictions can be made concerning climate and the potential for altering the oceanic uptake of anthropogenic CO_2.

Transient tracers (CFCs, bomb tritium) are also a valuable tool to study time scales of oceanic processes due to their time dependent input. The concentrations of tritium are a result of the variable input as well as of its radioactive decay. Measuring ^{3}Helium as well enables us to determine the tritium-helium age, which is an estimate for the elapsed time since the last contact of a water mass with the atmosphere.

Cruise M45/3 studied the deep circulation in the western subpolar North Atlantic which is a critical region for the climate of the North Atlantic region. Here, strong water mass transformations take place, with far-reaching consequences. This region is formation as well as transformation region of cold water masses, which are exported and as a consequence require northward compensating flow of warm water masses.

The deep western boundary current, fed by the Denmark-Strait-Overflow at the lowest level and by the Deep Water from the Gibbs-Fracture-Zone above, flows along the topography in the Labrador Sea and continues past the Grand Banks. Indications exist for a deep cyclonic recirculation cell located between the Grand Banks and the Mid-Atlantic Ridge, but firm proof of its existence and its physical explanation are still unclear. Several sections were operated across this deep circulation system.

A main water mass objective during M45/3 was the Labrador Sea Water (LSW). After its formation in late winter in the central Labrador Sea it seems to circulate along complicated paths in the western basin and crosses the Mid-Atlantic Ridge far into the eastern basin. Only much later the LSW export to the south within the deep western boundary current takes place. The LSW seems to participate also in the recirculation east of the Grand Banks.

Large differences might exist between different years. Further, the flow paths of the LSW are not continuous, but its spreading paths are actually made up by a complicated interaction of eddy transport

and mean advection. Until recently it was believed that the exchange of LSW with the water masses of the Irminger Sea takes place on time scales of several years, but recent measurements within WOCE indicated that the LSW can progress within less than a year far into the Irminger Sea and also that the time scale for the spreading of LSW into the East Atlantic is shorter than previously thought.

Investigations prior to SFB 460 suggested that convection takes place not only in the central Labrador Sea, but also at its southern margin. The water mass formed there seems to make up the upper part of the deep water export south of New Foundland, and as tracer data show, it moves there faster and more directly than the LSW.

The SFB program in the northwestern Atlantic began with a VALDIVIA-cruise in summer 1996. It aims at investigating the variability of this circulation on interannual and longer timescales. So far, not much is known on these scales. Large-scale depth changes in the hydrographic distributions of the subpolar North Atlantic were observed, but their causes and connections with ocean-atmosphere-ice exchanges are still unknown. With a METEOR cruise in summer 1997 and a VALDIVIA-cruise in summer 1998 the cruise M45/3 was the fourth annual repeat investigation.

An array of moorings in the convection region and the boundary current of the western Labrador Sea is maintained since 1996 and provides information on the seasonal and interannual variability of deep convection and its effects on the circulation. Much of the work of cruise M45/3 was devoted to retrieving, refurbishing and redeploying the various types of moored instrumentation.

3.2 VEINS

The ideas on the source waters for the Denmark Strait overflow have undergone continuous change. Starting out with being solely Arctic Intermediate Waters from the convective centers in the Iceland and Greenland Seas, the strongly intensified investigations on the circulation and water mass transformations have related the overflow to the waters of the western boundary currents in the Nordic Seas. This results in arctic, polar and atlantic contributions to the Denmark Strait Overflow. The present concept consists of equal contributions from Arctic Intermediate Waters, Arctic Ocean Deep Water and recirculated Atlantic Water.

With this composition it is to be expected, that variations in the source water characteristics show up as variations in the Denmark Strait Overflow characteristics. This has recently been found: There is a significant coherence between interannual temperature changes of the DSOW at 64°N and temperature changes in the Atlantic Water of the Westspitsbergen Current, with the latter three years preceding. The causes for the variability are presently seen in the longer-term variability of the atmospheric forcing. These data constitute one of the first examples of a direct effect of low frequency atmospheric variability on the formation of North Atlantic Deep Water.

The field work for the VEINS project south of Denmark Strait is a cooperative effort between institutions from Germany, Iceland, Finland and Great Britain. The leg M45/4 aims at a repeat description of the large scale distribution of the Denmark Strait overflow waters along 6 sections across the continental slope east of Greenland using CTD/Rosette measurements. In addition to CFC´s measurements, SF6 will be measured as part of a deliberate tracer release experiment in the central Greenland seas. An moored array of recording instruments over the east Greenland slope near 64°N will be recovered and deployed again. This array consists of 6 currents meters moorings, 2 inverted echo sounders and 1 bottom mounted ADCP. The are all near bottom-mounted systems designed to monitor the speed and the thickness of the dense overflow layer.

3.3 CANIGO/ESTOC and DOMEST

The research activities during the M45/1 as well as the M45/5b cruise are related to the scientific programs CANIGO and DOMEST.

Near the Canary Islands, the scientific work focused on the BMBF funded project DOMEST. The DOMEST project started in 1997 and is dedicated to the development of data transmission into and from the deep ocean, based on acoustic modems and a bi-directional link from the deep ocean via satellite to a land based laboratory. The bi-directional data link is based on a sensor network moored in the deep ocean near the Canary Islands and consists of three main moorings, the surface buoy unit (SBU), the moored sensor unit (MSU) and the deep ocean bottom station (DOBS). With DOMEST, element and particle transport in the deep sea will be measured remotely, i.e. without recovering sensors from the deep ocean. Data access will be possible at any time via Internet and satellite communication, including a remote adjustment of sampling intervals of particle traps and remote status checks of instruments and download of data. These possibilities allow advanced data collection in response to events, such as indicated by changes in ocean colour or dust storms, which can in turn be monitored via satellites.

Communication underwater is based on 4 independent acoustic modem clients, combined with different sensors. Bi-directional data transmission between these modems is possible up to 2.400 baud. An integrated digital controller, responsible for hand shaking and data-management controls each sensor package and acoustic modem. A permanent surface buoy is moored in 3.600 m water depth. Above the water the OrbComm based satellite network establishes the data transport between the moored systems and the land based ground station in Italy where messages are routed via SMTP into the Internet.

Within the framework of the deep-sea device testing programme DOMEST the following work was done during M45/1:

1. Service of the permanent surface buoy (SBU). Test of satellite telemetry via OrbComm satellites. Controlling of the GPS-data. Programming and interface tests between the under water (UW) and satellite communication. Test of UW communication via the top buoy as master unit.
2. Test of UW communication from the ship to devices and also on ships wire down to 3500 m water depth.
3. Deployment of MSU with UW-Platform (SSP, 200 - 500 m water depth with the Multi Sensor Device (3000 m water depth) and the unit for the Deep Ocean Bottom Station (DOBS, 3500 m water depth). Location of the anchor position of MSU and location in the water column via SSP position.
4. Communication with acoustic modems in SSP, MSD, DOBS and SBU. Test of the total communication, including the satellite link.
5. Test of Deep Ocean Profiler (DOP) and the optical Refractometer (OPRA).

