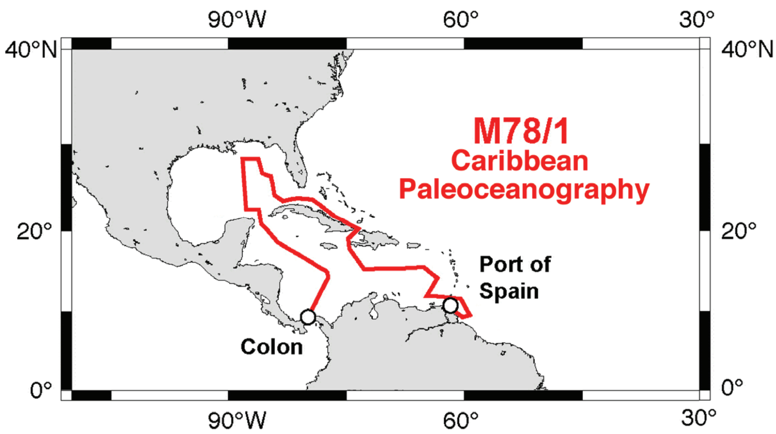
METEOR-BERICHTE 11-6

Surface and Intermediate Water hydrography, planktonic and benthic biota in the Caribbean Sea – Climate, Bio and Geosphere linkages (OPOKA)

Cruise No. 78, Leg 1

February 22 – March 28, 2009,

Colón (Panama) – Port of Spain (Trinidad and Tobago)



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1 Summary

Abstract - The main scientific objective of R/V METEOR cruise M78/1 was to describe the linkage of western Atlantic Warm Pool variabilty with changes of North Atlantic thermohaline circulation during the late Pleistocene and Holocene. In particular, the spatial and temporal dynamics of the Loop Current as link between the central Caribbean and Gulf Stream system had to be assessed. Emphasis was given to temperature and salinity preconditioning of Caribbean surface waters, the short-term dynamics of the Gulf Stream, and its impact on benthic communities in Caribbean sea straits. Sediment, water and plankton samples were collected in order to describe the recent and paleoceanographical impact of freshwater shedding from the main rivers into the Caribbean. Plankton tows and hydrographic measurements revealed the environmental conditions and physical fine structure of the surface ocean in the central Caribbean and close to the Orinoco mouth. The topography and internal structures of sedimentary drifts, deep-water mounds and lag sediments in Caribbean sea straits were surveyed with hydroacoustics. Benthic biota and sedimentary processes were documented with OFOS observations and surface sediment samples. The environmental settings in Caribbean sea straits were assessed with sea floor observatory deployments. Historical climate archives from the intermediate water were retrieved with piston and gravity coring. The new data and samples from this cruise will allow to describe the variability of Orinoco river shedding, to validate geochemical proxies for reconstructions of surface ocean properties, to reveal the population dynamics of planktonic foraminifera, and to characterise the past near-surface and intermediate water mass dynamics in the Caribbean. This will accomplish the objectives of cruise M78/1.

Zusammenfassung - Das wissenschaftliche Hauptziel der METEOR Reise M78/1 war die Koppelung der Variabilität des Westatlantischen Wärmepool mit Änderungen der thermohalinen Zirkulation im Nordatlantik während der geologischen Vergangenheit zu beschreiben. Schwerpunkte der Untersuchungen waren die Dynamik des Loop Current als Bindeglied zwischen der zentralen Karibik und dem Golfstrom-System, die Temperatur- und Salzgehaltskonditionierung karibischer Oberflächenwässers, sowie die Kurzzeitdynamik des Golfstroms und sein Einfluss auf Benthosgemeinschaften in karibischen Meeresstrassen. Sediment-, Wasser- und Planktonproben wurden genommen um den paläozeanographischen Einfluss des Süßwassereintrags der grossen Flusssystemen in die Karibik zu beschreiben. Planktonnetzfänge und hydrografische Messungen zeigten die Umweltbedingungen und physische Feinstruktur des Oberflächenozeans in der zentralen Karibik und vor der Orinoco Mündung auf. Die Topografie und interne Strukturen von Driftsedimenten, Tiefwasser-Mounds und Restsedimentdecken in karibischen Meeresstrassen wurden hydroakustisch vermessen. Benthische Lebensgemeinschaften und sedimentäre Prozesse wurden mit OFOS Beobachtungen und Oberflächensedimentproben dokumentiert. Vorherrschende Umweltfaktoren am Boden der Meeresstrassen wurden mit Einsätzen des POZ-Landers erfasst. Historische Klimaarchive aus dem Zwischenwasser wurden mit dem Schwerelot und Kolbenlot gewonnen. Die neuen Daten und Proben von dieser METEOR-Reise werden es ermöglichen, die Variabilität der Orinoco Flusszufuhr zu beschreiben, geochemische Proxies für Oberflächenwasser-Salinität und Temperatur zu verbessern, die Populationsdynamik von Planktonforaminiferen darzustellen, und die Dynamik der oberflächennahen und Zwischenwasserzirkulation der Karibik in der jüngsten geologischen Vergangenheit zu beschreiben und damit die wissenschaftlichen Ziele der Reise zu erreichen.

