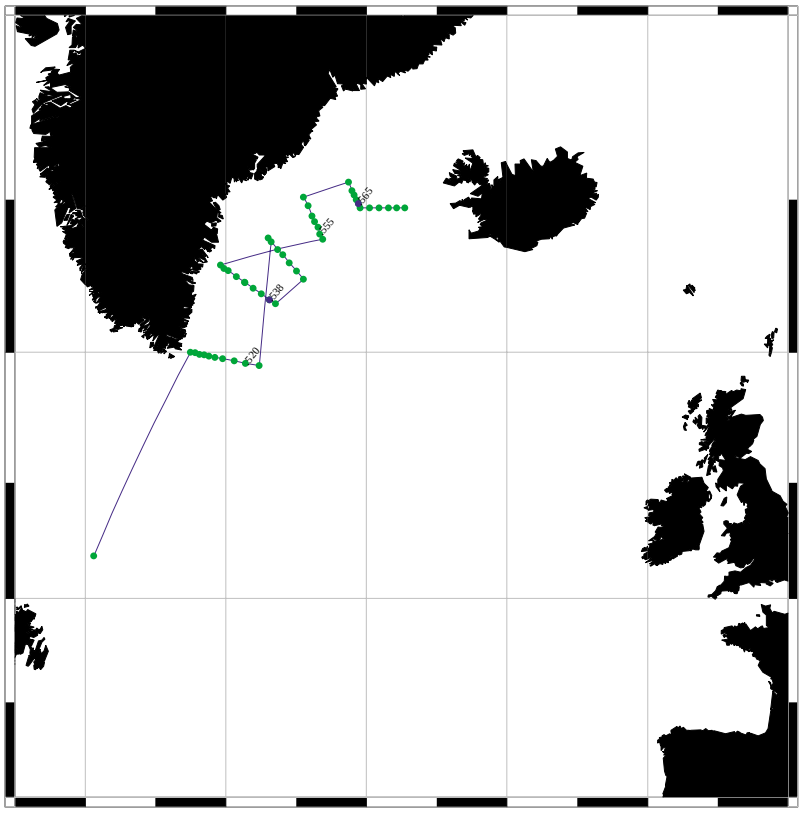
A. Cruise Narrative: AR25



A.1. Highlights

WHP Cruise Summary Information

WOCE section designation	**AR25**
Expedition designation (EXPOCODE)	**06MT45_4**
Chief Scientist/affiliation	**Jens Meincke/IfMH***
Dates	1999 AUG 13 - 1999 AUG 31
Ship	*R/V METEOR*
Ports of call	St. John's, Newfoundland – Rendsburg, Germany
Number of stations	46
Stations' geographic boundaries	65°31.19'N 49°22.91'W 27°14.59'W 51°54.77'N
Floats and drifters deployed	see section 4.2; LEG 2
Moorings deployed or recovered	8 recovered and redeployed
Contributing Authors	J. Meincke O. Plähn K. Bulsiewicz I. Schlimme G. Kahl

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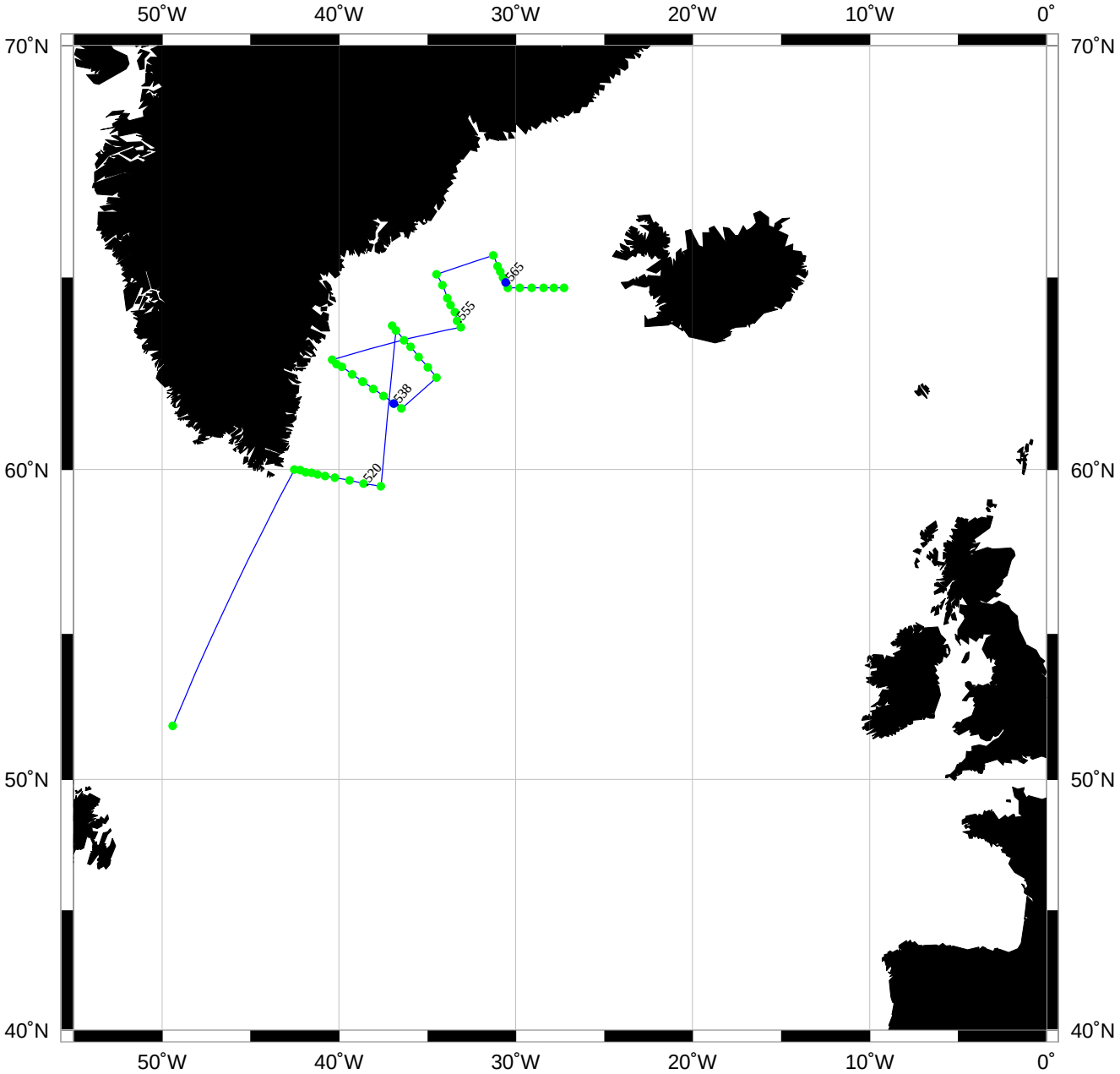
WHP Cruise and Data Information

Instructions: Click on headings below to locate primary reference or use navigation tools above. (Shaded headings were not available when this report was assembled)

Cruise Summary Information	**Hydrographic Measurements**
Description of scientific program	**CTD Data**
Geographic boundaries of the survey	CTD - general
Cruise track (WHPO) (PI)	CTD - pressure
Description of stations	CTD - temperature
Description of parameters sampled	CTD - conductivity/salinity
Bottle depth distributions (figure)	CTD - dissolved oxygen
Floats and drifters deployed	
Moorings deployed or recovered	**Bottle Data**
	Salinity
Principal Investigators for all measurements	Oxygen
Cruise Participants	Nutrients
	CFCs
Problems and goals not achieved	Helium
Other incidents of note	Tritium
	Radiocarbon
Underway Data Information	CO2 system parameters
Navigation	Other parameters
Bathymetry	
Acoustic Doppler Current Profiler (ADCP)	**DQE Reports**
Thermosalinograph and related measurements	CTD
XBT and/or XCTD	S/O2/nutrients
Meteorological observations	CFCs
Atmospheric chemistry data	14C

Acknowledgments	**References**	**Data Processing Notes**

Station locations for AR25 • Meincke • 1999



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M E T E O R - B E R I C H T E

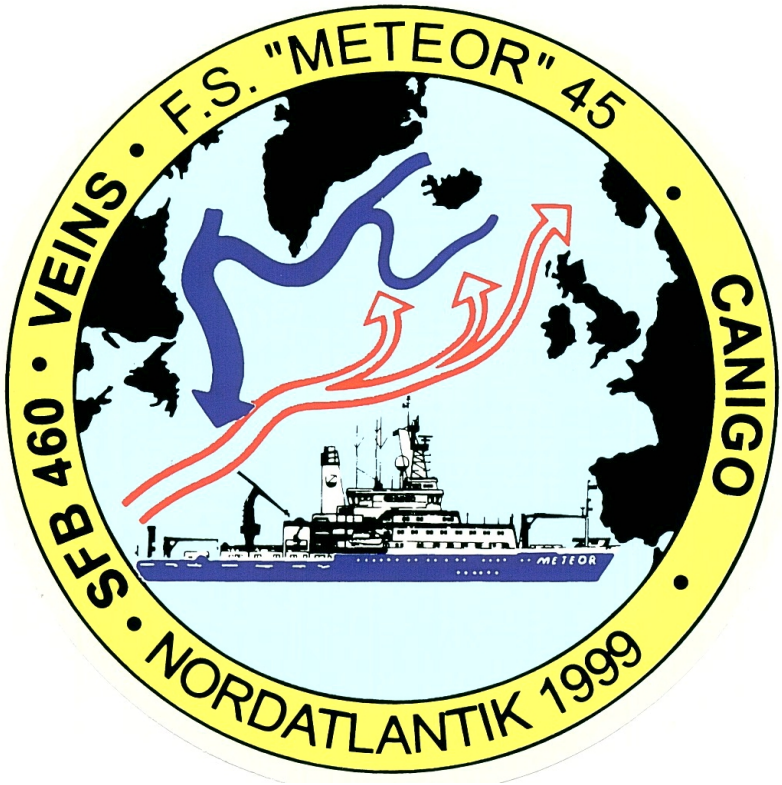
00-4

North Atlantic1999

Cruise No. 45
18 May - 4 November 1999

Edited by:

Friedrich Schott, Jens Meincke, Gerrit Meinecke, Susanne Neuer and Walter Zenk



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Leitstelle METEOR
Institut für Meereskunde der Universität Hamburg

2000

The **METEOR-Berichte** are published in an irregular sequence. They are working papers for people who are occupied with this specific expedition and are intended as reports for the funding institutions. The opinions expressed within the **METEOR-Berichte** are only those of the authors. The reports are obtainable at:

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Table of Contents

Abstract

METEOR cruise M45 took place in the North Atlantic Ocean in 1999 and consisted of five legs.