A major emphasis of leg M45/5b was the testing of deep-sea research equipment in the framework of DOMEST at a station about 100 km north of Tenerife. Tests conducted on this cruise included communication with several instruments via modem and the deployment of two moorings to establish a communication link between moored instruments and a shore-based laboratory via satellite. The work also included maintenance of a large surface buoy, which served as the acoustic link between the moored instruments and the satellites. Various tests were performed of the underwater communication with equipment attached on the ship's wire down to 3500m water-depth.

Parallel to the DOMEST activities, scientific work related to the EU funded CANIGO project was done during M45/1 and M45/5b. Particle flux was be investigated by servicing two sediment trap moor-

ings (CI mooring“ and LP mooring) on a zonal transect from the shelf to the outer oligotrophic region of the Canary archipelago.

At the ESTOC station standard parameters of hydrography, nutrients, oxygen, chlorophyll a and DIC have been determined monthly at since 1994. In addition, particle flux was measured with moored traps that have been deployed at the station since 1991 and seasonally with free drifting traps. On M45/5b, the monthly measurements for October and November were carried out, in addition to an extensive set of measurements of the dissolved and suspended trace metal content in the water column. Also, for the first time ^{14}C-based primary production measurements were carried out in-situ in parallel to shipboard incubation experiments measuring phytoplankton growth rates.

Two sediment trap moorings, one at ESTOC and the other one between the islands of Fuerteventura and Lanzarote and the shelf (EBC, Eastern Boundary Current) were exchanged during M45/5b. In addition to sediment traps the ESTOC-mooring also contains in-situ-pumps for sampling of trace metals, in addition to three sediment traps (20-cup collectors). The EBC mooring contains current meters (IfM Kiel) in addition to two sediment traps. The particulate material collected will be analysed to determine total flux, particulate flux, particulate organic carbon, particulate nitrogen, biogenic opal, carbonate and stable isotopes of organic matter, and lithogenic material. The trapped material also will be investigated for species composition of the planktonic organisms (pteropods, foraminifera,coccolithophorids, and diatoms). Particle flux was also investigated with free-drifting surface tethered traps that were collecting particulate material from below the mixed layer both in the DOMEST/ESTOC investigation area as well as in the Cape Ghir filament region.

The coast of Cape Ghir, NW Africa, is the site of prominent upwelling filaments that can reach several hundreds of kilometers off shore. They may have important implications for particle flux and biogeochemical parameters in the coastal margin of these areas. Work in the Cape Ghir filament region during M45/5b included hydrographic and biochemical measurements in and across the filament, as well as primary productivity and particle flux measurements using drifters. The work was aided by satellite observations of ocean colour (SeaWIFS) and ocean temperature (AVHRR) and was designed in parallel to a study conducted in February 1999 on POSEIDON 248 .

3.4 Sedimentology/Paleoceanography

The first part of M45/5 focused on sedimentological investigations in the North Sea, Azores frontal system and Cape Ghir that aimed at the reconstruction of paleoenvironmental conditions in these areas.

The structures of near-surface sediments which reflect the effects of paleo-oceanographic and paleoclimatic variability during the sedimentation processes, were continuously recorded in the three investigation areas with the PARASOUND echosounder. Its digital data acquisition is performed with the PARADIGMA system developed at the Bremen University. In addition, a survey of the general morphologic setting was achieved by the swath bathymetry system HYDROSWEEP. Both acoustic board systems were used on site as a proven tool to find suitable locations of sampling sites. Thus, echographic measurements provided basic information for sediment sampling. After an intensive geophysical survey on selected locations in the North Sea, on a profile in the Azores Frontal system and the Cape Ghir area suitable locations were sampled with conventional wireline coring techniques (multicorer, boxcorer, gravity corer and piston corer) and subsequently analysed using physical, isotopic, micropaleontological and sedimentological methods.

a) North Sea

he aim of the planned studies in the North Sea was to develop a high resolution reconstruction of paleoenvironmental conditions in the North Sea area for the last 5000 years. These investigations, which were carried out within NEBROC (Netherlands Bremen Oceanography), are a continuation of the work that has begun during M40/0. Continuous sedimentary sequences are restricted to only a few areas in the North Sea. Two of the areas, the Skagerrak and the Outer Silver Pit (water depths between 20m and 120m) were sampled during M45/5a) by gravity corer and by multicorer. Based on a multi-parameter approach this study investigates the impact of Late Holocene climatic variations (e.g. the mediaeval warm epoch, the little ice age) on the North Sea and the surrounding land areas.

b) Azores frontal system

The impact of hydrographic fronts on the population dynamics and on the distribution of fossil planktonic foraminifers (e.g. mixing or separation of faunas) is of special interest, because hydrographic fronts are potential areas of enhanced production of plankton. The reaction of planktonic foraminifers and pteropods to changes of the front was recorded as well as the flux of empty tests to the sea floor. The quantitative and qualitative distribution of planktonic and benthic foraminifers, including their stable isotopic composition and the distribution of pteropods will facilitate the reconstruction of the Quaternary evolution of the Azores Frontal Zone. The working program included (a) sampling of the sediment with a piston-corer, (b) sampling of surficial sediments with a multicorer, (c) vertical multinet hauls down to 2500 m, (d) water sampling to provide a description of the water column with respect to the calcareous zoo- and phytoplankton, and (e) hydrographic data of the water column that were recorded by CTD. All sites were located in 3000 m water depth. The transect of 5 sampling stations crossed the area of the recent position of the Azores Front, and served to recover recent and late Quaternary frontal dynamics.

c) Cape Ghir

The sedimentological investigations in the Cape Ghir area were closely related to the recently concluded multidisciplinary EU-project CANIGO (Canary Islands Azores Gibraltar Observations), especially to subproject "Particle Flux and Paleoceanography in the Eastern Boundary Current System". Aim of this research is to investigate the glacial-interglacial history of the influence of coastal upwelling, filaments and Saharan dust on the magnitude and composition of particle flux in the Canary region. Studies carried out on M45/5 focused especially on the under-sampled Cape Ghir filament region which is part of the Moroccan upwelling area. The sediments were sampled intensively with multicorer and gravity corer, thus complementing sediment samples already obtained on previous cruises to the area (M37/1 and M42/4b).

4 Narrative of the Cruise

4.1 Leg M45/1 (G. Meinecke)

METEOR cruise M45/1 started on 19 May 1999 in Malaga. At the beginning of this cruise, a condensed geological sampling program has been conducted during the first four days in the Gulf of Cadiz (Fig. 2).

