

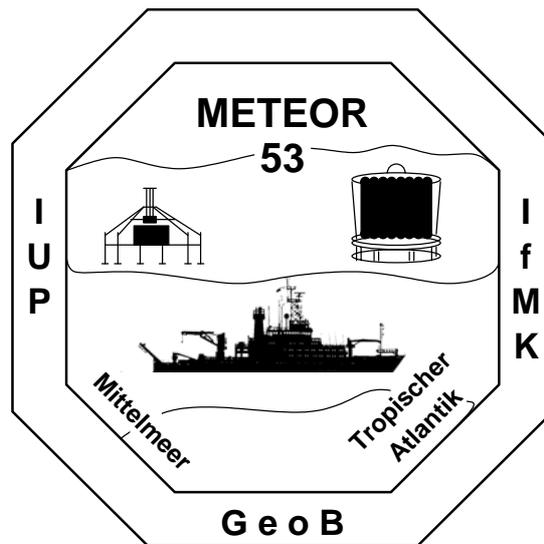
METEOR-Berichte 05-2

Circulation and Particle Fluxes
Mediterranean – Canary – Tropical Atlantic – Caribbean

METEOR CRUISE

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I Abstract

The main focus of leg M53/1 (Limassol – Las Palmas – Mindelo) were particle flux studies in the Mediterranean Sea and in the Northeast Atlantic. The objective is to determine and understand the processes controlling the varying fluxes of carbon on times scales from weeks to glacial-interglacial periods. The work is related to several projects: ANIMATE (EU), DOLAN (BMBF), ESTOC (Spanish-German Cooperation) and the Research Center Ocean Margins RCOM of the University of Bremen. Furthermore research in the context of two DFG-projects “In-situ measurements and sampling of marine aggregates” and “Zooplankton structures and particle flux in the Levantine Sea against the background of the changes in the thermohaline circulation” were carried out.

During M53/2 (Mindelo-Recife) physical oceanography studies of the western tropical Atlantic were carried out by the Institut für Meereskunde of Kiel University within the context of CLIVAR (Climate Variability and Predictability studies). The investigations in the upper ocean aimed at understanding the coupling of the tropics with the subtropics by the shallow tropical-subtropical thermohaline cell and the associated climate variability. The deep sea work focussed on the determination of transports and pathways of North Atlantic Deep Water in the tropical deep western Atlantic

During M53/3 (Recife – Pointe a Pitre), the Institut für Umweltphysik, Universität Bremen, carried out physical oceanography studies in the subtropical – tropical Atlantic. The measurements were part of the DFG project ‘West-East Passages’ in which the transport of lower deep water from the western to the eastern North Atlantic through deep fractures zones in the Midatlantic Ridge is studied. The measurements also contributed to the CLIVAR Program to study the inflow of southern hemispheric water into the Caribbean through the passages south of Guadeloupe and to study the transport and variability of the deep water in the western North Atlantic along 16°N (MOVE).

Zusammenfassung

Der Schwerpunkt des ersten Fahrtabschnittes M53/1 bildeten Arbeiten zu den Stoffkreisläufen im Mittelmeer und im Nordost-Atlantik. Ziel der Untersuchungen war die Erfassung der Variabilität der Partikelflüsse auf kurzzeitigen, saisonalen, zwischenjährlichen bis hin zu glazial-interglazialen Zeiträumen um damit auch ein besseres Verständnis des marinen Kohlenstoffkreislaufs zu erhalten. Die Untersuchungen wurden durchgeführt im Rahmen von ANIMATE (EU), DOLAN (BMBF), ESTOC (Spanisch-deutsche Kooperation) und des DFG Forschungszentrums Ozeanränder der Universität Bremen RCOM sowie zweier DFG Projekte „In-situ Messung und Beprobung mariner Aggregate“ und „Zooplanktonstrukturen und Stoffflüsse in der Levantischen See auf dem Hintergrund der Umstellung der Thermohalinen Zirkulation“ im Mittelpunkt der Untersuchungen.

Während des zweiten Fahrtabschnittes (Mindelo-Recife) standen physikalisch-ozeanographische Untersuchungen des Instituts für Meereskunde der Universität Kiel im tropischen Westatlantik im Mittelpunkt. Diese Untersuchungen fanden im Rahmen des Projektes CLIVAR (Climate Variability and Predictability) statt. Im oberen Ozean ging es um die Kopplung der Tropen mit den Subtropen durch die flache tropisch-subtropische Zelle und die Rolle ihrer Variabilität bei Klimaschwankungen. Hauptziel der Arbeiten im tiefen Ozean war die

Bestimmung von Transporten und Ausbreitungswegen des Nordatlantischen Tiefenwassers im tropischen Westatlantik.