2 Participants

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Dr. Brian Haley	Water sampling	IFM-GEOMAR
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3 Research Program

The main scientific objective of R/V METEOR cruise M78/1 was to describe the linkage of the western Atlantic Warm Pool variability with changes of North Atlantic thermohaline circulation during the late Pleistocene and Holocene. In particular, emphasis was given to the spatial and temporal dynamics of the Loop Current connecting the W-Atlantic warm pool in the central Caribbean and the Gulf Stream system, the temperature and salinity preconditioning of Caribbean surface waters, and the paleoceanographical impact of discharge from large river systems into the Caribbean. The fine-scale structure of the ocean surface mixed layer and the intermediate water was to be investigated in order to improve Mg/Ca and oxygen isotope calibrations of planktonic foraminifera by using these hydrographic measurements. The occurence, architecture, population structures, and governing environmental factors of deep water mounds in Caribbean sea straits were to be explored. The early diagenesis of pelagic carbonate sediments from the last Interglacial and the influence on geochemical proxies was to be assessed.

We intended to concentrate our operations on single stations and small working areas which were aligned to the surface water circulation through the Caribbean. The work programme comprised:

- 24-h Plankton Stations with CTD, water sampler, multinet and plankton pump to capture the day – night variability of surface-dwelling planktonic foraminifera, and to collect living specimens and water samples for Mg/Ca - and isotope measurements.
- Transects of CTD, fluorometer, water, and sediment sampling stations at Orinoco mouth (Boca Grande), in the Gulf of Paria, and to the north of Paria Peninsula in order to capture the brackish surface layer.
- Surface sediment sampling in the southern and central Caribbean, and in the Gulf of Mexico in order to accomplish the Mg/Ca - and oxygen isotope calibration data sets, to better characterise fluvial and marine organic material with biomarkers, and to track the distribution of Orinoco suspension with εNd.
- Retrieval of long piston cores (>15 m) as palaeoceanographical archives from high-accumulation sites at 300 to 600 m water depth at Florida Ramp, southern Florida Strait, Yucatan Channel, off Venezuela, and at shallower depths in the Gulf of Paria.
- Hydroacoustic exploration for deep-water mounds and survey of their small-scale topography in the southern Florida Straits and Yucatan Channel.
- Ocean Floor Observation System (OFOS) observations of benthic habitats, population structures and detail morphology of deep water mounds in the southern Florida Straits and Yucatan Channel. Video-controlled sampling, near-bottom hydrographic and current measurements with the POZ-Lander sea floor monitoring system.

We collected a sufficient number of samples and data sets of high quality, They will facilitate to achieve the goals of the research cruise by subsequent, shore-based investigations. The cruise plan and work programme was strictly followed as initially proposed and outlined in the cruise information leaflet. Only one coring site and one Plankton Station had to be skipped due to delayed departure from Colon, Panama, and due to strong headwinds on transit. We had to cancel the 24-h long operations at Plankton Stations because of an intermittant failure of the Plankton

Pump, which was planned to operate there for several hours. We also abstained from video-controlled sampling of deep-water mounds as these features were too small and sparse in the areas where they were identified by OFOS observations.

The research program mainly comprised routine sampling and surveys at designated locations, but none-the-less new discoveries and unexpected observations were made. In particular, new deep-water mounds were found to the north of Yucatan Peninsula at 500 to 650 m depth on top of extended sediment drifts moulded by the inflow of Antarctic Intermediate Water into the Gulf of Mexico. Similar structures were recorded at the western Florida Slope. They were sparsely colonised by cold water corals and associated organisms thriving at their distribution limits.

A low-salinity surface water lid with salinities <34.5 PSU was not encountered in the southern Caribbean in March 2009. Instead, the surface salinity was on average higher by 0.1 PSU than in May and June 2002 as recorded on R/V SONNE cruise SO164 at the same locations. Cold and low-saline Gulf Common Water from the Gulf von Mexico was recorded for the first time in the southern Florida Straits between 120 and 160 m depth, where usually warm and high-saline Subtropical Underwater prevailed. This observation clearly demonstrated the dynamics of the Loop Current and the immediate transfer of environmental signals from the Gulf of Mexico to the northern Atlantic current system.