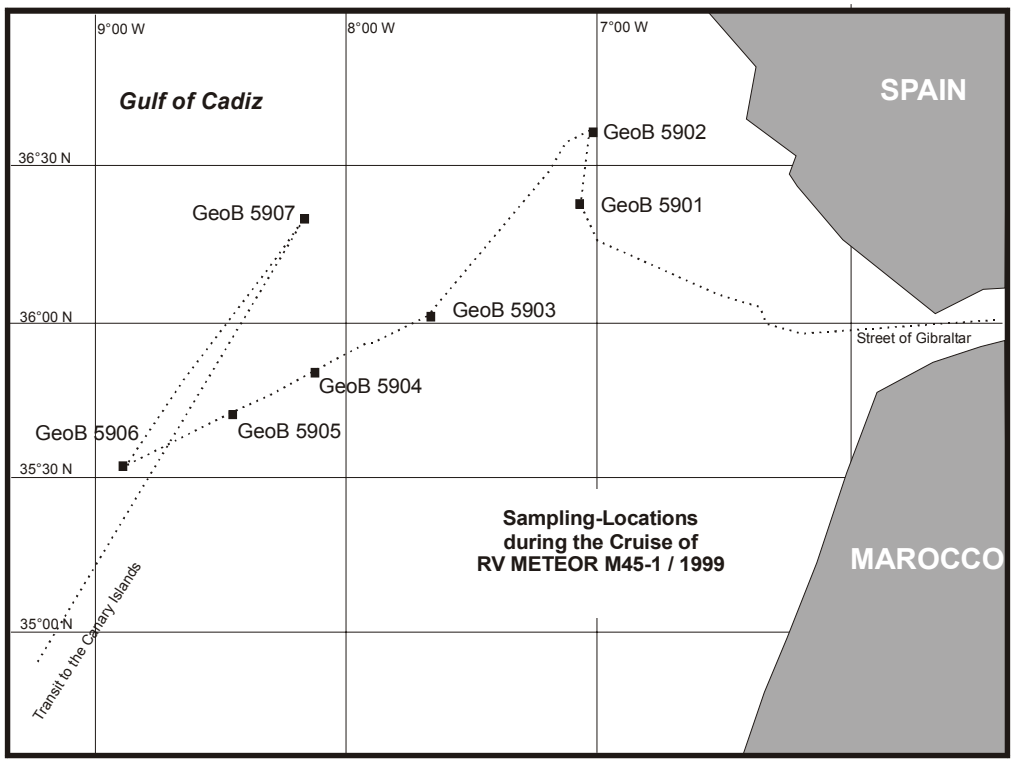

Fig. 2: Cruise track and sampling locations in the Gulf of Cadiz.

The structures of the near-surface sediments have been continuously monitored at high resolution with the PARASOUND echosounder system. In addition, a survey of the general morphologic setting was achieved HYDROSWEEP. Both acoustic board systems were used on site as a proven tool to find suitable locations for 7 sampling sites on an SW-transect through the Gulf of Cadiz. On these sites, sediments samples were taken with gravity- and multi-corer. The sites are located on the outer shelf (500 and 580 m water depth) and on the continental slope in different depths down to 3029 m water depth. The final location GeoB 5907 was used to run the single-pump systems, in order to analyse the Mediterranean Outflow Water and to run the first test of the new designed optical Refractometer (OPRA). At the end of the tests, METEOR left the Gulf of Cadiz on Saturday 22 May with destination Canary Islands (Fig. 3).

Near the Canary Islands, the scientific work was focused on the national project DOMEST. The scientific work schedule started on the 25 May at the DOMEST location. First, the permanent surface buoy had to be maintained. The satellite electronics were complete destroyed, due to a leakage into the electronic cases. In addition to this, the transducer cable, 30 m below the buoy, has been cut by fishery activities. New devices, like the integrated Multi Sensor Device (sediment trap, acoustic CTD and micro controller), the deep sea YoYo profiling vehicle, deep sea winch system and again the optical Refractometer were tested for their functioning on board and in the deep ocean with great success. Afterwards, acoustic data-transmission into the deep ocean were tested again, as well as the connection to the OrbComm satellite communication network. On this cruise, is was possible to run the first complete ”close loop test” for the communication line. Two underwater clients with scientific sensors has been installed before this

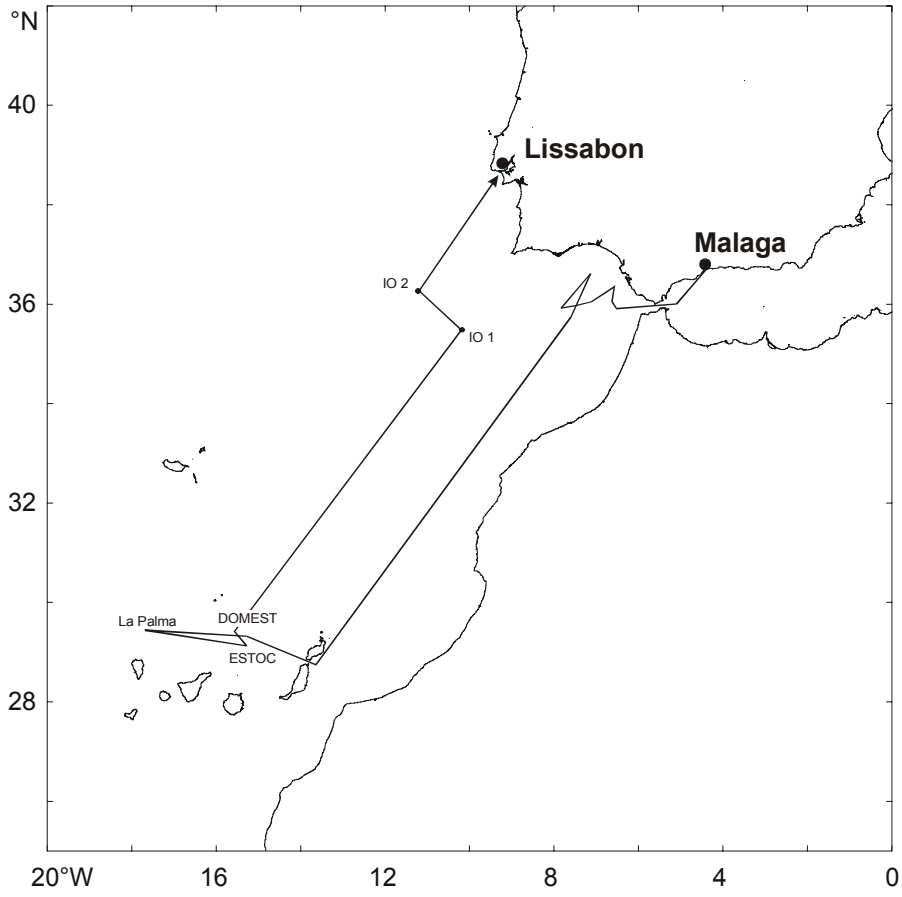

Fig. 3: Cruise track and working locations during RV Meteor cruise M45/1.