The research activities during the METEOR cruise M45/1, which started in Malaga on 19 May 1999, were related to the scientific programs CANIGO/ESTOC and DOMEST. The DOMEST project concentrates on marine technology and data transmission, mainly tested in the Canary Island region. On this cruise the CANIGO/ESTOC project concentrated on seafloor and water probing. In the morning of June 8 the RV METEOR arrived in Lisbon.

During the second leg (Lisbon - St. John's) the aim was the investigation of water mass spreading and mixing within the eastern basin of the eastern North Atlantic. The work was part of the yearly field programmes of the "Sonderforschungsbereich" SFB 460. Elements of the repeat hydrographic survey in the Iceland Basin included observations with CTD and rosette sampler. For determining deep circulation and water mass transformation, nutrients and tracer samples (CFCs, tritium/helium) were taken. In addition an array of moored current meters for monitoring the Overflow Water close to the Reykjanes Ridge was recovered. The array was then partly redeployed for an additional year. RAFOS float observations for the determination of the drift of Labrador Sea Water in the eastern basin were continued during M45/2.

The third leg (St. John's - St. John's) focussed on the deep circulation and water mass distribution of the Labrador and Irminger seas, also within the context of the SFB 460. The distribution of water masses and circulation was studied along standard repeat sections using current profiling, hydrography and tracer (Freon, tritium/helium) observations. In the Labrador Sea, a number of tomography, convection and boundary current moorings were recovered and redeployed for measuring deep convection activity. A new moored array was deployed off the Grand Banks to measure the export of Deep Water out of the Subpolar North Atlantic.

The fourth cruise leg (St. John's – Rendsburg) was devoted to mooring work and hydrographic measurements on sections normal to the southeastern slope of Greenland. It was aimed at repeatedly describing the state of the Denmark Strait overflow as one of the contributions to the EU-Project VEINS on the Variability of Exchanges in the Northern Seas. Leg M45/4 METEOR ended on 1 September in the ship yard in Rendsburg.

Cruise leg M45/5 started on 1 October 1999 in Bremen and ended on 3 November 1999 in Las Palmas. It was subdivided into two parts with an interim stay in Las Palmas during 20 - 22 October. During the first leg (M45/5a), sedimentological investigations and plankton sampling were carried out in the North Sea, Azores Frontal System and off Cape Ghir (NW Africa) with the purpose to collect data on the reconstruction of paleo-environmental conditions of these regions. During the second leg (M45/5b), equipment testing, mooring work and water column measurements were carried out. Water column sampling, including primary production and particle flux measurements, were carried out around the time-series station ESTOC (European Station for Time-series in the ocean, Canary Islands) as well as off Cape Ghir.

Zusammenfassung

Die Meteor-Reise M45 fand 1999 im Nordatlantischen Ozean statt und bestand aus fünf Fahrtabschnitten.

Die durchgeführten Untersuchungen während der Meteor-Reise M45/1, die am 19. Mai 1999 in Malaga begann, bezogen sich auf die wissenschaftlichen Programme CANIGO/ESTOC und DOMEST. Das DOMEST-Programm beschäftigt sich mit mariner Technologie und Datenübertragung, die vor allem in der Region der Kanarischen Inseln durchgeführt wurde. Das CANIGO/ ESTOC-Programm konzentrierte sich auf Meersbodenuntersuchungen und Wasserprobennahme. Am Morgen des 8. Juni lief Meteor in Lissabon ein.

Während des zweiten Fahrtabschnitts (Lissabon - St. John's) bestand das Ziel darin, die Ausbreitung und Vermischung von Wassermassen im östlichen Becken des subpolaren Nordatlantiks zu untersuchen. Die Arbeiten gehören zu den jährlich durchgeführten Feldprogrammen des Kieler Sonderforschungsbereichs SFB 460. Im einzelnen wurde eine wiederholte Aufnahme der hydrographischen Schichtung mit CTD-Sonde und Kranzwasserschöpfer im Islandbecken ausgeführt. Die Beobachtungen zu Tiefenzirkulation und Wassermassentransformation umfaßten auch Nährstoff- und Tracermessungen (FCKWs, Tritium/Helium). Ferner wurden verankerte Strömungsmesserketten zur Aufzeichnung des Overflow-Wassers am Reykjanesrücken aufgenommen und teils für ein weiteres Jahr verankert. Die Beobachtungen mit RAFOS-Floats zur Quantifizierung der Drift von Labradorseewasser im östlichen Becken wurden auf M45/2 fortgeführt.

Im dritten Abschnitt (St. John's - St. John's) wurde, wiederum im Rahmen des SFB 460, die Tiefenzirkulation und Wassermassenverteilung in der Labrador- und Irminger See untersucht. Hierzu wurden Standardschnitte über das westliche Randstromgebiet abgefahren, auf denen profilierende Strommessungen, CTD-Hydrographie und Tracermessungen (Freon, Tritium/ Helium) eingesetzt wurden. In der Labradorsee wurden eine Reihe von Tomographie-, Konvektions- und Randstromverankerungen geborgen und durch neue Verankerungen ersetzt. Östlich der Grand Banks wurde ein Randstrom-Array zur Messung des Tiefenwasserexportes aus dem subpolaren Nordatlantik eingerichtet.

Der vierte Abschnitt (St. John's – Rendsburg) unter der Leitung des Instituts für Meereskunde der Universität Hamburg hatte Verankerungsarbeiten und hydrographische Messungen entlang der Südostküste Grönlands von Kap Farvel bis zur Dänemarkstraße zum Ziel. Sie dienten der Zustandsbeschreibung der Overflow-Komponenten im nordwestlichen Atlantik, die im Rahmen des EU-Projektes VEINS (Variability of Exchanges in the Northern Seas) für den Zeitraum 1997-2000 wiederholt gewonnen werden. Nach Abschluß von M45/4 war Meteor vom 1. bis zum 29. September in der Werft in Rendsburg.

Der fünfte Fahrtabschnitt begann am 1. Oktober 1999 in Bremen und endete in Las Palmas am 3. November 1999. Meteor 45/5 war unterteilt in zwei Teilabschnitte. Während des ersten Teilabschnittes (M45/5a) wurden sedimentologische Untersuchungen und Planktonfänge in der Nordsee, im Azorenfrontsystem und vor Cape Ghir (NW Africa) durchgeführt, um Daten für die Rekonstruktion des Paleoklimas dieser Regionen zu gewinnen. Während des zweiten Teilabschnittes wurde Gerätetests, Verankerungsarbeiten und Wassersäulenmessungen durchgeführt. Wassersäulenuntersuchungen, einschliesslich Primärproduktion und Partikelflußmessungen wurden in der Umgebung der europäischen Zeitserienstation ESTOC (European Station for Time-series in the Ocean, Canary Islands) wie auch vor Cape Ghir durchgeführt.

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.

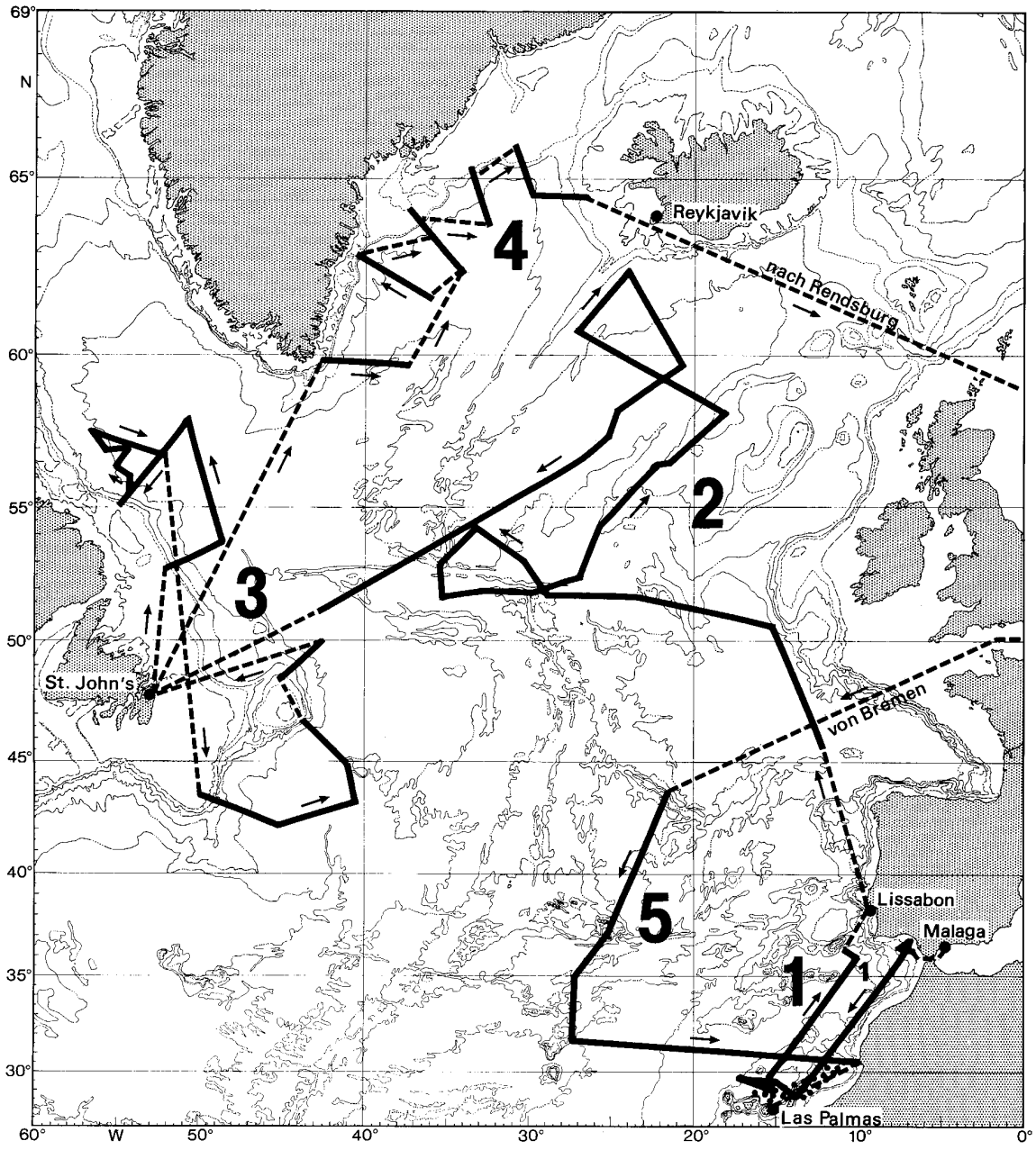

Fig. 1: Cruise track of the 5 legs of METEOR cruise M 45. For details of the work in the Skagerrak and the North Sea see Fig. 8.

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).