4 Narrative of the Cruise

The cruise M78/1 began on the19th of February with a long journey for the cruise participants from five cities in Europe, Venezuela and the USA. After spending a night in Panama City, we took a bus ride across the Panama land bridge, to arrive around noon on the 20th of February at the METEOR, berthed in Manzanillo International Terminal at Colón. We used the one day prolonged harbour time for unpacking, moving of equipment into the laboratories, and installing our instruments.

On the 22nd of February at 14:00 local time, the METEOR set sail and headed for the Hess Escarpment at 14°N 77°W. The first station (M78/1-162) was reached on the 24th of February at 11:30. We first performed a CTD cast in order to obtain a sound velocity profile to calibrate the hydroacoustic systems, and a plankton tow with the multi closure net. Thereafter, we performed a hydroacoustic survey across the Hess Escarpment as presite survey for the Caribbean Large Igneous Provinces Project (CLIP; Kai Hörnle, IFM-GEOMAR), which was finished on 25th of February at 2:40. On the 26th of February at 14:00, we arrived at Misteriosa Bank and performed a Plankton Station with CTD hydrocasts, plankton tows, and the new KC-Denmark plankton pump. This device filtered up to 8 cubicmetres of water at a certain depth. The plankton sampling was accomplished by a box core surface sediment sample.

Then we headed to Yucatan Strait working area at 21°N 86°W where we arrived on the 27th of February at 16:00. Due to favourable winds, we were able to make more than 10 knots during transit and catched up about half of our delay. Our aim was to describe i) the hydrographic structure, ii) the influence of Yucatan currents on benthic communities and iii) characterise the sediment export from the Campeche Bank carbonate platform. We concentrated on the western part of the sea strait and first explored the Mexican slope with hydroacoustics. Then we deployed the OFOS seafloor video observation system to search for deep-water corals. Operating the

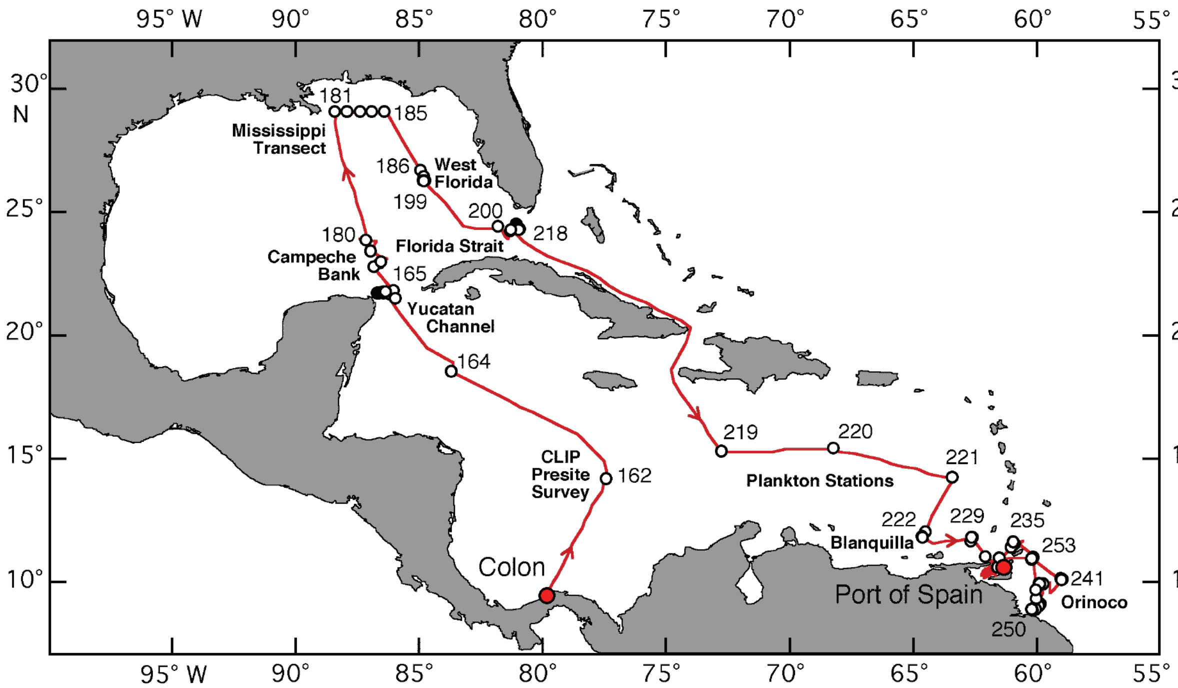

Fig. 4.1 Cruise track and stations of METEOR cruise M78/1. The station numbers refer to the first or last station in the respective working areas.