test and each client was tested separately. From aboard Meteor a request for CTD data (sensor was located in 2000 m water depth) was send via satellite to Italy, routed back via satellite to the surface buoy, transferred to the acoustic underwater modem and send into the deep sea as an acoustic data stream to the deep ocean bottom station (DOBS). From here the request was passed through acoustically to the multi sensor device (MSD) which itself asked the CTD sensor for data and send these data back to the surface buoy as an acoustic data stream. Here these data were transferred to the satellite transceiver and send back via satellite to Italy. In Italy the data were routed back to the mobile satellite station aboard Meteor. This complete test takes only 8 minutes from request to answer. Parallel to the DOMEST activities, scientific work related to the EU funded CANIGO/ESTOC project has been done. The ESTOC sediment-trap-mooring was maintained and finally the La Palma mooring was recovered without replacement. In addition, vertical profiles with the high resolution particle-camera system ParCa were recorded at defined locations, drifting sediment traps were used twice in the ESTOC region and intense water column sampling and -probing with multi-pumps and a rosett watersampler for has been done at ESTOC and DOMEST locations, performed by the marine chemistry working group. The scientific work was finished on 4 June and Meteor left the Canary Island region with destination to the Portuguese Sound Sources Moorings IO1 and IO2 father in the north.

On 6 June, is was planned to recover the IO1 mooring. The recovery failed and the mooring could not be recovered due to a collapsed top buoyancy of the mooring line. At the next day, the IO2 mooring was recovered without any problems and the scientific work for this cruise ends and Meteor started its transit to Portugal. In the morning of 8 June Meteor arrived in the harbour of Lissabon and a very successful scientific cruise found its end.

4.2 Leg M45/2 (W. Zenk)

On 11 June METEOR left her berth at the inshore site of *Doca de Alcântara in Lisbon*. On board were scientists, students and technicians from Kiel, Bremen and Warnemünde. After leaving the mouth of river Targus at Cascais we headed north towards a test station (Fig.4). This was reached three days later after we had abandoned the Exclusive Economic Zone (EEZ) of Spain at the western entrance of the Bay of Biscay. Until then, all continuously recording vessel mounted systems, thermosalinograph, acoustic Doppler current meter profiler (ADCP), HYDROSWEEP and chemistry loggers, had become and remained fully operational for most of the expedition time. After successful completion of the test station which turned out to be a revisit of the near-by *Transient Tracer in the Ocean* (TTO) station 115 (inbound of the EEZ) we preceded towards Porcupine Sea Bight.

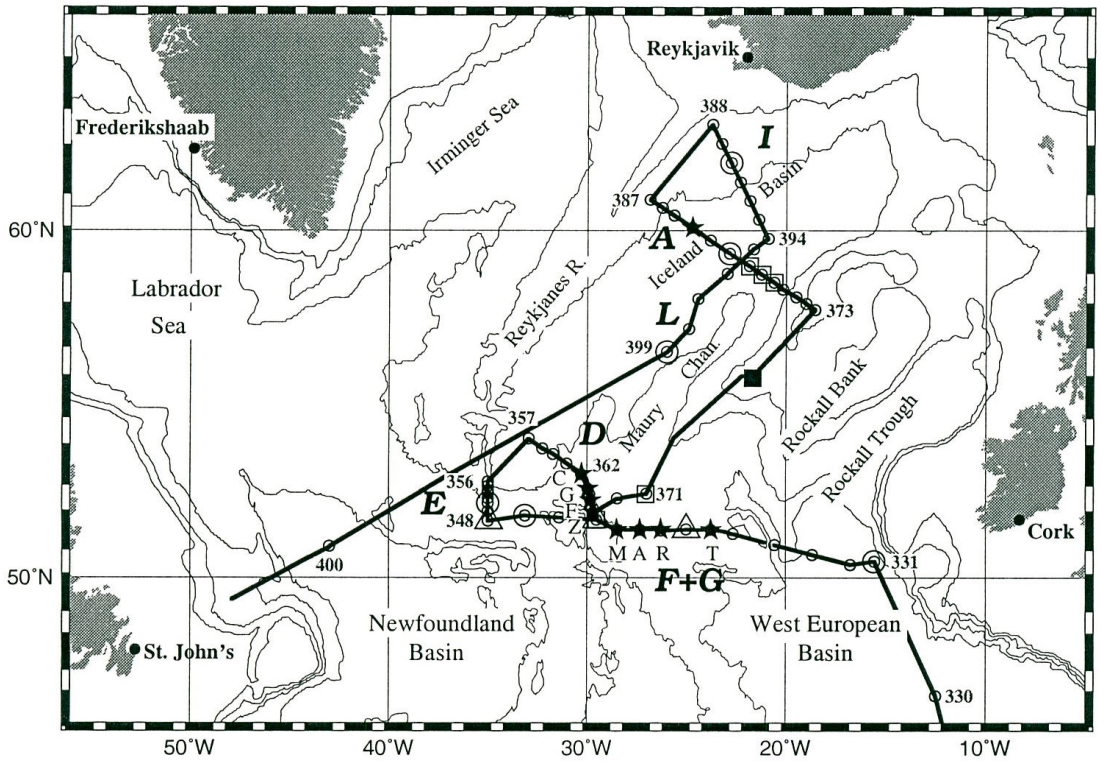

Fig. 4: Cruise track and station map of METEOR leg M45/2.
o CTD station O Station in θ/S Δ APEX float ☐ RAFOS float deployment
■ RAFOS float recovery ★ mooring deployed/recovered

For the next six days, 14 -20 June, we occupied the hydrographic section at the southern base of the Iceland Basin. The region had first been sampled by the *Sonderforschungsbereich 460* (SFB) with METEOR (M39/2) in May 1997 and again with POSEIDON in August 1998 (cruise no. 242). The new section of M45/2 consists of 14 CTD (conductivity, temperature, depth) stations (no. 311 - 348) between the continental rise off southwestern Ireland at ~15°W and the southern side of the Charlie Gibbs Fracture Zone (CGFZ) at ~35°W. Occasionally stronger westerly winds and some fog at the northern rim of the Azores High reduced our cruising speed. The routine CTD work (see Table 7.2.1) included extended collection of water samples for a variety of physical, tracer and chemical analyses including salinity, dissolved oxygen, CFC (Freon 11 & 12), CO_2, helium, tritium, 13C/ 14C, thorium, protectinium, and nutrient salts.