Im Fahrabschnitt M53/3 (Recife – Pointe a Pitre) wurden physikalisch-ozeanographische Untersuchungen des Instituts für Umweltphysik der Universität Bremen im subtropisch-tropischen Atlantik durchgeführt. Die Arbeiten standen in Zusammenhang mit dem DFG Projekt West-Ost Passagen, in dem der Transport von unterem Tiefenwasser vom West- in den Ostatlantik untersucht werden soll. Sie standen ebenfalls im Zusammenhang mit den in Clivar geplanten Untersuchungen zum Einstrom von südhemisphärischem Wasser in die Karibik durch die Passagen südlich von Guadeloupe sowie der Clivar Studie über tiefe Transporte und ihre Variabilität im Westbecken entlang 16°N (MOVE).

II Research Objectives

During RV METEOR cruise M53/1, research was carried out in connection with the following projects:

- ANIMATE (“Atlantic Network of Interdisciplinary Moorings and Time series for Europe”)
- DFG-Projects
 - “In-situ measurements and sampling of marine aggregates”
 - “Zooplankton structures and particle flux in the Levantine Sea against the background of the changes in the thermohaline circulation”
- DOLAN (“Operational Data Transmission in the Ocean and Lateral Acoustic Network in the Deep-Sea”)
- ESTOC (“European Station for Time-Series in the Ocean, Canary Islands”)

The main objectives of the first leg of M53/1 were particle flux studies in the Mediterranean Sea and in the NE-Atlantic (Fig. 1). The aim of this study was to determine and understand the processes controlling the varying fluxes of carbon on short-term, seasonal, inter-annual back to glacial/interglacial time-scales.

For logistical reasons this leg was subdivided into three subparts (Fig. 1). During M53/1a from Limassol to Las Palmas a sediment trap mooring of the University of Hamburg was recovered in the Iapetra-Deep. The aim of this work is to understand the particle flux mechanisms and their relation to the deep-sea biology in the Levantine Sea south of Crete.

M53/1b concentrated on the area north of the Canary Islands. One goal of M53/1b was the monthly sampling work at ESTOC (“European Station for Time-series in the Ocean, Canary Islands”) for April 2002. ESTOC is located 60 nm north (upstream) of Gran Canaria in the eastern boundary flow of the subtropical North Atlantic gyre (at 29°10'N and 15°30'W). The time-series station was initiated in the year 1994 and is co-operated by two Spanish (Instituto Canario de Ciencias Marinas in Telde (Gran Canaria) and Instituto Espanol de Oceanografia in Santa Cruz (Tenerife)) and two German institutes (Department of Oceanography of the University of Kiel and Department of Earth Sciences at the University of Bremen). The main purpose of the station is to build a long-term oceanographic data base to be able to discern seasonal from long-term variability of hydrographic and biogeochemical parameters in this

environmentally sensitive region of the Eastern Boundary Current of the North-Atlantic gyre. The region is especially interesting because of episodic dust depositions from the African continent that likely influence productivity and particle formation.