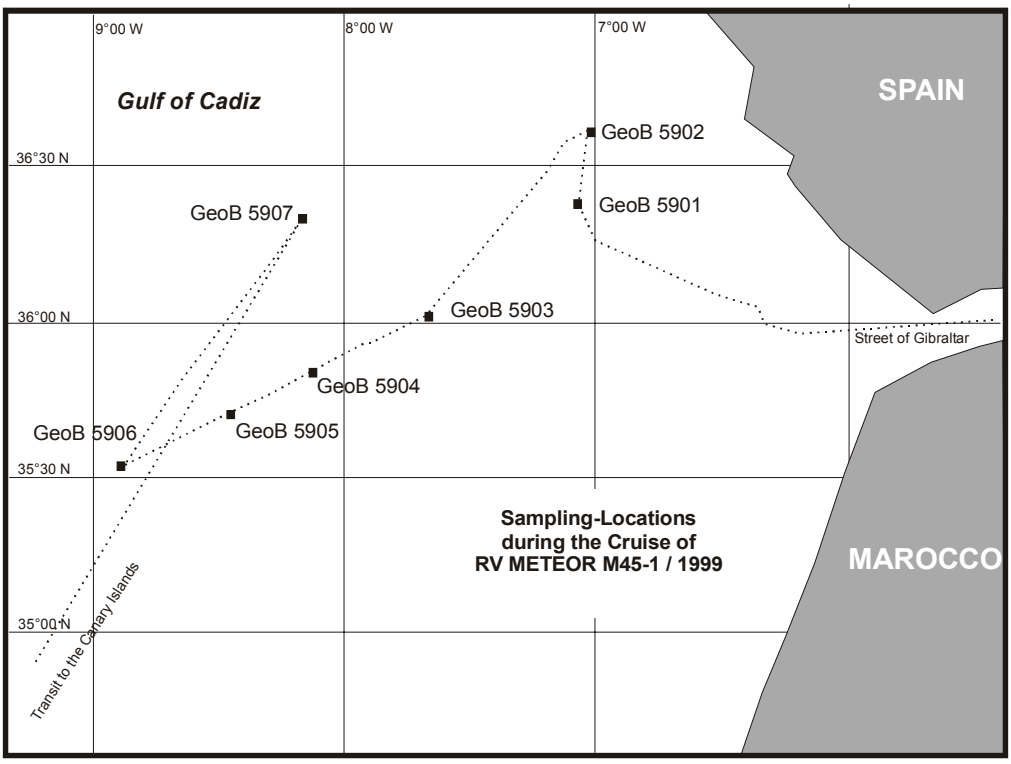

Fig. 2: Cruise track and sampling locations in the Gulf of Cadiz.

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

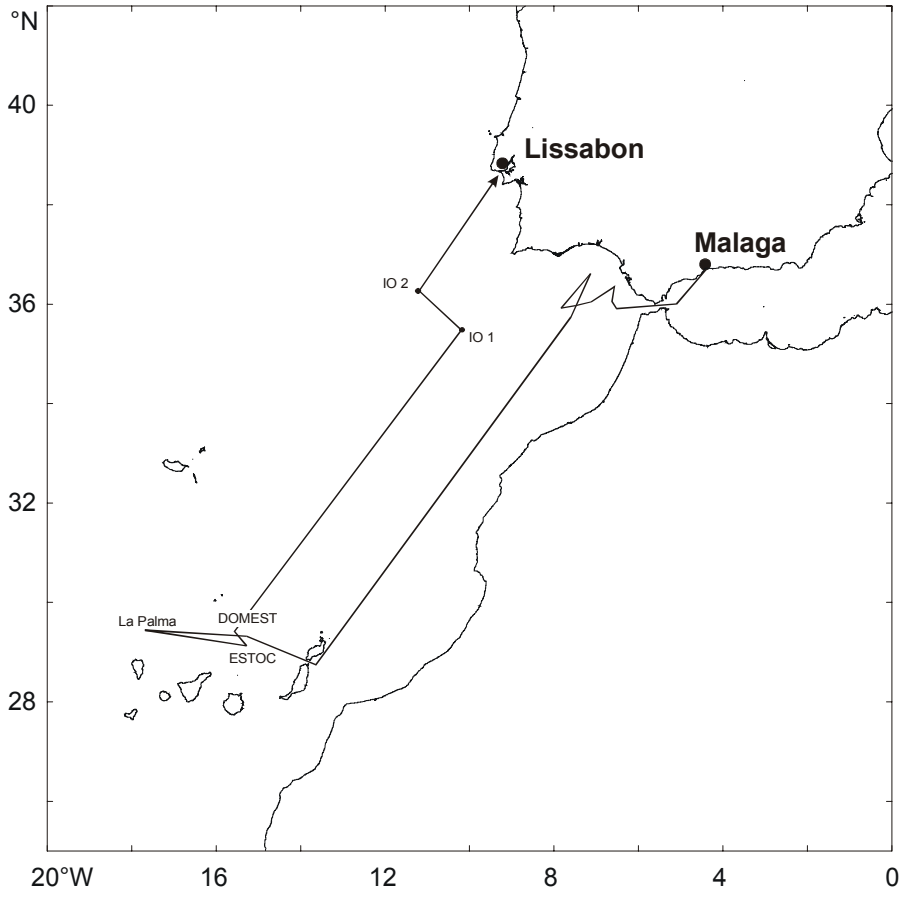

Fig. 3: Cruise track and working locations during RV Meteor cruise M45/1.

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.

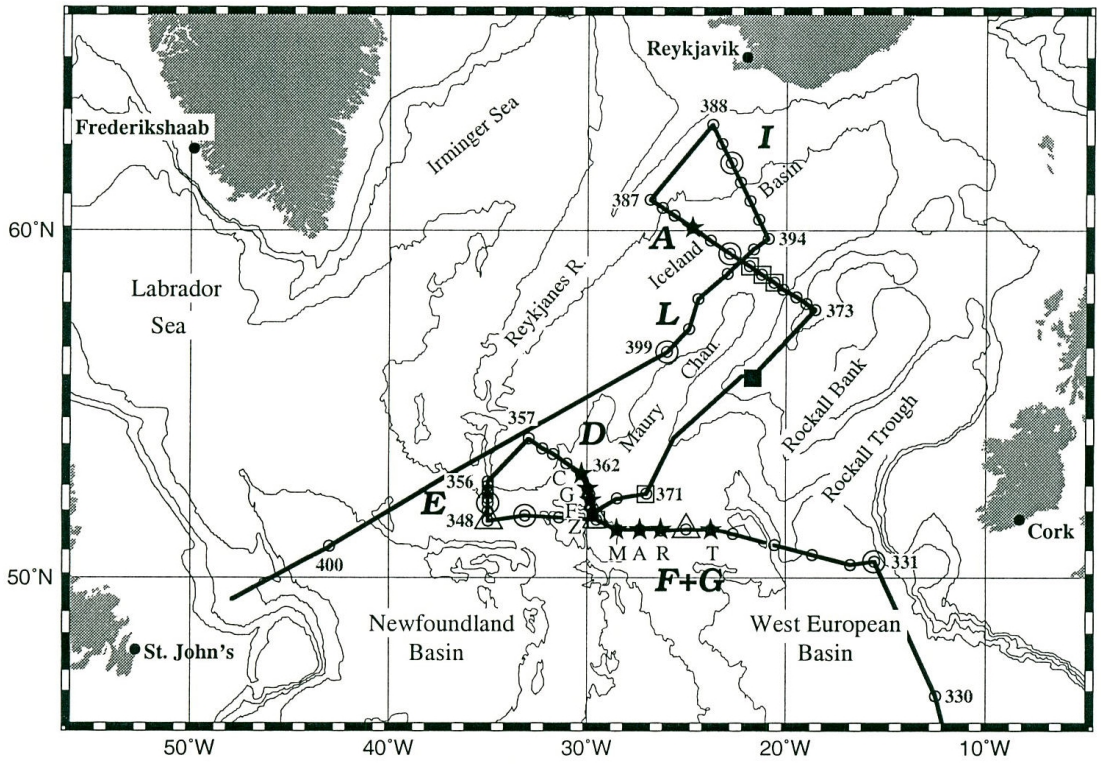

Fig. 4: Cruise track and station map of METEOR leg M45/2.
o CTD station O Station in θ/S Δ APEX float ☐ RAFOS float deployment
■ RAFOS float recovery ★ mooring deployed/recovered

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.

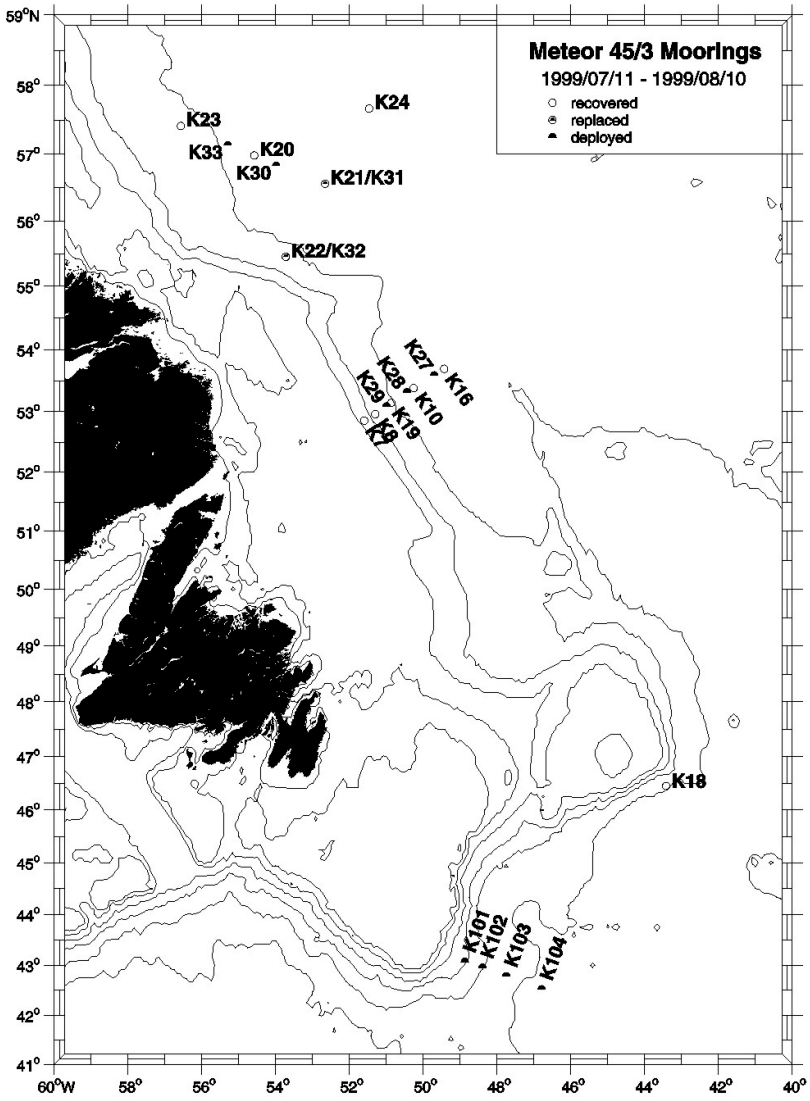

Fig. 5: Locations of mooring work during METEOR cruise M45/3 in July and August 1999.