The sequence of CTD stations was interrupted by the 100% successful recovery of the four current meter moorings (Table 7.2.2) of the **M**id-**A**tlantic **R**idge **T**ransport array (M, A, R, T). The latter were moored since the Poseidon cruise in August 1998. We also reequipped our RAFOS float park (Sta. 345) with four instruments and launched three profiling APEX drifters on request of *Bundesamt für Seeschifffahrt und Hydrographie* in Hamburg at Sta. 338, 345, and 348 (Table 7.2.3).

With the completion of the southern section we had also crossed the North Atlantic Current at approximately 29°W reaching the eastern limb of the subpolar gyre with surface temperatures well below 12°C. From midday of 20-21 June we occupied the meridional section at 35°W through **C**harlie **G**ibbs **F**racture **Z**one (Sta. 348 - 356). It enables the exchange of water masses between the eastern and the western basins of the North Atlantic.

At Sta. 357 Meteor reached the initial point of a further cross section between the southern end of the Reykjanes Ridge and the just recovered MART array. The southern end of this section cuts at 29 ¾°W again through the eastern extent of Charlie Gibbs Fracture Zone. There we launched a set of four current meter moorings on a line orthogonal to the two channel entrances. As acronyms for this array we chose the abbreviation of its location: **C**, **G**, **F**, **Z** (Sta. 361, 363, 367, 368). After all current meter mooring works was finished, Meteor paid a revisit to the historic TTO station 121 at our modern Sta. 371.

The next days we headed northwestward where we encountered much more stormy conditions. In spite of the rough seas we located a freely drifting RAFOS float (#416) by means of repeat internet links with the computer of *Systeme ARGOS* in Toulouse and a ship-borne direction finder in the afternoon of 26 June and retrieved it intact. It had been deployed from Meteor in May 1997 and recorded the drift of Labrador Sea Water at intermediate depths (~1500 m) for an 18 months period.

After the RAFOS recovery along the way to the northern crossing of the Iceland Basin we reached its easternmost extension on the peak of Hutton Bank. During 26 - 30 June a repetition of the hydrographic section A of cruise M39/2 from May 1997 (Sta. 373 - 387) was carried out. The routine CTD work with water sampling was only interrupted by the deployment of the three remaining RAFOS floats at Maury Channel (Sta. 377 - 379) and the exchange of sound source mooring IM1 (Sta. 382).

After the completion of section **A** Meteor sailed northward to an additional section (**I**) which was occupied between 30 June and 1 July (Sta. 388 - 394). Work carried out on section **I** will be a valuable base for the planned current meter array on the shoulder of the Reykjanes Ridge in the summer of 2000. A final CTD section (**L**) paralleled the 2800 m isobath from its northern extend to about 57°N (Sta. 395 - 399). Due to the forecast of severe weather conditions beyond this station we run out of time for further CTD soundings and headed for St. John's.

Approaching to the Grand Banks on the way to Canada Meteor stopped for her ultimate CTD station (No. 400) of Leg M45/2 in the afternoon of 5 July. This station represents a revisit to TTO station no. 214 and GEOSECS station no. 03 in the central Newfoundland Basin. It will allow valuable comparisons of chemical parameters referenced to the situation in July 1972 and September 1981, respectively.

In summary, we had gathered 65 CTD profiles and collected over 1200 water samples for tracer and chemical analyses. Eight RAFOS floats and three APEX floats were launched, one float could be recovered after its two-year-mission. Four current meter moorings were recovered, other four moorings were newly deployed, one was exchanged. In the morning of 8 July Meteor entered the port of St. John's where Leg M45/2 was terminated.

4.3 Leg M45/3 (F. Schott)

Cruise M45/3 left the port of St. John's at noon time on Sunday, 11 July for a transit leg toward the 53°N section where 5 moorings were to be retrieved, 3 to be redeployed (Fig. 5; Table 7.3.1) and closely spaced CTD/LADCP profiles to be collected across the boundary current (Fig. 6; Table 7.3.2). The site of mooring K7, located at 1200 m water depth, was reached in the evening of 12 July and the mooring could be retrieved that same day, although shifting fog caused some uncertainties as to the location after surfacing. On 13 July three moorings (K8, K19, K10) could be retrieved intact and on 14 July the redeployment of the first two (K28, K29) of the three planned stations followed at locations spread further out than the original 5-mooring array was.

The final retrieval along that section, of mooring K16, was accomplished on 15 July. While CTD stations were carried out along the section, a quick evaluation of the two-year long deep records of K16 was performed. It showed that the Deep Western Boundary Current (DWBC) had decayed at the coastal distance of that location, and it was therefore concluded to locate the third redeployment mooring, K27, further inshored than originally planned. In between the mooring operations, a total of 13 deep CTD/LADCP casts were taken along the 53°N section. With M45/3, we have now four coverages of that section, beginning in 1996.

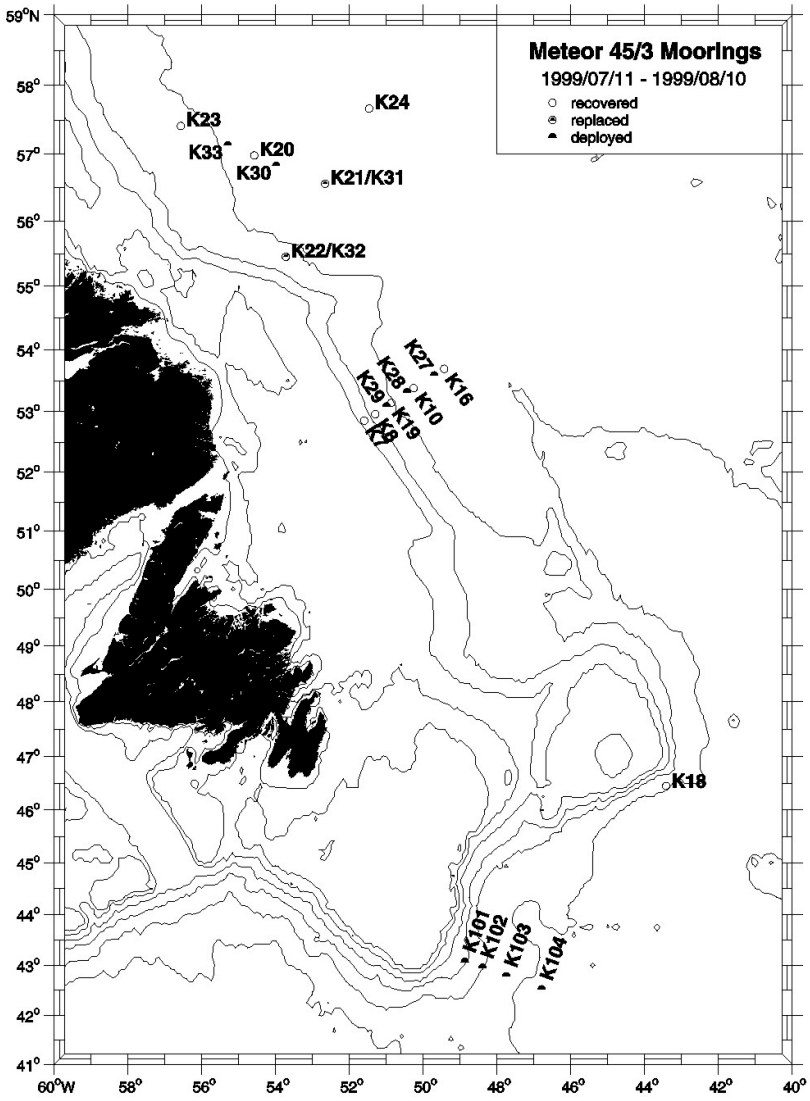

Fig. 5: Locations of mooring work during METEOR cruise M45/3 in July and August 1999.