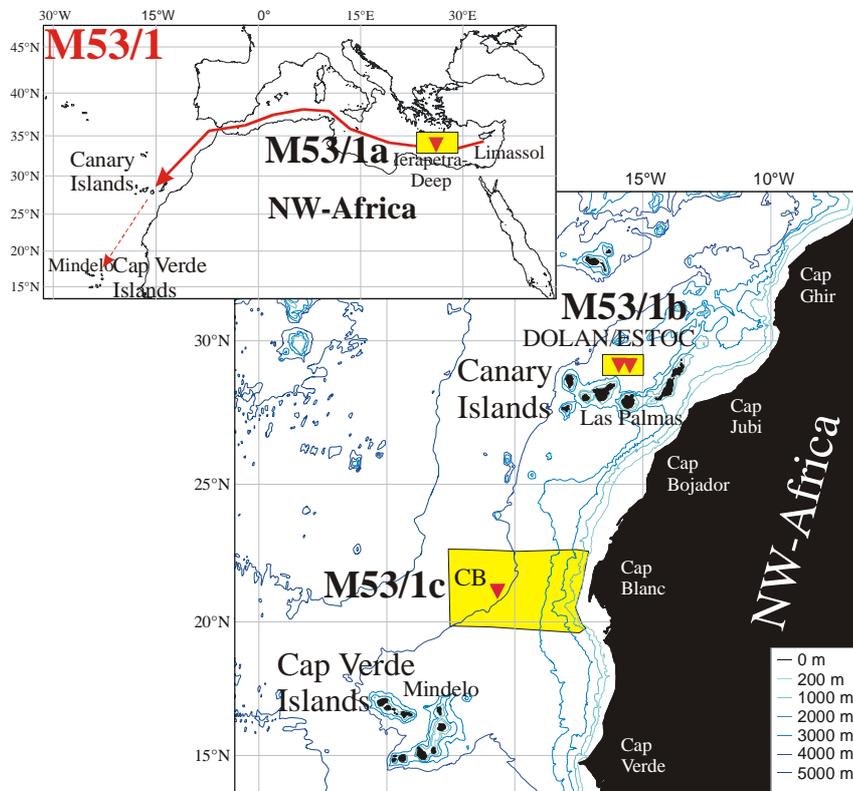


Fig. 1: Working areas during METEOR cruise M53/1 (M53/1a: south of Crete in the Ierapetra-Deep; M53/1b: mainly north of the Canary Islands at ESTOC and DOLAN-moorings; M53/1c: mainly off Cape Blanc and Timirist (Mauritania)).

Also on M53/1b the establishment of the operational transmission of datasets at the DOLAN mooring site was performed. In addition to that, mooring-, maintenance works and tests of the technical devices were done within the scope of the BMBF project DOLAN (“Operational Data transmission in the Ocean and lateral acoustic Network in the Deep-Sea”). This gauging station is located 30 nm west of ESTOC and comprises technology for the transmission of data by means of acoustics in the water column via satellite and internet. Closely linked to ESTOC and DOLAN is the EU project ANIMATE (“Atlantic Network of Interdisciplinary Moorings and Time series for Europe”). In the ANIMATE project, moorings were deployed at key sites in the northern Atlantic in order to gain data of CO₂, nutrients and fluorescence, which will be directly transmitted via satellite to the participating scientific institutes. A significant element in ANIMATE is the technology used in the DOLAN project for the transmission of datasets from the deep-sea. Furthermore, ESTOC is the reference site for the subtropical NE-Atlantic within the ANIMATE project.

The mooring work at ESTOC and DOLAN were accompanied by the deployment of a “Remotely Operated Vehicle” (ROV), which can reach depths up to 1000 m. With aid of this new and innovative technology, high resolution datasets for the quantitative balancing of particle fluxes through the water column will be obtained. The intention is the measurement, sampling

and subsequently analysis of the sinking and suspended material, against the background of the not sufficiently understood processes of the formation of aggregates and their vertical and lateral transport processes in the ocean. For this purpose, a remotely from the ship movements independent and free flying vehicle was deployed. This vehicle was equipped with a new technology for the simultaneous measurement of the in-situ characteristics and selective sampling of single marine aggregates. The obtained datasets will be compared and interpreted with datasets of the size distribution of marine aggregates provided by deep-sea cameras, optical sensors (optical backscatter and fluorescence), CTD profiles and results from particle flux measurements provided by sediment traps. For the immediate comparison of the aggregate- and particle flux data, the grain size distribution of the lithogenic fraction (wind transported dust) in marine aggregates and settling material, will be used as an independent transportation proxy.