OFOS was very difficult because of strong currents, high suspension load and bad sight at depth. We initially planned a deployment of the new POZ-Lander deep-sea observatory close to a coral occurrence. As no corals were found, we abstained from a lander deployment here. The sediment distribution at the Mexican margin was assessed with a transect of grab sampler and box core samples following a PARASOUND subbottom profiling line. Mainly sands of shallow-water carbonate debris were encountered. On Sunday, 1st of March, a low-pressure system passed Yucatan Strait, which was followed by strong, cold northerly winds. We continued our hydroacoustic survey at the northeastern flank of Campeche Bank but ground-truthing of the recorded features by seabed sampling was impossible due to the strong swell. Before departure to the North, we finally were able to retrieve a gravity core and multiple corer on Monday, 2nd of March at 14:00, when wind and waves calmed down. The cores recovered carbonate ooze.

On Wednesday, 4th of March 2009, we arrived at the Mississippi Transect on station M78/1-181. Here, we intended to assess the sedimentary record of eastward diminishing influence of Mississippi discharge to surface water hydrography. We successfully performed five sediment stations with multicorer and piston corer sampling, and two CTD casts. Grey terrigenous muds were recovered. On the 5th of March 2009, we arrived at 14:00 in the West Florida working area. We intended to re-core a location from where a prospective sedimentary record was reported, and to explore deep-water coral occurrences. We first deployed a multiple corer and a gravity corer, both were successful. The bathymetry and subsurface characteristics around the coral occurrences were recorded with hydroacoustics on the 5th and 6th of March 2009, followed by an extensive OFOS survey which showed corals in places. We deployed the POZ-Lander observatory between two coral patches, and it was successfully recovered after 29 hours. In the meantime, we performed plankton tows and a 13-hours CTD station. Unfortunately, the plankton pump failed due to a leakage in a deep-sea socket, which could not be repaired immediately.

Furthermore, we verified the OFOS observations by grab and box core sampling in the vicinity of the POZ-Lander position. They recovered coarse sands with coral rubble.

After a short transit, we arrived on the 8th of March at 11:40 in the southern Florida Straits. In this area, we intended to explore deep water coral occurrences and carry out hydrographic measurements near them. Our aim was to confirm whether deep-water corals are associated with specific density conditions of the surrounding seawater. Furthermore, we intended to obtain sediment cores and surface sediment samples from the northern slope of the Florida Strait. We commenced with an extended hydroacoustic survey in order to identify suitable locations for sediment coring, and to depict coral mounds on Pourtales Terrace, from where coral occurrences were reported. Surprisingly, the mapping did not show any mounds. We deployed the OFOS system and performed a track across a known deep-water coral mound. But deep-water corals or even *Lophelia* colonies were not observed in the real time videos. They were identified later, when digital still photos were reviewed. The POZ-Lander was deployed close to the deep-water coral habitats. After 48 h of constant measurements, the lander was successfully retrieved. When recovering the lander, it drifted within the water column by 0.5 miles in 8 minutes within the Florida Current. Simultaneously to the lander deployment, we carried out continuous hydrographic measurements with the CTD over 13 hours, took plankton samples with the multinet, and sampled the sea floor with a grab and box corer on a transect heading north to Sombrero Key. Medium and coarse carbonate sands were recovered. We did not proceed into waters shallower than 200 m because we had to keep out the Florida Keys National Marine Sanctuary. Close to the lander position, we retrieved a *Lophelia* fragment with the box grab, which verified the occurrences of deep-water corals here. Our PARASOUND records from the northern slope of the southern Florida Straits revealed stratified drifts between 450 and 800 m depth which overly each other. We retrieved two long piston cores and multicorer samples from 530 and 730 m. The sediments were foraminiferal and calcareous oozes, respectively.

We left the southern Florida Straits on the 11th of March at 15:30 heading for the southern Caribbean. After 77 hours transit along northern Cuba and through Windward Passage, we arrived at station M78/1-219 on the 14th of March. At this location, we resumed to work on a series of widely spaced Plankton Stations. At each station, we performed i) hauls with a multi closing net, ii) hydrocasts with a CTD, iii) measured the pigment distribution with a fluorometer and iv) took water samples for phytoplankton investigations and for trace element and isotopic analyses. The Plankton Stations were preferentially placed at locations where a surface sediment sample was readily available from SONNE cruise SO-164. We finished the Plankton Stations on the 19th of March at 10:30 at station M78/1-222 close to Isla de Blanquilla. Here, we also took a box and gravity core, which recovered green clays and pale carbonate oozes. We boarded an observer from the Venezuelan Navy at Isla de Blanquilla on the same day. We took advantage of the opportunity at Blanquilla to deploy the rescue vessel METEORIT and examine the feasibility of shallow water deployments. In particular, we took sediment and water samples with a grab and a bottle, and performed hydrographic measurements with a hand-held CTD at depths of 4.5 to 40 m.