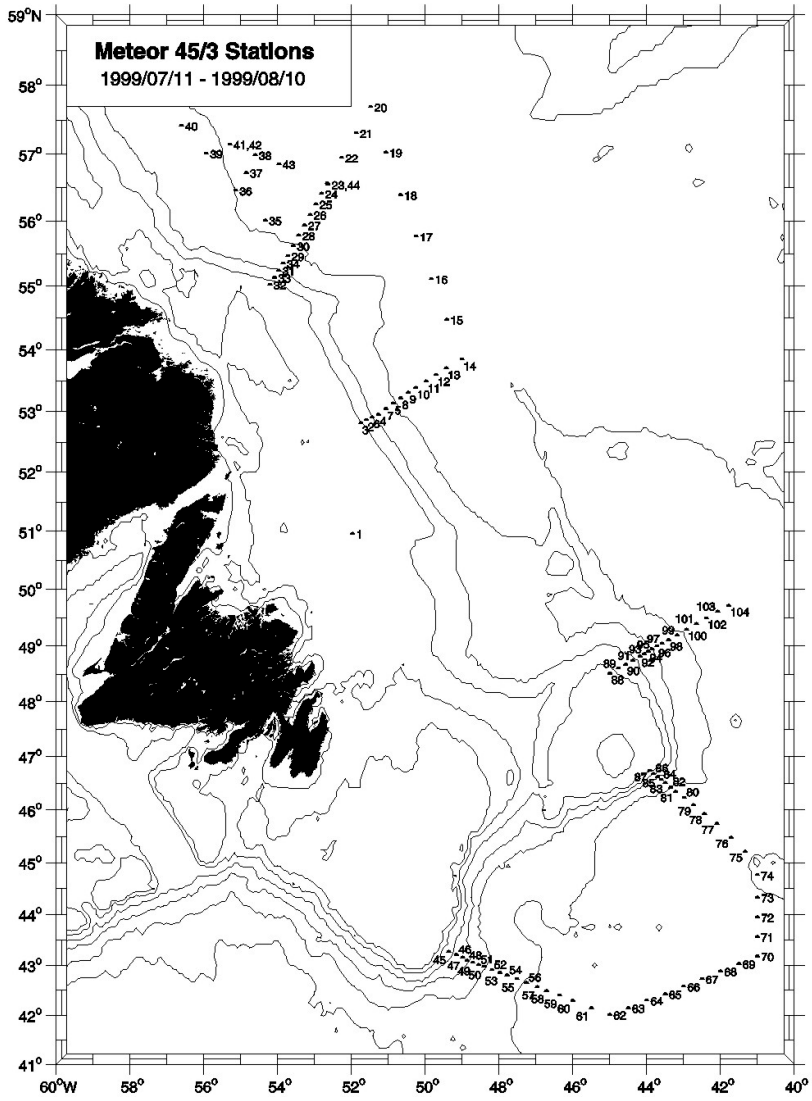

Fig. 6: CTD-Station map of METEOR cruise M45/3 (11 July to 10 August 1999).

From the outward end of the 53°N section, a section along the axis of the Labrador Sea brought us to station K24, the first of the tomography stations which was retrieved on 17 July. From K24 toward the Labrador coast, the WOCE-AR7 section was covered by a total of 15 CTD/LADCP casts, with increased resolution towards the western boundary. On 17 July the Tomography/convection station K21 and associated 3 navigation transponders were recovered. The redeployment of that station, called K31, was scheduled for later in the trip, in order to have time to refurbish instruments and analyze data. On one of the CTD casts, a number of the retrieved Seacat recorders were lowered in a high-frequency sampling mode to obtain a post-calibration.

The third tomography mooring, K22 at the western end of the section, and its 3 transponders were recovered on 19 July and immediately redeployed with available exchange instrumentation, as station K32. Then we moved northeastward to retrieve the cycling CTD mooring K20 (to be replaced by K30) and the fourth tomography mooring K23 on 21/22 July. CTD casts were taken along the different tomography ray paths for calibration and intercomparison. The tomography redeployment consisted of a triangle K33, K32 and K31. Station K33 is now closer to the other two than in 1998/99 because it is equipped with a less powerful sound source. The Labrador Sea part of the work was terminated on 24 July after deploying K31 with refurbished instrumentation.

On the 3-daylong transfer leg to the southern Grand Banks where the second part was to begin, refurbishing of retrieved mooring equipment for redeployment in the south was carried out. In an informal evaluation workshop, participants discussed calibrations and first results during this time period. One of the striking results from the moored ADCP and Seacat recordings over the past winter as well as from the water mass distributions this summer, was that Labrador Sea convection activity was at its weakest during winter 1998/99 in a decade. On a more touristic note, a number of whales were encountered over the shelf, and during a technical stop, a couple of whale watching outings were made with the rubber dinghy.

South of the Grand Banks, where the coldwater export out of the subpolar North Atlantic is concentrated, four moorings were deployed during 27-29 July in the depth range 2000-4300 m (K101-1 to K104-1), to be out for two years. Each deployment was preceded by HYDROSWEEP surveys. After passing the about 200 km wide range of the southward coldwater flow with 3-4°C temperatures we suddenly encountered the Gulfstream with 18-23°C water, which made the parkas on deck disappear and the shorts come out.

Since our own previous surveys of the Irminger Sea and other evidence, including TOPEX/POSEIDON altimetry maps that we received on board suggested small energetic cells and eddies in this region, the station spacing was kept at <25 nm, even over the deep New England Basin. The 48°N WOCE section was followed until 41°W with a total of 20 deep CTD/LADCP/tracer stations occupied along that line. The course then changed northward to 45°N and from there a second boundary section was occupied (Profiles 75-87, Fig. 6), running into Flemish Cap past the position of mooring K 18 which was recovered on 4 August.