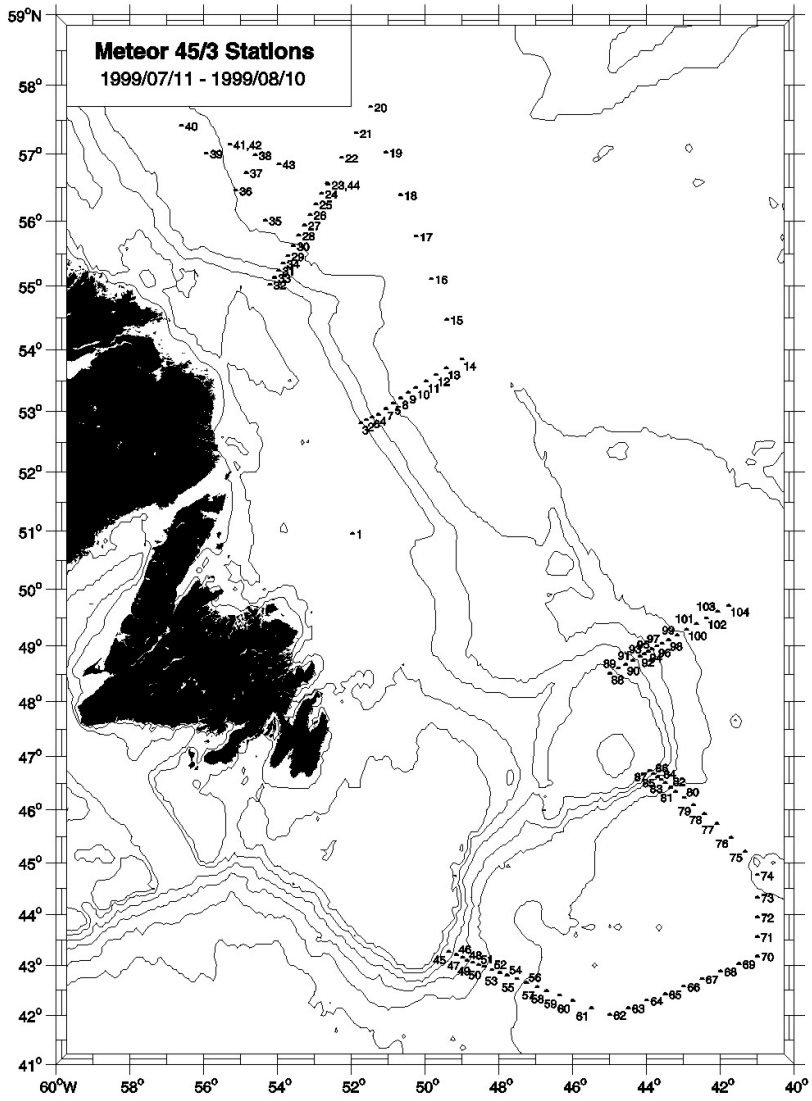

Fig. 6: CTD-Station map of METEOR cruise M45/3 (11 July to 10 August 1999).

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

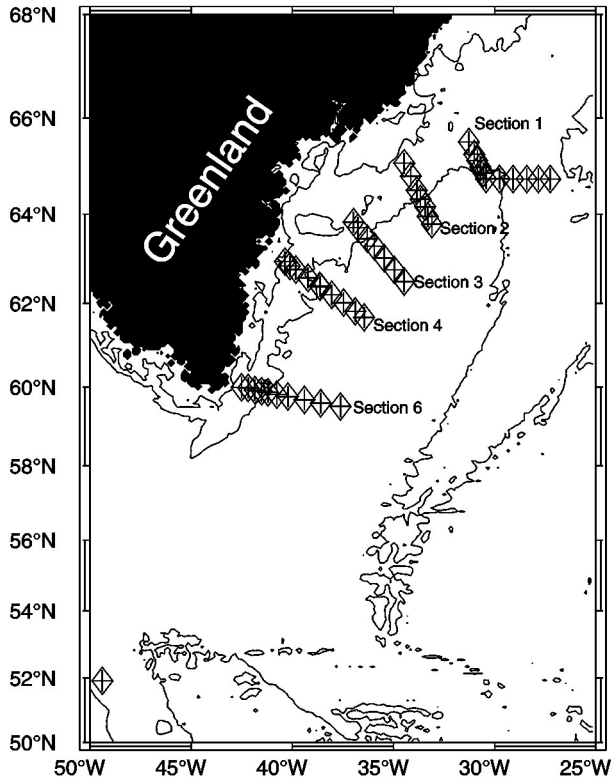

Fig. 7: Positions of the CTD profiles acquired during M45/4 and hydrographic sections. The mooring array is located along section

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

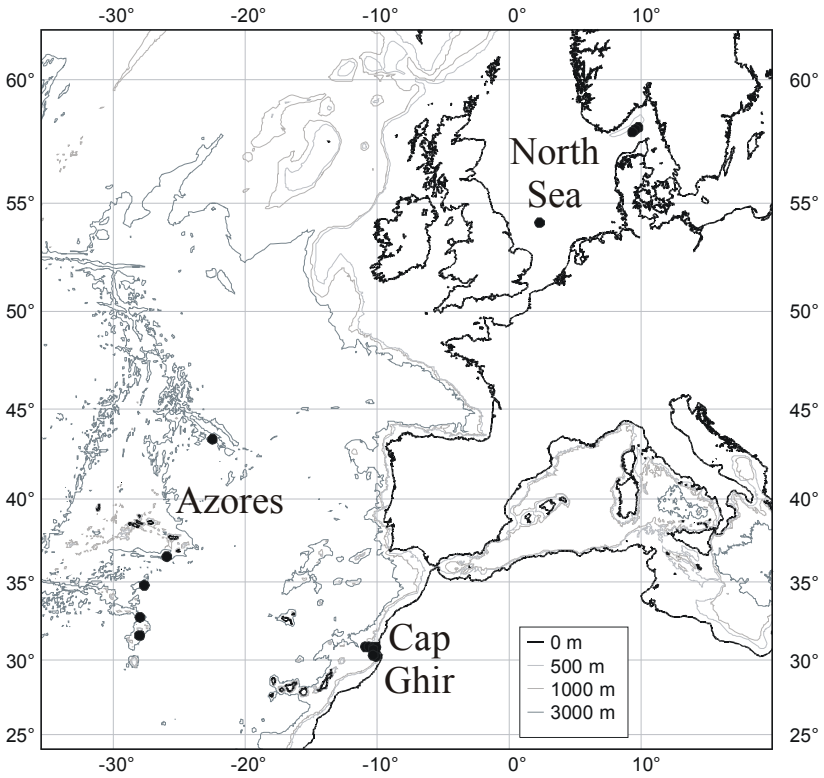

Fig. 8: Stations and the three working areas of M45/5a (Bremen to Las Palmas).

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

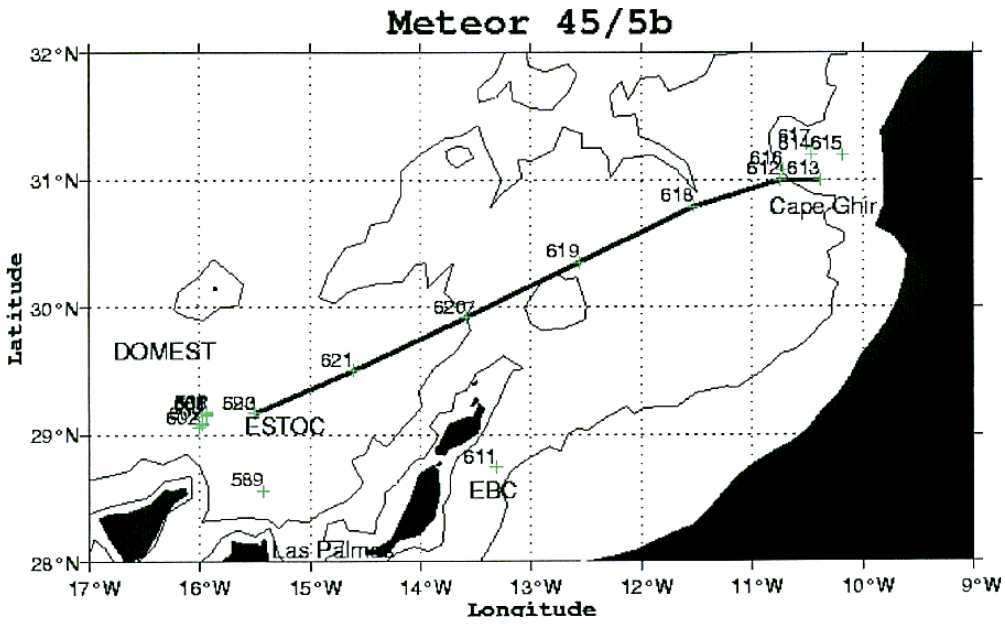

Fig. 9: Cruise track and stations of M45/5 b (Las Palams-Las Palmas).

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.

5.4 Leg M45/4

5.4.1 Hydrography

The hydrographic measurements were done with 2 Seabird CTD´s (Table 10). At station 557, an instrument was attached to the rosette for testing purposes. At a pressure of about 1900 dbar this instrument imploded and damaged the CTD (SB3). After several short test profiles at the following station it was concluded, that the CTD could not be repaired on board and following stations were done with the second CTD (SB1). Apart from a pressure offset in air of 1.14 dbar (SB3) respective 1.33 dbar (SB3), a comparison with the reversing thermometers showed that no additional in situ calibration of temperature and pressure were necessary. Bottle salinities were determined with an AUTOSAL salinometer, which was calibrated using standard seawater. The conductivity showed a time independent offset, after calibration the accuracy for conductivity (respective salinity) is better then 0.003 (Fig.57).