The regular station work was resumed with a hydroacoustic survey at the southern slope of the Grenada Basin off Venezuela on the 19th of March. We explored locations for sediment coring at mid depth with the PARASOUND in order to retrieve high-resolution records of intermediate water circulation. The PARASOUND records showed a steep and structured slope where sedimentary drifts filled small depressions. Surface sediment sampling with multicorer and box corer was successful, but we retrieved only one piston core with soft mud and intercalated metre-thick beds of glauconitic shell sands with redeposited shelf foraminifera and *Lophelia* fragments. We ceased sampling in the Grenada Basin on the 20th of March at 21:00 and turned to the anchorage off Port-of-Spain in the Gulf of Paria, where we boarded two observers from Trinidad and Tobago on the 21st of March in the morning. After taking a short gravity core at the anchorage, we headed northeast for the southern slope of Tobago Basin. We had a sediment core from the western side of this basin already, but expected higher sedimentation rates at the southern side due to the higher influx of riverine mud from South America. We successfully retrieved multicorer and piston cores from two sites on wedge-shaped sedimentary drifts at 200 and 840 m depth. Green clays and sandy clays were recovered.

To the west of Trinidad at mid depth, we deployed the POZ-Lander for the third time at station M78/1-238 on the 23rd of March. We initially expected indications for deep-water coral occurrences here, but found only muddy grounds. In addition, we performed a CTD and multiple closure net deployment on this location. This station served as reference of the conditions in the Guyana Current before flowing into the Caribbean Sea. Then we turned south heading for the upper slope off the Orinoco delta. Again, we explored with an extensive hydroacoustic survey locations for sediment coring on channel-levee systems of the upper Orinoco Fan tributary at mid depth, and on wedge-shaped sedimentary drifts on the uppermost slope. Identifying a levee that was prospective for a continuous high-resolution climate archive was not simple. Finally, we retrieved two gravity cores and two piston cores, each accompanied by a multicorer, from 280 to 1670 m depth. Green muds and banded silts were recovered. These cores will facilitate a detailed description of the past surface and intermediate circulation dynamics. They will also allow constraints of the land-ocean linkages in much more detail than it has been possible before.

We approached the main tributary of the Orinoco, Boca Grande, on the 25th of March. We came as close as "Buoy 01" at the entrance of the shipping route. We sampled and described the fresh water lid with CTD, Niskin bottle and bucket water sampling, and we sampled the sea floor with multicorer, box corer, and RUMOHR corer. Extremely soft, grey muds were encountered, and only the REINECK box corer was proven suitable for sea floor sampling here. We also deployed the plankton pump below the fresh water lid. The high-voltage socket had been refurbished, and the pump operated without problems.

Then we turned north again and retrieved two box cores on the outer shelf, which recovered green mud and glauconitic biogenous sand. We successfully recovered the POZ-Lander off Trinidad on the 26th of March at 5:30 in the morning. We continued our way into the Gulf of Paria where we performed an extensive hydroacoustic survey up to the end of the cruise. On the basis of these PARASOUND records, we identified a coring location and took a gravity core on the 27th of March in the morning. We continued with the hydroacoustic survey and disembarked the Venezuelan Navy observer off Güiria in the afternoon. While still recording PARASOUND, we used the 27th of March for disassembling our devices, and stowing of our equipment and samples. The ship reached the harbour of Port-of-Spain on the 28th of March in the morning. We finalised stowing of our containers, and the cruise ended with the disembarking of the scientists in the afternoon.

5 Preliminary Results

5.1 Hydrographic Measurements and Water Sampling

5.1.1 CTD Casts

(Christian Dullo, Sascha Flögel)

The major objective of CTD measurements during cruise M78/1 was to determine general water mass characteristics and the influence of physical parameters of water masses bathing cold-water coral assemblages in the Caribbean and Gulf of Mexico. Additionally, we wanted to get an overview of the variability of water masses in the ultimate vicinity of these coral habitats in space (locally-regionally) and time (tidal cycles). Bottom water samples were taken at all localities to assess the geochemical characteristics of these water masses as well as samples from chosen intervals in the water column. Furthermore, we supplied other scientific groups on the vessel with data on physical properties of the water masses within all working areas visited during this cruise.

The Conductivity-Temperature-Depth (CTD) profiler used for investigations of the water column during METEOR cruise M78/1 was a SEABIRD "SBE 9 plus” underwater unit and a SEABIRD "SBE 11plus V2” deck unit. Additionally, it was equipped with two dissolved oxygen sensors, a chlorophyll-a sensor and a SEABIRD bottle release unit including a rosette water sampler. For the analysis and interpretation of the measurements, the downcast raw data were processed with "SBE Data Processing” software. For the visualisation of the data we used "OCEAN DATA VIEW (mp-Version 3.3.2)”. The CTD system provided by IFM-GEOMAR operated very reliable. Measured O_2 values were verified by using the WINKLER titration method (Grasshoff, 1983). We performed single casts, various transects, and three yoyo-CTDs with repeated casts over 13 hours covering one complete tidal cycle. A total of 42 CTD profiles have been measured during the cruise.