During M53/1c sedimentological field work of the Research Center Ocean Margins of the University of Bremen started. The upwelling area off NW-Africa is one of the most important upwelling systems of the world and is influenced by high amounts of Saharan dust, which is transporting nutrients into the ocean. Both processes are of fundamental importance for the particle production in the ocean and influence with the processes biological pump and carbonate pump the global atmospheric CO₂-budget. Despite the main driving-force for climatic variability is situated in the northern North-Atlantic, the upwelling area off NW-Africa is suitable to reconstruct the past climatic variability, because of high accumulation rates in the sediments and thus a good paleoceanographic resolution. The phenomenon of abrupt climatic change was in the focus of research. Various ice-core studies and paleoceanographic investigations have shown that climatic change in the past often happened abrupt within a few decades. In high resolution sediments of the North Atlantic numerous short-termed climatic changes were described from “Bond-cycles” and “Heinrich-Events” in the Glacial to the Little Ice Age (1300-1870). These abrupt changes in the climatic system, the knowledge and the worrying prospect that global change could also occur very spontaneously within a few decades at present times have brought the paleoceanographic studies more and more in the focus of the public attention. Especially the analyses of highly resolved Holocene marine sediments give the potential to classify historical climatic changes of the last 2000 years like the Little Ice Age or the Medieval Warm Period in the context of the long-term climatic variability of the last 11,500 years. On the basis of the results of previous METEOR cruises (M37/1, M42/4, M45/5) and the knowledge that the particle flux is higher in the Cape Blanc area due to yearly upwelling in relation to seasonal upwelling in the Canary Islands region, we expect higher sedimentation rates off Cape Blanc and therefore good climatic archives for high-resolution paleoceanographic studies. The POSEIDON cruise POS 272 in April 2001 gave valuable information by first profiling work of Cape Bojador and Cape Blanc and by first sampling of the sediments with multicorer and gravity corer. On the basis of this information work during M53/1c could be done specifically after short surveys with HYDROSWEEP and PARASOUND. Sediments were recovered using a multicorer and a gravity corer with different pipe lengths. These acoustic board systems were used on site as a proven tool to find suitable locations of sampling sites. Suitable locations were sampled with conventional wireline coring techniques (multicorer and gravity corer).

Also during M53/1c as during M53/1b surveys with a particle camera system and the ROV were carried out to describe and sample the marine aggregates off Cape Blanc and to compare these results with that of the Canary Islands region. SeaWiFS satellite images of the structure of

the filament will be transmitted from Bremen in real-time to aid in the investigation of the complex structure of the filament off Cape Blanc.

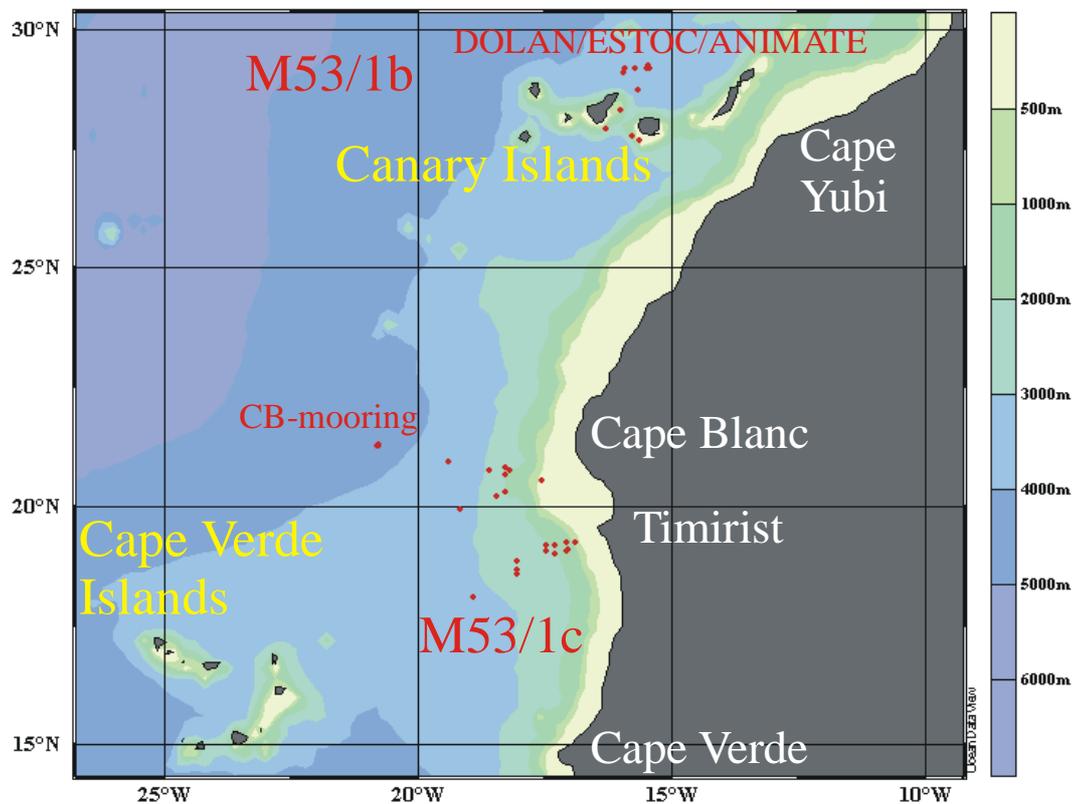


Fig. 2: Stations during METEOR cruise M53/1 b and c.