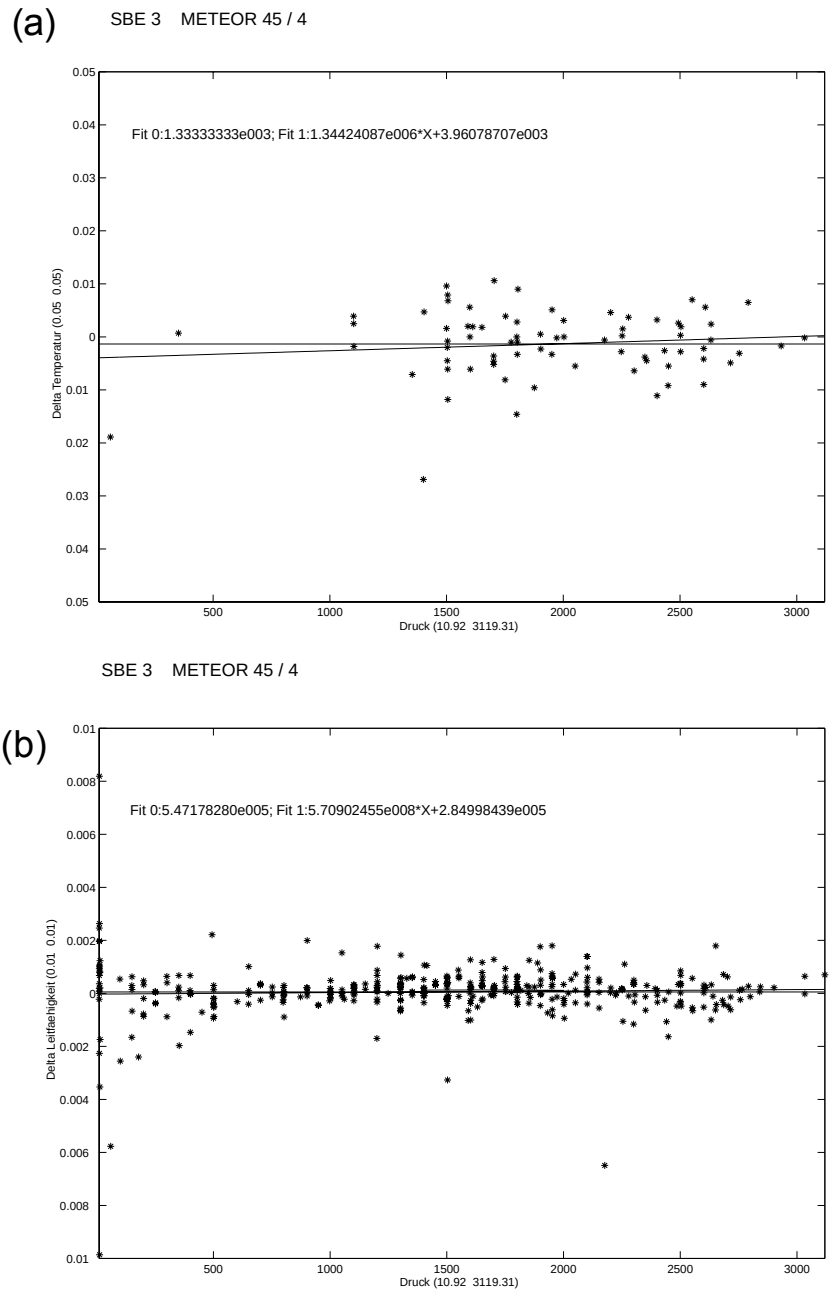

Fig. 57: Difference in temperature (a) and conductivity (b) between CTD (SB3) and bottle data after calibration.

At section 1 (Fig.58) the Denmark Strait Overflow water can be clearly seen as a layer of low salinity and temperature sitting on the Greenland slope. This layer can be traced till the southernmost section 6, although with increasing temperature and salinity due to mixing with ambient water. In comparison with previous cruises (Meteor 39/5 and Valdivia 173, Fig. 59) it can be noted: There was more overflow water than in 1997 and 1998, it was fresher and colder and its CFC-concentration (see below) was higher than seen before. It is concluded that the overflow was composed of more water from shallower levels in the source area north of Denmark Strait. The amount of deep water from the Labrador Sea was found to be less and with slightly higher temperature and salinity than in the preceding years. This result is consistent with the reduced convective formation of Labrador Sea Water observed in recent years. The preliminary analysis has also revealed a reduced fraction of high salinity components in the Atlantic Irminger Water. This corresponds to the recently observed eastward expansion of the subpolar waters in the Northwestern North Atlantic, which has terminated an increased influx of saline waters to the north of Denmark Strait found in 1997 and 1998.

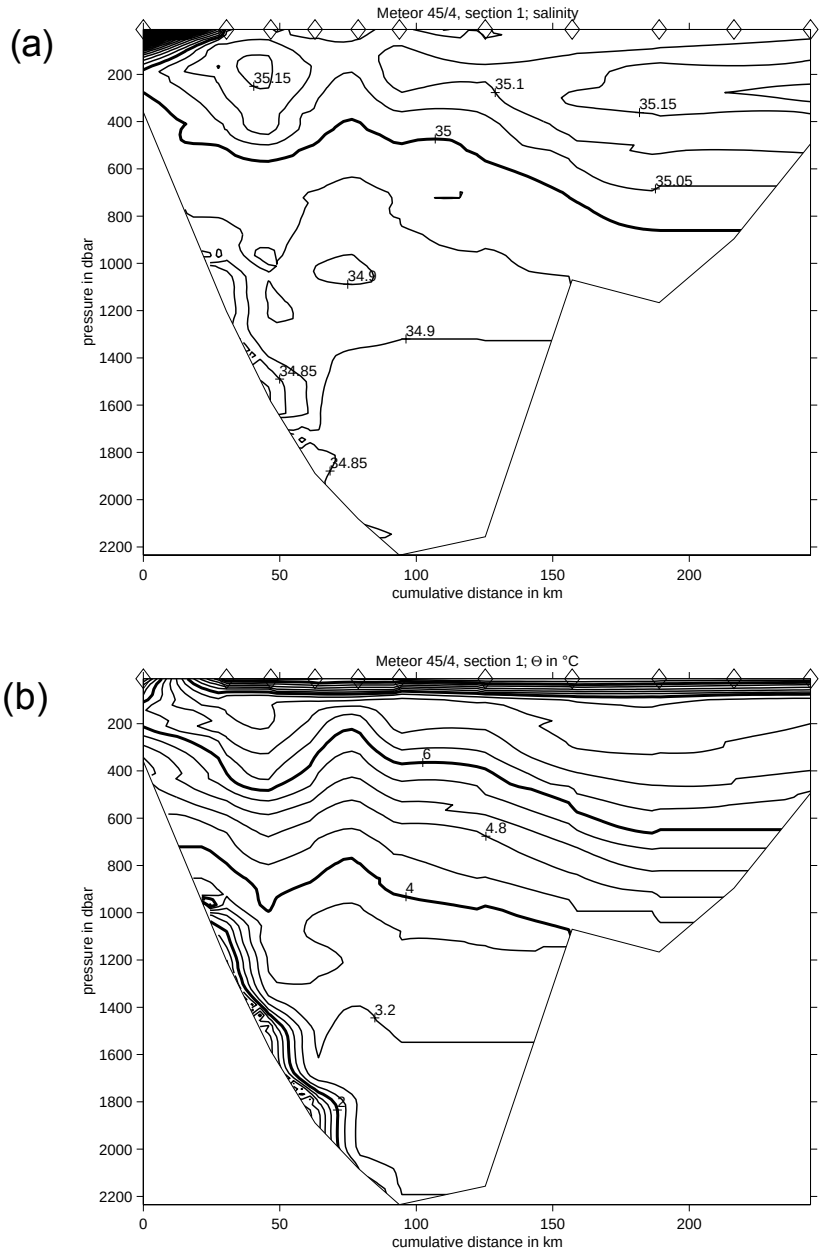

Fig. 58: Salinity (a) and potential temperature (b) along section 1.

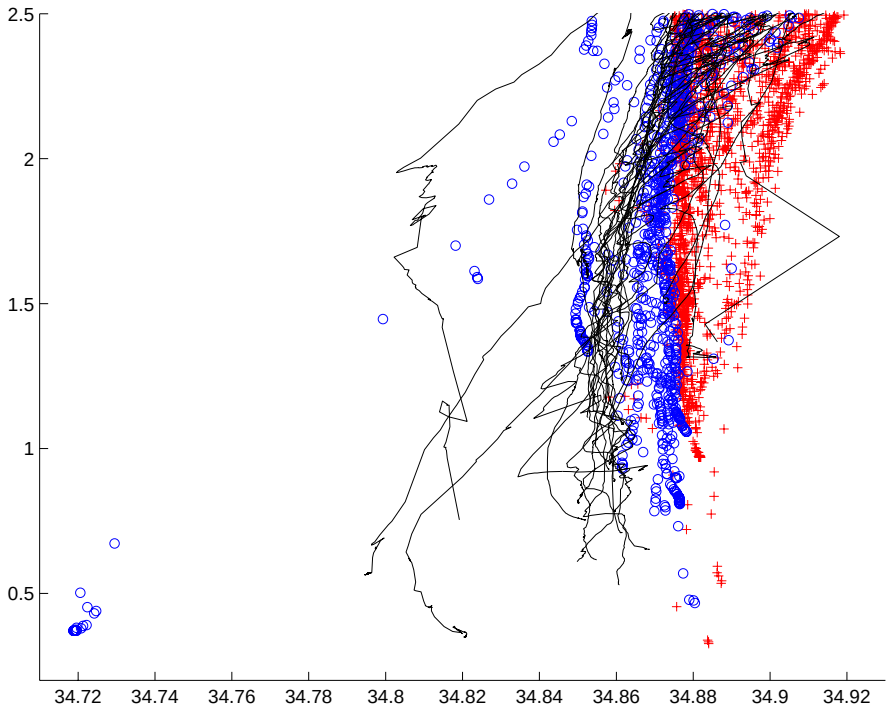

Fig. 59: Composite θ/S diagrams of cruise M45/4 (lines) compared to M39/5 (+) and VALDIVIA 173 (o).

Tab. 10: Coefficients of the in situ conductivity calibration :

Conductivity = Conductivity(raw) + a0 + a1*Pressure

CTD	a0	a1
SB3	+9.70443784e-3	-2.91765989e-7
SBE	+3.02555052e-3	-1.55125204e-7

5.4.2 Moorings

The current and temperature data from the recovered Aandera meters was available short after recovery. Data from the inverted echo sounders needs more processing and is still not available. The mooring array also included for the first time a SeaCat instrument so that high quality salinity time record is available. Surprisingly very low salinity values (Fig. 60) were found for a period of approximately 90 days, the respective T/S characteristics were not found in any of the corresponding hydrographic sections. Corresponding characteristics were just found in one station of the northernmost section 1 during the Valdivia 173 cruise in 1998.