In the Caribbean (Station M78/1-164), the uppermost 60 m of the water column was characterised by the occurrence of relatively fresh water with salinities lower than 35.5 PSU. This water mass is called Caribbean Water (CW) and believed to be a mixture of the Amazon and Orinoco River outflow, as well as North Atlantic surface water. A salinity maximum of about 37 PSU has been recorded between 140 to 180 m (Fig. 5.1) and this maximum is characteristic for Subtropical Under Water (SUW). This water mass is formed in the central tropical Atlantic, where evaporation exceeds precipitation. It is found almost in the entire Caribbean region. Further below, at water depths of around 800 m, a salinity minimum of 34.7 PSU is found. It is attributed to the Antarctic Intermediate Water (AAIW) that is characterised by its low salinity and high oxygen content. The lower depth limit at approximately 1200 m is due to the sill depths in the passages between the Lesser Antilles where the AAIW protrudes into the Caribbean.

Additionally, we have performed so-called YoYo-CTD casts which are consecutive casts in one position to cover changes in water mass properties over one tidal cycle (12-13 hours). In Figure 5.2 is shown an example from the West Florida Slope where, eg. changes in oxygen content over one tidal cycle are displayed. In this case, the variation is with about 0.05 ml/l very low. These YoYo-CTDs have been performed at two additional locations in the Florida Straits.

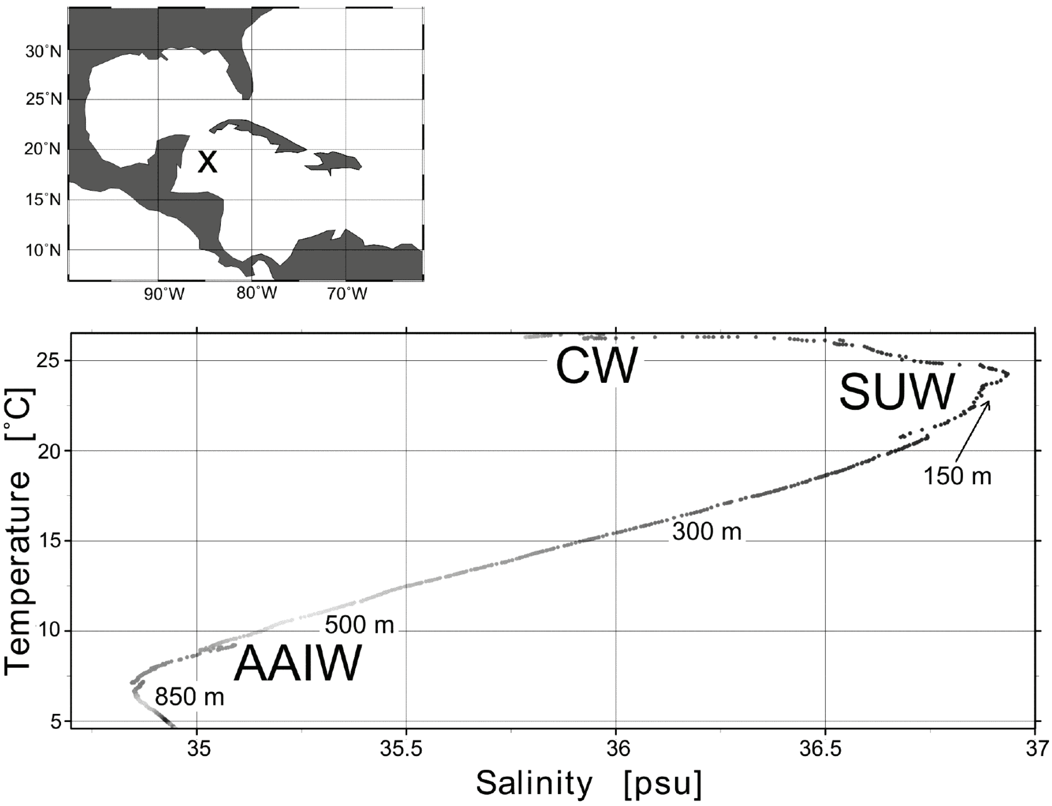

Fig. 5.1 Water mass structure of the western Caribbean. Shown is a Temperature-Salinity plot from station M78/1-164.