Physical Oceanography Studies during M53/2 and M53/3

The thermohaline circulation (THC) and especially the meridional heat transport of the THC plays an important role for climate and climate change. In the Atlantic the THC consists of a northward transport of warm water in the upper ocean and a southward transport of cold deep water. The transports occur mainly in western boundary currents, but along the boundary currents complex recirculation cells exist with different horizontal extensions, intensities and fluctuations. These have an impact on the THC.

The cold branch of the THC transports North Atlantic Deep Water (NADW). NADW has several components with different water mass characteristics. They are formed by convection and by overflow processes and entrainment. Two of the NADW components, the water formed in the Labrador Sea and the lower deep water overflowing the Denmark Strait are marked by CFC maxima. The CFC signal is caused by the intimate contact of these water masses with the surface layer of the ocean and they might be most sensitive to climate change. Below the NADW, one finds the Antarctic Bottom Water (AABW) flowing into the North Atlantic through the Equatorial channel.

The warm branch of the THC consists of warm water of South Atlantic origin. The water crosses the equator mainly in the North Brasil Undercurrent and in the South Equatorial Current. Both currents meet between 35°W and 40°W to form the northwestward flowing North Brasil

Current (NBC). North of the NBC-NECC retroflection, the northward transport occurs through eddies, and the transport are difficult to estimate.

Studies of the surface- and deep water spreading in the tropical Atlantic during WOCE (World Ocean Circulation Experiment) and the initial phase of the Climate Variability and Predictability (CLIVAR) Program have shown a very complex interaction of the western boundary circulation with the equatorial regime, and the inherent physical processes are only poorly understood.

Objectives of the two legs M53/2 and M53/2 are unresolved questions of the warm water circulation and of the deep water spreading in the equatorial Atlantic.

Warm water circulation objectives:

- coupling of the tropics and subtropics through the shallow tropical-subtropical thermohaline cell;
- spreading paths and transport of the warm water path of the Atlantic thermohaline circulation in the equatorial zone;
- role of anomalies of the meridional circulation for tropical ocean-atmosphere interaction, especially role of the North Brazil Undercurrent for equatorial SST-anomalies;
- contribution of equatorward thermocline layer transport within the interior basin, east of the boundary current array at 11°S;
- the influence of ENSO-effects on inter-hemispheric exchanges.
- Study of the water mass characteristic and the velocity field of the Caribbean inflow

The objectives regarding the warm water circulation are related to the project area B2 of the German Ocean/CLIVAR-program as well as the Principle Research Areas (PRAs) D2 (Tropical Atlantic Variability) and D3 (Atlantic Thermohaline Circulation) of the international CLIVAR-program.

Deep Water circulation objectives:

- mean values of the Deep Western Boundary Current (DWBC) and recirculation in the 5-11°S area;
- water mass transformation at the passage of the equatorial zone;
- annual cycle and anomalies south of the equator and their relation to possible driving mechanisms.
- Location and horizontal extension of the deep recirculation cell in the Guiana basin
- Deep water exchange between the western and eastern Atlantic through passages of the MAR south of the Vema Fracture Zone and their role for the recirculation in the Guiana basin
- Study of the stratification and circulation along the MOVE array at 16°N

The work was carried out in cooperation with colleagues from the University of Sao Paulo (Prof. Edmo Campos), who run numerical models for the area. The French-Brazil-USA project PIRATA maintains a surface mooring network which may provide wind forcing and surface variability for our data interpretation. On the other hand our measurements will provide the information on the northward inflow into the PIRATA region.