5.4.3 Tracer Measurements (CFC-11 and CFC-12)

(O. Plähn, K. Bulsiewicz, I. Schlimme)

Two Chlorofluorocarbons (CFC) components, CFC-11 and CFC-12, were analyzed during the cruise M45/4. After sampling, 20 mL of water were transferred from precleaned 10 L Niskin bottles to a purge

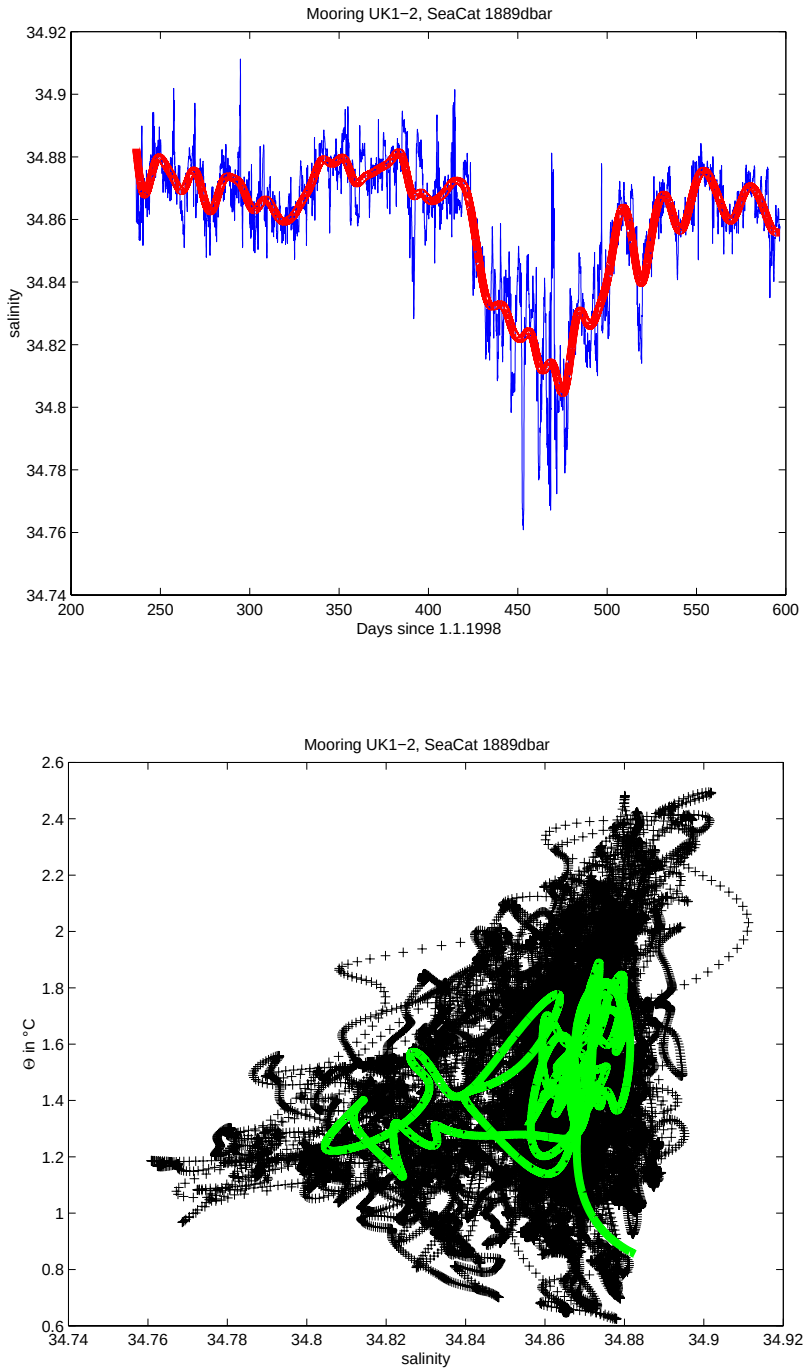

Fig. 60: Data from the SeaCat instrument located in the Denmark Strait Overflow Water at section 3. a) Salinity as a function of time (the thick line is is low-pass filtered data) b) θ/S diagram (the line being the low-pass filtered data).

and trap unit. The gases were then separated on a gaschromatographic column and detected with an Electron Capture Detector (ECD). A standard gas was used to convert the ECD signals in concentrations. The efficiency of the ECD was very stable in time, the observed temporal variations were about 6% for both components. To correct the temporal drift of the ECD, a calibration curve with six different gas volumes was taken before and after each station assuming that the temporal change between two calibration curves is linear in time.

During the cruise, the CFC system worked continuously, thus 560 water samples from 38 CTD stations were analyzed. The CFC samples were collected from different depths covering the whole water

column, but the survey was focused on the deep water masses. The blanks or CFC-11 and CFC-12 were negligible. Accuracy was checked by analyzing about 70 water samples at least twice. It was found to be +/-0.45% for CFC-12 and +/-0.53% for CFC-11. The saturation at the surface of both components was about 100% +/-5%. The CFC-11/CFC-12 ratio was between 1.9 and 2.1.

The aims of the CFC analysis were to study the circulation and to analyze the variability of the deep water masses Labrador Sea Water (LSW), Gibbs Fracture Zone Water (GFZW), and Denmark Strait Overflow Water (DSOW) east of Greenland. Along five different sections south of the Denmark Strait CFC measurements were carried out.

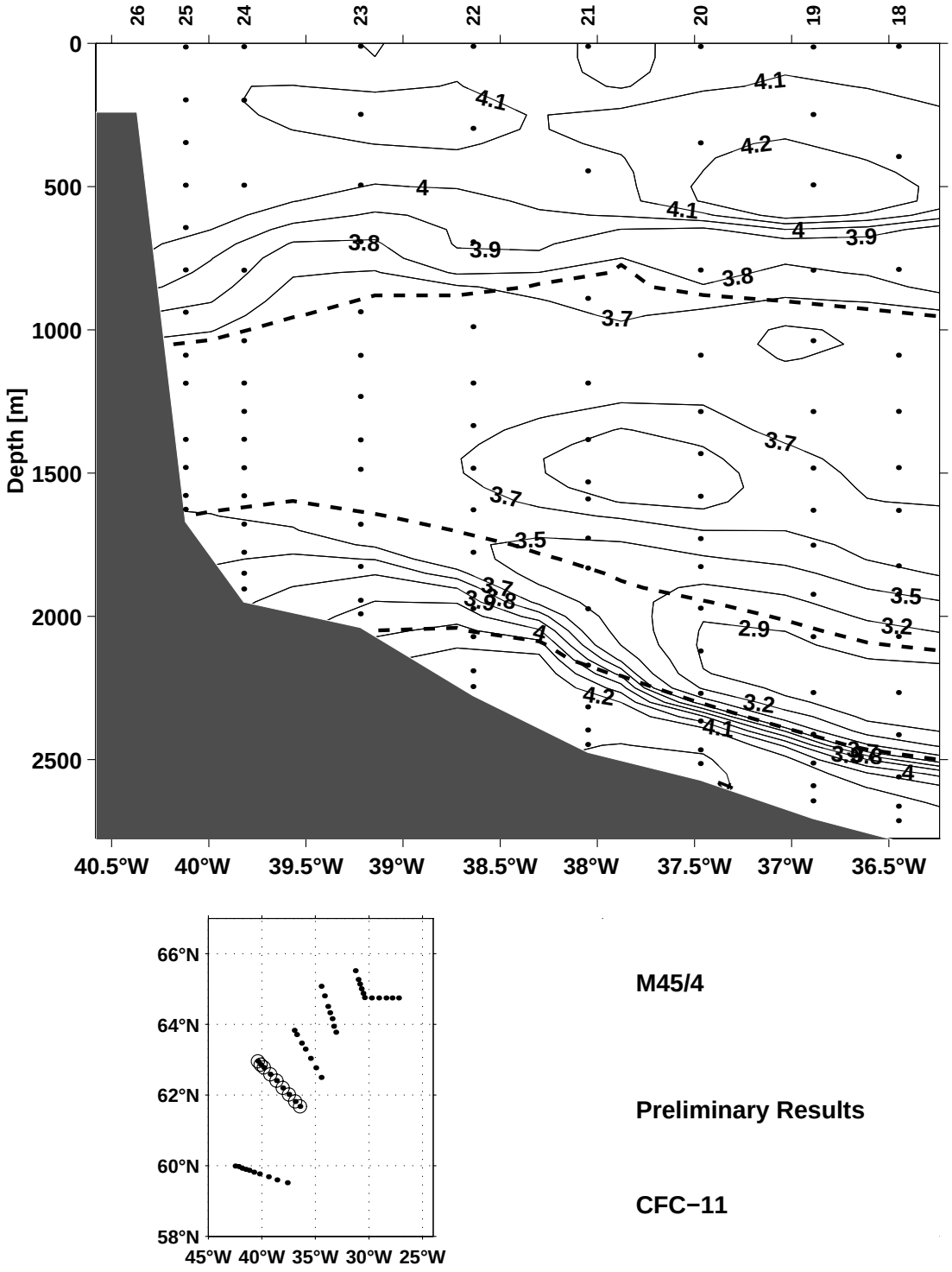

Fig. 61: CFC concentration along section 4.

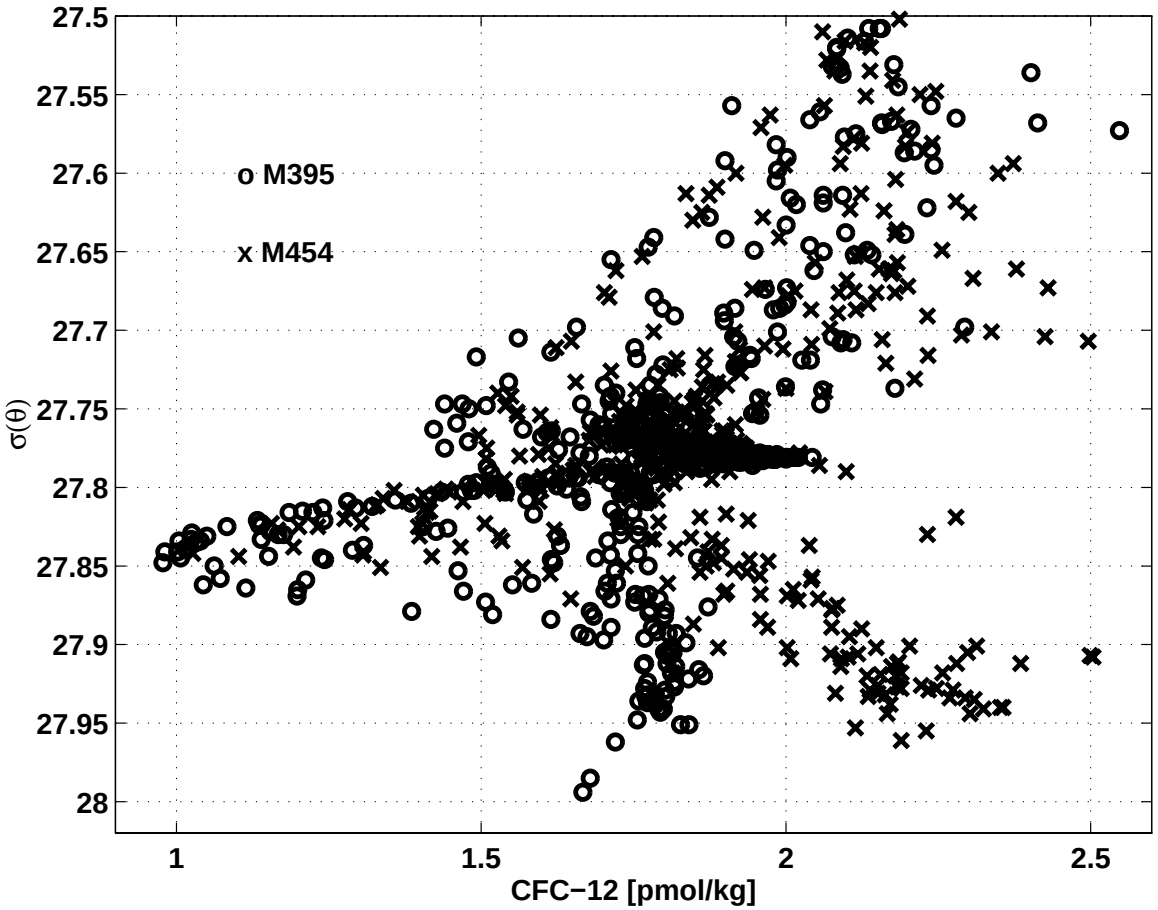

Fig. 62: Comparison of the CFC concentration between METEOR cruises M39/5 and M45/4.