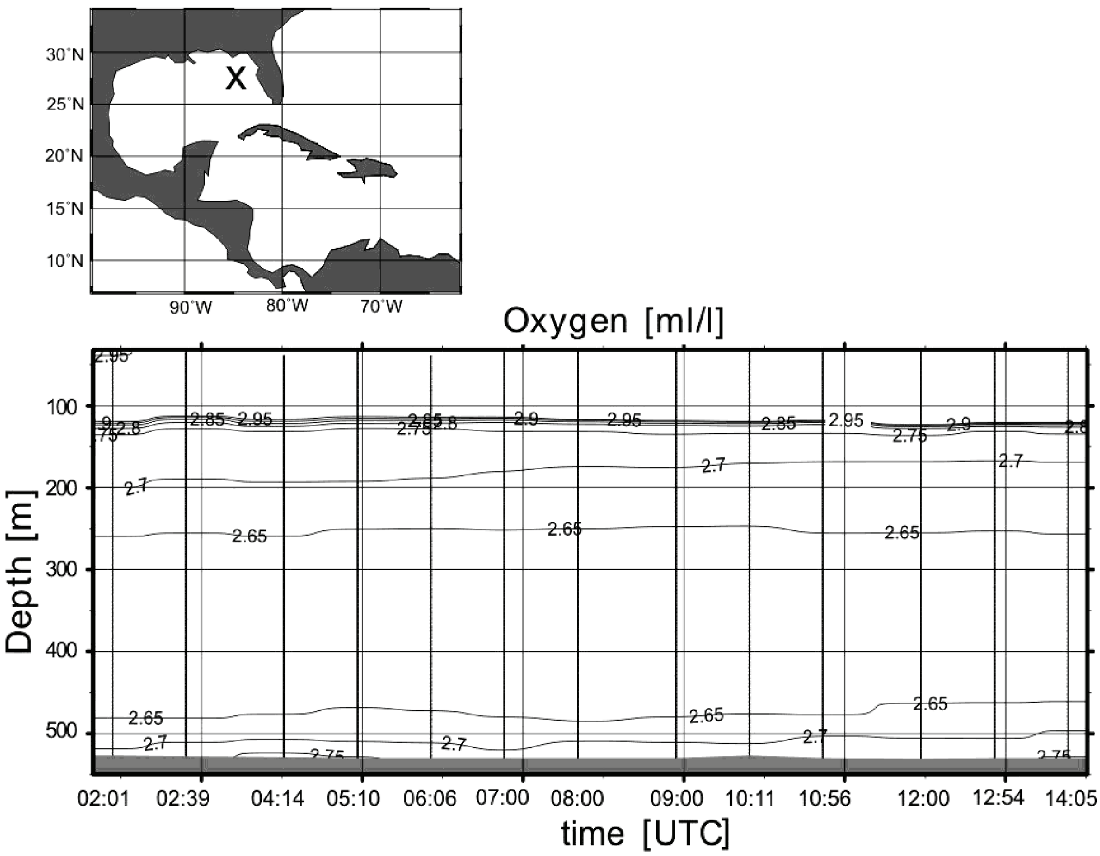

Fig. 5.2 Results of YoYo-CTD casts over 13 hours (oxygen), covering one tidal cycle on the West Florida Slope (stations M78/1-194-1 – M78/1-194-13).

5.1.2 Shallow CTD and Fluorometer Measurements

(Joachim Schönfeld, Anne-Sophie Bayer, Sascha Flögel, Wolf-Christian Dullo)

A small RBR XR-420 CTD was used to assess the hydrography of near-surface waters at depths of plankton sampling. The maximum deployment depth was 400 m. The sensor response times were 0.1 s for conductivity and 3 s for temperature. Up- and downcasts were recorded. The sampling rate was 15 or 12 s, averaged over 5 or 3 s. A comparison of near-surface values to METEOR's thermosalinograph readings revealed significant offsets in temperature and salinity. This was later confirmed on station M78/1-221-1 when the RBR was mounted to the Seabird SBE09 CTD. These parallel measurements were used for a correction of the RBR CTD values. The CTD was mounted to the Plankton Pump on 4 deployments and to the Multinet on 13 deployments. Off Boca Grande, we mounted the RBR CTD 1.8 m above a 120-kg depressor weight and operated with 0.1 m/s on 2 stations. A bbe Moldaenke FluoroProbe was used to determine the total chlorophyll concentration. The probe also detects the presence of green algae, bluegreen algae, diatoms, cryptophytes, and indifferent yellow substances by spectral fluorometry. The sampling rate was 3 seconds. The FluoroProbe was mounted to the Multinet on the first 700-m deployment on each Plankton Station and operated with 0.5 m/s.