Overall the sections south of the Grand Banks with CTDs 45-87 enclosed a box with densely sampled CTD/LADCP profiles that should yield a good base for box budget analyses of the North Atlantic Current and Deep Western Boundary Current. During 6-8 August a third and final deep boundary section was carried out northwestward of Flemish Cap, where we had earlier sections from M39 in 1997 and Valdivia in 1996. A total of 15 deep stations could be taken along that section from the Cap down to the deep sea basin, before we had to terminate the station work on Sunday noon in order to arrive on Tuesday morning, 10 August, in St. John's. The leg M45/3 ended with a reception on board METEOR on 11 August 1999, given to inform the local authorities and scientific community about the cruise and to thank for the support and help during this and earlier cruises, especially the help by the Canadian Coastguard, received during the previous year's operations.

4.4 **Leg M45/4** (J. Meincke)

METEOR left St. John's on Aug. 13, 08.00 LT and headed to the southern tip of Greenland. The hydrographic work comprising of vertical profiling of temperature and salinity and water sampling at 10 to 20 levels for analysis of CFC's along section 6 (Fig.7) was started with station #512 on Aug. 17, 00.52 UTC. When the section was finished (station #521) the vessel moved on to the area of section 3 to recover the 8 moored instrument arrays that were deployed in 1998 by RV „Valdivia". This activity took all day Aug. 19 and was successful except for one inverted echo sounder on position 63°21.9N 036°03.4W, which could neither be contacted acoustically nor released. In the following period until Aug. 22 the hydrographic work along section 3 (stations #530-#536) and section 4 (stations #537-#545) was completed. Late on Aug. 22 the redeployment of the 8 moored arrays of current meters, inverted echo sounder and acoustic doppler current profiler was started and took until Aug. 23, 16.25 UTC. During the night Aug. 22/23 an HYDROSWEEP survey was made along the mooring line. The last part of the scientific program consisted of hydrographic work along section 2 (stations #554-#560) and section 1 (stations #561-#571). When

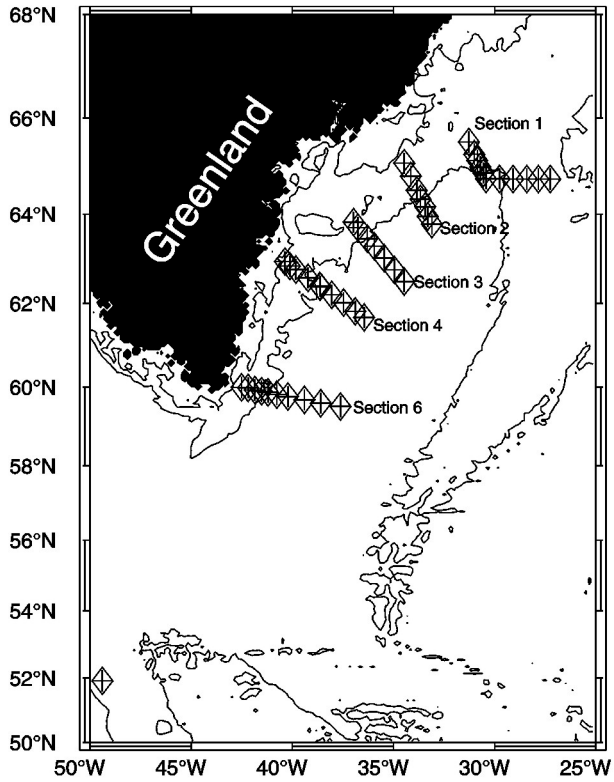

Fig. 7: Positions of the CTD profiles acquired during M45/4 and hydrographic sections. The mooring array is located along section

completed on Aug. 26, 08.00 UTC at position 64°45.1N 027°14.6W the vessel took course for Rendsburg, where it was berthed on Aug 31, 16.00 LT. In addition to to the work done when the ship was stopped during stations there was continuous recording of atmospheric data, sea surface temperature and salinity and the current profile from the surface to 400m depth throughout the cruise leg. The weather conditions during the period of station work were fine, all instrumentation worked up to expectation. The resulting data sets are of high quality.

4.5 **Leg M45/5** (S. Neuer)

METEOR departed Bremen's Europahafen on 1 October 1999 at 10:00 for the fifth leg of cruise M45. The scientific crew onboard included 8 scientists from the Department of Geosciences in Bremen, four from the Marine Geology Department of the University of Tübingen, one scientist from the University of Göttingen and one scientist from the Geology Institute in Lisbon, as well as two meteorologists from the German Meteorological Service in Hamburg. Several guests, including 15 journalists accompanied the ship to Bremerhaven. The press coverage on this departure day concluded a week of public relation activities, including an Open Ship Day that focused on marine science topics and the preparation for this cruise. The guests disembarked the ship on 13:30 with the tugboat 'Bremen'. High winds on the same day of Bft 8 with gusts up to Bft 9-10 did not allow the projected coring at the first coring site south-east of Helgoland but, instead, an echosounder profile was recorded. The ship took course to the second working area in the Skagerrak (Fig. 8), which was reached on the evening of Oct. 2. Beginning with a PARASOUND profile at 57°53'N, 009°31'E, three sites were cored with multicorer and gravity corer on Oct. 3 in water depths of 300-460 m. Winds were weakening from Bft. 10 to Bft. 7 during the same day. The next coring site off the

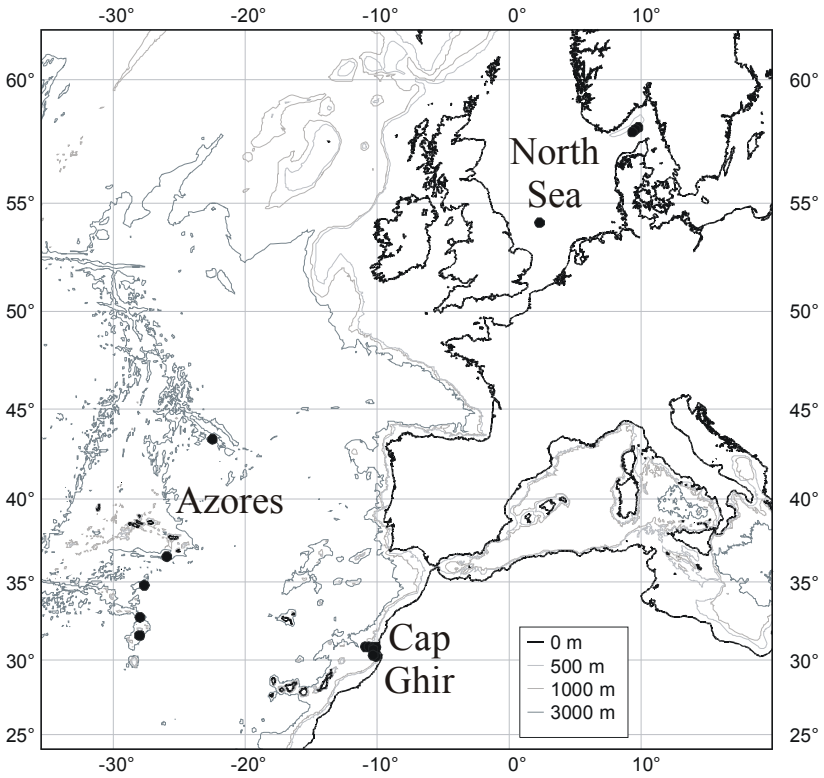

Fig. 8: Stations and the three working areas of M45/5a (Bremen to Las Palmas).