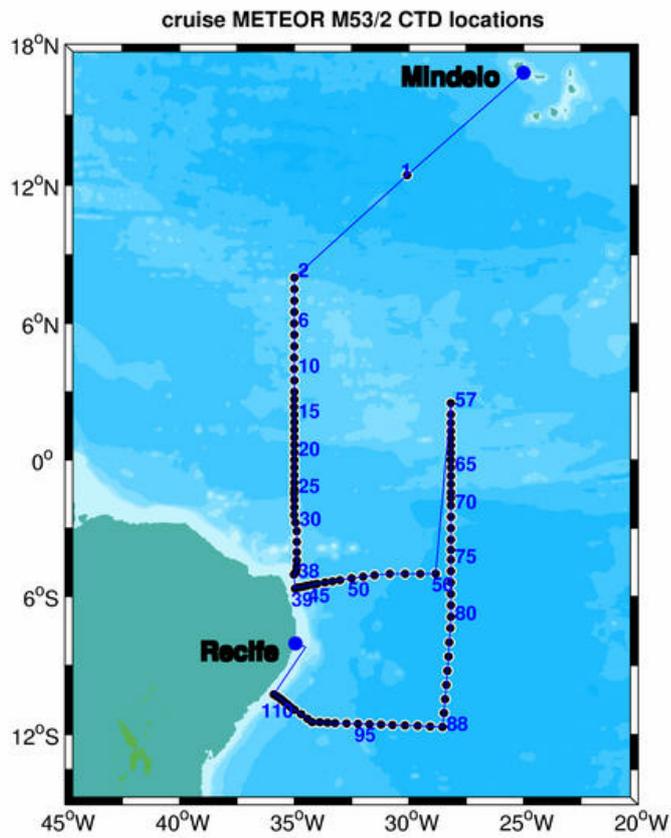


Figure 3: CTD stations of METEOR cruise M53/2

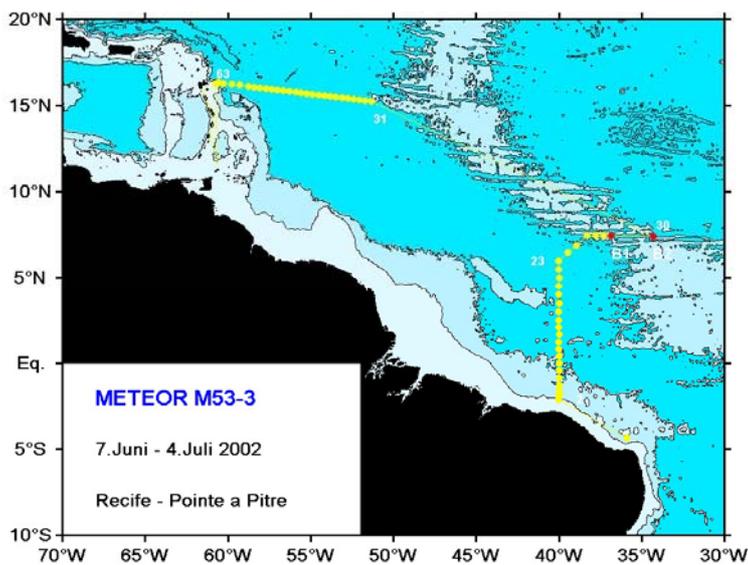


Figure 4: CTD stations of METEOR cruise M53/3

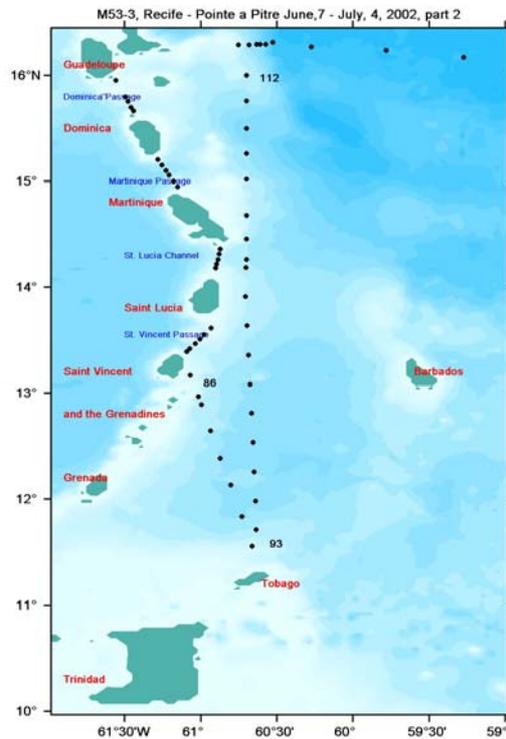


Figure 5: CTD stations of METEOR cruise M53/3

III. Acknowledgements

All groups and institutions acknowledge the excellent cooperation and technical assistance of Captain Kull and his crew, contributing substantially to the success of the METEOR cruise M53. The contributions and assistance of Captain Kull and his crew in the numerous receptions and ship guide tours of the 'Jahr der Geowissenschaften' is gratefully acknowledged. Special thank is expressed to the Deutsche Forschungsgemeinschaft DFG for METEOR shiptime and funding.