Two years ago, CFC's were measured at the same sections during the cruise METEOR 39/5 (Aug./Sep. 1997). The comparison of the recently collected data with the older measurements shows new interesting results. It is known from former studies that LSW and DSOW are marked by high CFC concentration, whereas the GFZW is characterized by a CFC minimum (Fig. 61). During this cruise, the measured concentration in the DSOW were much higher than observed two years ago (Fig. 62). The mean CFC-12 values increased from 1.7 pmol/kg (1997) to about 2.3 pmol/kg and the CFC-11 concentration rised from about 3.7 pmol/kg to 4.5 pmol/kg. Whereas in the density level of the LSW (27.74-27.8) the CFC values stagnated in the last two years or even decreased some percents.

The increase of freon concentration in the DSOW correlates with a decrease in salinity, but the temperature did not change significantly. The stagnation in the LSW might be caused by the absence of deep convection in the Labrador Sea in the last years. The largest concentration in the LSW were observed at the eastern edge of each section. As we did not measured in the eastern Irminger Sea, it cannot be excluded that the core of the LSW moved eastward. During the cruise METEOR 45/2 in the eastern North-Atlantic, it was observed that the CFC concentration in the LSW increased in the last two years.

6 Ship's Meteorological Station

6.1 Meteorological Conditions During Leg M 45/1

(L. Kaufeld, W. Th. Ochsenhirt)

After having left the harbour of Malaga at 19 May at about 10.00 hours, the wind blew from southwest with increasing forces 5 to 6 bft. The well known funneling effects caused the wind to freshen up in the Strait of Gibraltar. There it reached 7 bft from westerly direction despite of only weak pressure differences between the Gulf of Cadiz and the Alboran Sea. Due to the short fetch, the wind sea was not adapted to this wind force.

The next few days with scientific measurements in the Gulf of Cadiz, a northerly breeze blew with force 4 associated with a bright sky. During the two days passage to Lanzarote northerly winds with 5 bft were observed.

From 25 to 31 May during the research work north of the Canary Islands, only weak winds occurred from northerly directions. The visibility was good to excellent: Sometimes the northeastern part of Teneriffa could be seen and once even the volcano Pico de Teide in a distance of 120 km. In the morning of 31 May, an old depression which had penetrated the subtropical ridge and had reached the region north of Madeira caused some showers in the ships vicinity.

By the change of the months, a weak depression moved northeastward away from the Portuguese coast and a strong anticyclonic ridge extended eastward from the Azores high. Since the heat depression over Northwest Africa remained stationary, the pressure differences around the Canary Islands intensified. This weather development was well forecast several days in advance by the numerical model of *Deutscher Wetterdienst.* On the cruise leg to Lissabon the northnortheasterly wind increased to 6 bft during the night to 4 June and shortly reached 7 bft.

The last four days of this cruise, METEOR gradually "sailed" into the regime of the anticyclonic ridge with weakening winds from northerly directions. For a short time they freshed up a little before entering the mouth of the Tejo river.

In the morning of 8 June, this voyage ended in Lissabon with bright sunshine.

6.2 Meteorological Conditions During Leg M 45/2

(G. Kahl)

When METEOR left Lisbon on 11 June 1999, the subtropical anticyclone was centered just west of the Bay of Biscay, its central pressure being 1032 hPa. Over the Iberian Peninsula, however, low pressure was prevailing, so that the vessel had to deal with headwinds up to Beaufort 7 while on her way to the position where oceanographic work began on 10 June 1999. While on her way to the CGFZ, the Charlie Gibbs Fracture Zone, the research vessel experienced moderate southwesterly winds most of the time. On 19 June, however, the wind force rose to 8 Bft during passage of a front. The general circulation consisted of fast moving waves that passed between a gale center west of Iceland and the aforementioned Azores High. The gale force winds thus did not last very long. While work was going on over the CGFZ, METEOR experienced light to moderate winds from westerly directions.

Meanwhile however, some intensification of the General Circulation was taking place over the North-west Passage, a well developed low of under 990 hPa central pressure reaching Davis Strait on 23 June 1999. In due course, a flat low over Cape Walloe, Southeastern Greenland, started intensifying during 24 June 1999 to lie southwest of Iceland on 25 June 1999 as a gale center of under 985 hPa central pressure.

As the gale center continued eastward Bft 8 was observed on Meteor from Southwest, veering West later. Gale force winds of 8 Bft from the northeast were blowing on 26 June 1999 while the gale center stalled south of Iceland and finally began filling. The seas that had developed in the region hampered operations only to a little effect by reducing the ship's speed. Winds abated and were light only in the days to follow when the research vessel probed the Reykjanes Ridge.

When Meteor finally began heading for her next port of call on 2 July 1999, the general circulation had adopted a more southerly route, a gale center with a central pressure of under 985 Pa moving east north of the Azores before stalling and filling just west of Ireland. Thus, moderate northeasterly winds were observed, veering southeast during 3 July 1999 and finally southwest during 4 July 1999 before abating. The low had been detected during 2 July 1999 west of the Great Lakes as it moved eastward quickly, passing the Strait of Belle Isle on 3 July 1999 with of central pressure of under 990 hPa, but then turning north and even northwest, thereby starting to fill. secondary depressions followed on a more southerly course so as not to influence Meteor as she proceeded on her way, reaching St. John's, Newfoundland, on 8 July 1999.

6.3 Meteorological Conditions During Leg M45/3

(G. Kahl)

When Meteor left St. John's, Nfld, on 11.07.1999, a gale center over the southern part of Baffin Island was governing the general synoptic situation. In ist reign, a flat low had just passed Newfoundland and another was due to follow. This resultet in light easterly winds while the vessel began her way northward into the Labrador Sea. Winds turned to westerly directions soon, however, and a secondary low formed over Hudson Bay during 15.07.. It developed into a gale center when still over the continent, passing the Strait of Belle Isle during 17.07. and moving away eastwards later. The Meteor was left unmolested because her work had carried her far enough northward. Meanwhile, however, another low had been travelling east from the region well west of the Great Lakes, developing into a gale center when passing Hudson Bay during 18.07. and Goose Bay, Labrador, during 20.07. when southeasterly winds of 6 Bft, backing northeast, were observed. The light winds that followed were of short duration because the low over Baffin Island was still active. So, the next secondary low was formed over Hudson Bay during 21.07., southeasterly winds of 6 Bft being felt by 22.07.. When the research vessel finished probing the Labrador Sea region and headed south to the southeastern rim of th Grand Banks, a low approaching from the Great Plains had developed into a storm center at the western tip of Hudson Bay, and a high had formed over the Maritimes. In consequence, light northerly winds accompanied our ship up to the 26.07. Meanwhile a low had formed near Cape Cod, Mass., moving northeast and developing but slightly. It passed along the south coast of Newfoundland on 28.07. while strong southeasterly winds, veering southwest, were felt on the southeastern Grand Banks. These tapered off soon, and winds remained light during the last days of July. The low in the upper atmosphere over Baffin Island had moved south somewhat to lie over northern Quebec. A secondary low had formed over the St. Lawrence Seaway during 31.07., moving northeast and developing into a gale center east of Hudson Strait during 01.08., then swinging northwest into Baffin Island as a storm center by 02.08.. At Meteor's position, southwesterly winds up to 6 Bft were observed, veering northwest on 03.08.. Light winds then accompanied the research vessel on her way to the Flemish Cap. During 04.08., a low had formed off the coast of South Carolina and had moved slowly along the eastern seaboard, thereby developing into a gale center so that southeasterly gales of 7 to 8 Bft were observed on 07.08.. Winds were light again on 08.08. while the Meteor began heading

for St. John's, Nfld., but by that day still another low had migrated east from a position southwest of the Great Lakes, thereby developing into a gale center. In the morning of 09.08., the gale center had reached Nova Scotia, swinging northeast to Belle Isle Strait and deepening further, strong to gale force southwesterlies ensuing during the last day of the voyage. Saint John's was reached by 10.08.1999.

6.4 Meteorological Conditions During Leg M45/4

(G. Kahl)

When METEOR left St. John's, Nfld, on 13.08.1999, a migrating high had just passed the city, heading away northeastwards. A trough of low pressure extended from the Foxe Basin over North Quebec to New Brunswick. In consequence, light southerly winds were accompanying the research vessel out to sea. Another flat low, situated over the Great Lakes, was moving east, thereby developing into a gale center by 14.08. when over the Gulf of St. Lawrence. It turned northward and moved up the west coast of Greenland . Its secondary low, however, continued to move east. During 16.08., it was a gale center near Southeastern Greenland. The air masses north of the gale center moved against the mountainous coast and were diverted to the south where METEOR was experiencing northeasterly gales of 9 Bft and storm force gusts up to 11 Bft. These conditions reduced her speed severely. Half a day was lost before the position where work was to begin was reached on 17.08., winds being light and variable by then. Conditions kept being favorable while a high was building east of Greenland and the next low moved due east from Newfoundland. By 20.08. another low had been swinging northeast from Labrador, its movements being influenced by a trough in the upper air that had reached eastern Greenland. As it made its way into Denmark Strait, southerly winds 7 Bft were felt shortly on the ship's position. Winds continued to be blowing from southerly directions, speeds being light to 5 Bft, in the days to follow so that oceanographic work was not impeded. On 26.08., however, a low in the upper atmosphere had moved to southeastern Greenland, a gale center denoting its position at surface level. As METEOR began heading for the Pentland firth, southeasterly gales 8 Bft hampered her for a few hours. The last days of the voyage continued to be under the influence of the upper air low migrating east as our ship was proceeding in the same direction. In consequence, several lows and their associated frontal troughs made themselves being felt by strong southerly winds up to 7 Bft. Winds abated in the North Sea so that Rendsburg was reached by 31.08.1999.