southeast coast of England (Outer Silver Pit) was reached on Oct. 5 and after conducting a PARASOUND survey one coring station was sampled with multicorer and gravity corer in 55m water depth (at 54°08'N, 002°20'E). Much improved weather and much weaker winds accompanied the transit through the English canal and into the Azores working area. The ship reached the northernmost station in the evening of Oct. 9 and a multinet, multicorer and piston corer were deployed at 43°22.2'N, 022°29,3'W. The second station north of the islands had to be cancelled because appropriate water depths could not be found. Water depths exceeded the necessary 3000 m mark and the bathymetric charts proved to be inaccurate. Instead a suitable station was found just south of the island of São Miguel at 36°33.2N, 025°56.9W. Three more stations followed with increasing distance from the islands covering the area of the recent Azores frontal system. Each station was sampled with a multinet, multicorer and piston corer and the final station was covered on October14 at 31°36.6'N, 028°01'W. Water was filtered continuously during the transit from the North Sea to the Azores to sample for planktonic foraminifera. The final working area of the first part of M45/5, off Cape Ghir (Morocco) was reached on October 17 at 30°53'N, 011°00'W. On the following two days, two PARASOUND and HYDROSWEEP profiles were recorded north and south of the Cape Ghir canyon, yielding much needed bathymetric information of the area. Seven stations were sampled along these transects with multicorer and gravity corer. After concluding work off Cape Ghir the ship took course to Las Palmas where the ship called port in the evening of October 20. During the 1.5 d stay in port equipment and most of the scientific crew were exchanged.

The ship left port again on October 22 for the second part of M45/5 with 28 scientists onboard. The scientific crew included 13 members of the Geosciences Department in Bremen /Marum (Marine Environmental Sciences Institute), two scientists from the Marine Chemistry department in Bremen, two scientists from the Institute for Marine Sciences in Kiel, 5 scientists from the Canary Institute for Marine Sciences in Telde, Gran Canaria, one scientist from the University of Las Palmas, two members of OHB, an aeronautics

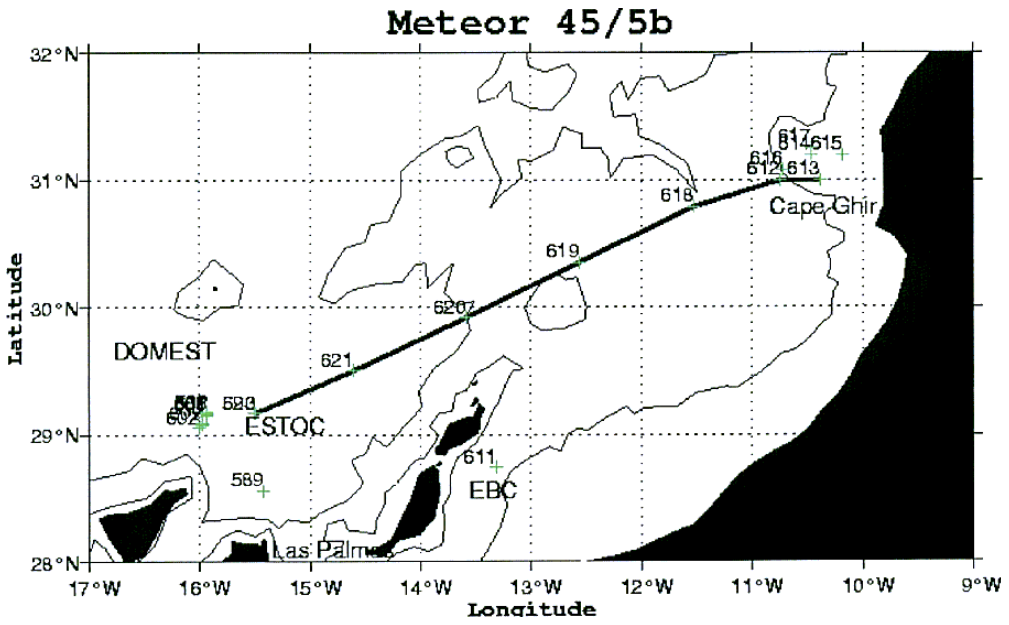

Fig. 9: Cruise track and stations of M45/5 b (Las Palams-Las Palmas).

company in Bremen, one member from STN Atlas and the two meteorologists from Hamburg. The ship left port at 10:00 in the morning with course to the ESTOC station (Fig. 9). Five expandable bathythermographs (XBT) were deployed underway and after a midway test-station, work commenced on the same day at ESTOC (29°10'N, 15°30'W) 100 km north of Las Palmas with the monthly sampling program for October and the deployment of a NOAA drifter. Also, some initial equipment tests were carried out. On the following day, a moored surface buoy and an underwater platform could be successfully recovered at the DOMEST site, 20 nm further west of ESTOC, despite of high swell. The ship remained at the station for the following three days and water column sampling and equipment tests were carried out in addition to drifter-bound rate experiments. On October 27 the DOMEST surface buoy and the underwater platform were deployed again at 29°10,2'N, 15°56.2'W after having been serviced onboard ship. The ship then took course to the EBC (Eastern Boundary Current) station east of the islands Fuerteventura and Lanzarote at 28°44'N, 013°18'W where a current meter-and sediment trap mooring was exchanged and water column sampling was carried out. Subsequently the ship headed north to the Cape Ghir filament region and water column sampling and drifter-bound experiments were carried out on the following two days until October 30. The station locations were guided by satellite remote sensing of both temperature and ocean colour tracing the site of strongest upwelling/filament activity. On the transit back from the Cape Ghir filament region to the DOMEST /ESTOC area, three additional water column stations were sampled in a distance of 60 nm of each other.

The DOMEST surface buoy was serviced again on Nov. 1 and, in the following night, the monthly sampling program for November was carried out at the ESTOC. On the morning of the same day, the sediment trap mooring CI 11 was recovered in the ESTOC area. More equipment tests were conducted on station and the station work was concluded with the deployment of a NOAA drifter in the afternoon. The ship left the ESTOC in the evening of November 2 and arrived in port as scheduled in the morning of November 3.

Due to mostly good weather and excellent collaboration between the ship's and scientific crews, the cruise could be completed successfully. A total of 5 foreign countries (Denmark, Great Britain, Portugal, Spain and Morocco) issued working permissions so that *Meteor* could conduct research in their waters.