6.5 Meteorological Conditions During Leg M45/5

(G. Kahl)

When METEOR began her voyage from Bremen on the first of October, 1999, a gale center on the south coast of Iceland was governing the North Sea. So she was greeted by strong Westerlies of 7 Bft and gale force thundersqualls even as she ventured into German Bight. Going north along the coast of Jutland, these calmed down on 02.10. and 03.10. while on METEOR scientific work was done on the Skaw. Meanwhile, the gale center had moved away to the Norwegian Sea, but a secondary low had formed and reached western Norway. In its wake strong to gale force Northwesterlies accompanied the ship on her way to the Silver Pit where winds calmed down a bit. By 5 October, a High had formed over the British Isles and Ireland, and when the ship headed for the Straits of Dover, there were light northerly winds only.

Passing the Bay of Biscay, METEOR was lucky in being met by the subtropical high being situated north of the Acores, extending a wedge into the area. So only moderate northwesterlies of 4 Bft were observed, and on her way on to the first probing position just north of the Acores, conditions were sometimes calm.

When Meteor went further south past the Azores reaching the vicinity of the Great Meteor Bank she was continually under the influence of high pressure so that only light winds were felt. The last mentioned position was probed on 14 October when course was changed to the east.
On her way to Cape Ghir the ship continued to be under the influence of subtropical high pressure so that light northerly winds were observed and scientific work was unhampered. When near the coast of Morocco, there were moderate Northerlies of 3 to 5 Bft.

Meteor called at Las Palmas de Gran Canaria from 20 October to 22 October, 1999. During the time that the ship was working in the Cape Ghir region and was calling at Las Palmas, a tropical storm called Irene had developed east of the Lesser Antilles, made her way past the Bahamas and near the Eastern Seaboard of the U.S.A.. There, Irene successfully transformed into a storm of the temperate latitudes, and when Meteor put out to sea again on 22 October, Ex-Irene was south of Greenland, its central pressure being estimated as 945 hPa. Thus, she was a very prominent feature of the synoptic chart indeed. The General Circulation was greatly intensified, and as a result a cold front passed Meteor while working on the DOMEST position just north of Tenerife on 24 October. Mean winds were of the order of 5 Bft before and after the frontal passage, veering from west to northwest and later abating again. So there were no strong winds, but in the wake of Ex-Irene swell up to 5 m height was observed while the ship stayed at the DOMEST position until 27 October.

In fact, the outbreak of cold air masses was such that a Low over and to the north of the Canary Islands was formed, central pressure being 1008 hPa before it slowly filled during the next few days. Meteor was in the center of the Low and experienced light winds only as she headed to the Cape Ghir Region again, probing it intensively up to the end of October. Light to moderate northerly winds were observed there.
During 01 November the DOMEST position was visited again. Meanwhile, in the General Circulation, which had been intensified again by storm force remnants of a tropical storm called José, a storm center of 960 hPa was near the Faroeer Islands on 31 October, moving north and filling but slowly. A secondary low had formed on its cold front just east of the Azores on 01 November, moving to Cape Finisterre and further on to the northeast. Its cold front reached the Canary Islands during 01 November. Northeasterlies were strong in and just behind the frontal passage, 6 Bft being observed for some hours before winds abated again.

Meteor called at Las Palmas on 03 November 1999.

7 LISTS (see original report* for all other lists)

7.6 List of Abbreviations

AAIW	Antarctic Intermediate Water
ADCP	Acoustic Doppler Current Profiler
CANIGO	Canary Islands Gibraltar Observations
CCD	Calcite Compensation Depth
CFC	Chlorofluorocarbons
CGFZ	Charlie Gibbs Fracture Zone
CRM	Certified Reference Material
CTD	Conductivity, Temperature, Depth (Pressure)
DCM	Deep Chlorophyll Maximum
DIC	Dissolved Carbon Dioxide
DOBS	Deep Ocean Bottom Station (DOMEST)
DOMEST	Datenübertragung im Ozean und Meßtechnik zur hochauflösenden Erfassung des Stofftransportes in der Tiefsee
DOP	Deep Ocean Profiler (DOMEST)
DSOW	Denmark Strait Overflow Water
DWBC	Deep Western Boundary Current
EBC	Eastern Boundary Current
ECD	Electron Capture Detector
ESTOC	European Station of Time Series, Canary Islands
FFT	Fast Fourier Transformation
GFZW	Gibbs Fracture Zone Water
GKG	Großkastengreifer (Box Corer)
IMW	Intermediate Mediterranean Water
ISOW	Iceland Scotland Overflow Water
JGOFS	Joint Global Ocean Flux Study
KL	Kastenlot (Piston Corer)
LADCP	Lowered Acoustic Doppler Current Profiler
LDW	Lower Deep Water
LSW	Labrador Sea Water
MART	Mid-Atlantic Ridge Transport
MSD	Multi Sensor Device (DOMEST)
MSU	Moored Sensor Unit
MLD	Mixed Layer Depth
MN	Multinet
MUC	Multicorer
MOW	Mediterranean Overflow Water
MW	Mediterranean Water
NAC	North Atlantic Current
NACW	North Atlantic Central Water
NADW	North Atlantic Deep Water
NAO	North Atlantic Oscillation
NEBROC	Netherlands Bremen Oceanography
NOAA	National Oceanic and Atmospheric Administration

7.6 continued

SBU	Surface Buoy Unit (DOMEST)
SPM	Suspended Particulate Matter
SPMW	Subpolar Mode Water
SSP	Sub Surface Platform
SST	Sea Surface Temperature
SW	Surface Water
VEINS	Variability of Exchanges in the Northern Seas
WOCE	World Ocean Circulation Experiment

8 Concluding remarks and Acknowledgements

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WHPO-SIO Data Processing notes

Date	Contact	Data Type	Data Status Summary
09/05/01	Uribe	CTD/BTL/DOC	FTP'd from JCREASE ftp site; Reformatting Needed
	The data for this cruise was copied from: NON_WHP/CM_HYDRO_2001.03.09_JCREASECURRENT_METER_WOCE_CRUISES/AR18_ACM8. Cruise Expocode is 06MT45_4 with date August 13 - 31st, 1999. It was decided from the Mooring chart and other ar25 directories that this cruise should be assigned the letter f. There are Bottle and CTD data in CSV format online. Documentation was provided via 2 htm files that were linked to the DOC section online. Small modification was made to the second DOC link so it would read the map it uses. The file name was changed from 19990123.gif to ar25_fdo_2.gif in the htm file.		
09/05/03	Anderson	SUM/CTD/BTL	Data Reformatted; needs to be placed online
	Formatted .sum, .sea, and .wct files. Sent notes to Jerry. Needs to be put online. Reformatting notes: Sept. 2, 2003 Made a .sum file using information from file ar25_hhy.csv. The .sum file has EXPOCODE, WOCE SECT, STNNBR, CASTNO, CAST TYPE, DATE, TIME, EVENT CODE, LATITUDE, LONGITUDE, NAV, and UNC DEPTH. After looking at the documentation I assumed that the cast type was ROS and the nav was GPS. I made the event codes all BE. Made a .hyd file from ar25_hhy.csv. The only parameters are STNNBR, CASTNO, CTDPRS, CTDTMP, and CTDSAL. There were no QUALT1 flags so I left them blank. Made individual .wct files from ar25_hct.csv which has all the stations in one file with no headers for the different stations. There were no QUALT1 flags, so I left those blank. There is CTDPRS, only integer values, CTDTMP, some integer, some to one decimal, some to two decimals, some to three decimals, and CTDSAL, some one decimal, some two decimals and some three decimals. The ctd casts are every decibar.		
11/03/03	Bartolacci	SUM/CTD/BTL	Website Updated; Data Reformatted/OnLine
	For the purposes of conversion to exchange and netCDF files, minor edits were made to all files recently reformatted by Sarilee. Notes on edits were sent to Jerry Kappa. All new files were placed in parent directory, old files moved to original directory and web page files regenerated to link all to website. Here are notes for edits that needed to be made in order to finish reformatting and conversion. All files are online and linked now. CTD: 20031102 DMB In order to convert CTD files to exchange and netCDF formats the following edits were made to all files: · Edited station number in station file 511 from 151 to 511. · Edited station number in station file 512 from 152 to 512. · Added missing value (-9) to Oxy and No. Obs. columns · added asterisks to all columns along with a Q1 byte of 2 for valid (present and assumed good) values and 5 for any missing values. This was needed for conversion purposes. Converted all files to exchange and netCDF and created inventory file with no errors detected. Linked all new files online and moved previous files to original directory.		

BOT/SUM: 2003.11.02 DMB

After experimenting with several edits in order to convert bottle file bottle and summary files:

SUM: Removed "H" from line designation AR25H. Removed "COR DEPTH" empty column.

BOT: Added missing value -9 to both SAMPNO and BTLNBR columns. It was necessary to add Q1 bytes to file in order to convert it to exchange and subsequent netCDF. A Q1 of 2 was added for all valid (present, assumed good) values, and 5 for any missing data values.

File converted to exchange and netcdf with no errors. Inventory files were generated and all previous files were moved to original directory. New files placed online and webpage files regenerated.

11/04/03	Kappa	DOC	Downloaded cruise report from METEOR website

http://www.marum.de/senkom-ozean/meteor-berichte/m45/m45.html

Emailed Jens Meincke for permission to use on our website.

11/12/03	Kappa	DOC	Permission to publish request

Wrote to Chi. Sci. for permission to put his doc on our webiste. Earlier request to publish by email didn't reach Meincke. Followed up with this letter:

Jens Meincke
Institut für Meereskunde an der Universität Hamburg
Tropolowitzstr. 7
22529 Hamburg - Germany

Dear Dr. Meincke,

I am responsible for assembling the cruise reports which are published concurrently with hydrographic data on the CLIVAR-WOCE- SIO website. I located your report for METEOR Cruise No. 45, 18 May - 4 November 1999 at the following website:

http://www.marum.de/senkom-ozean/meteor-berichte/m45/m45.html

Leg 4 of this cruise has been designated a CLIVAR cruise (Line AR25, ExpoCode 06MT45_4), and we would like to cite and publish the following sections of your report:

Cover Table of Contents, Abstract, Zusammenfassung Research Objectives, Participants, Research Programme, Narrative of the Cruise Preliminary Results, Leg M45/4 Ship's Meteorological Station Lists, Concluding Remarks, References

Please let me know if this is acceptable.

11/19/03	Kappa	DOC	Expanded Cruise report, assembled ascii version

PDF Version:

- Added pdf links from figures, table of contents, and WHPO-SIO Summary page to relevant text passages
- Added WHPO-SIO-generated station position track

PDF and Text Versions:

- Added WHPO-SIO Summary Pages (1 & 2)
- Added these WHPO-SIO Data Processing Notes