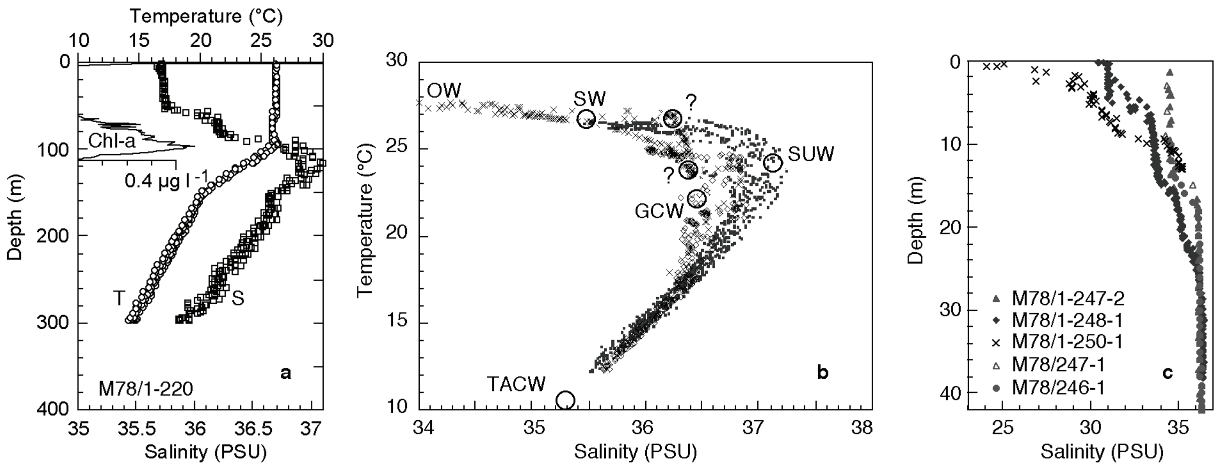

Fig. 5.3 **a:** Chlorophyll, temperature (T) and salinity (S) at station M78/1-220 as example, b: T-S diagram of measurements in the central Caribbean (dots), Florida Straits and Gulf of Mexico (diamonds) and western Atlantic (x). OW: Orinoco Water, SW: Caribbean Surface water, SUW: Subtropical Underwater, GCW: Gulf Common Water, TACW: Tropical Atlantic Central Water, c: salinity sections off Boca Grande, Orinoco.

A low-salinity surface water lid with salinities <34.5 PSU was not recognized on cruise M78/1 in March 2009. The surface salinity in the southern Caribbean was on average higher by 0.1 PSU than in May and June 2002 as recorded on cruise SO164. At depth, the hydrography was characterised by the SUW salinity maximum between 100 and 200 m (Fig. 5.3a). The low-salinity GCW was found in the Florida Straits for the first time. Different, yet undescribed water masses were recorded in the western Atlantic (Fig. 5.3b). At all stations, the halocline was shallower than the thermocline. This boundary was recognized at 120 m in the western Caribbean and at 40 m in its southeastern part. A deep chlorophyll maximum was recorded between the halocline and the thermocline. Green algae and bluegreen algae dominated the Caribbean surface water flora, while diatoms and green algae flourished at depth. Diatoms prevailed in the surface waters of the western Atlantic, probably due to river fertilisation. The Orinoco shedding significantly lowered the surface water salinity up to 20 m depth. But the freshwater influence largely diminished within 23 miles to the east of Boca Grande navigation channel entrance (Fig. 5.3c).

5.1.3 Water Sampling

(Brian Haley)

Water samples on Meteor cruise M78/1 were taken using the shipboard rosette and CTD. The rosette was equipped with 24 10-L NISKIN® water sampling devices, that were electronically triggered to fire at given depths on the up-cast of the CTD profile (CTD also attached to the rosette). In this way, the best attempt could be made to sample distinct water masses in the Caribbean Sea and Gulf of Mexico. The CTD operations were carried out by Christian Dullo and Sascha Flögel, who triggered the sampling bottles at depths determined by all the interested parties as a group (Table 5.1).

Water sampling had two main objectives: to characterize the modern watermasses of the Caribbean Sea and Gulf of Mexico, and to determine the nature of upper water (mixed layer) productivity –especially with respect to riverine influences of the Orinoco. Given these objectives, and the volumes of water required by the interested parties, a general approach to water sampling was to take samples at 8 depths for each cast (each station) made. Three depths were reserved for the upper mixed layer, in order to sample the surface, chlorophyll maximum, and below the chlorophyll maximum. The remaining 5 sample depths were then used to obtain deeper waters, at depths that appeared to reflect distinct water masses, as anticipated from the real-time CTD data. The actual depths sampled are listed in the Appendix.

In addition to the samples taken with the rosette, surface water samples were taken (1) by hand off the Isla Blanquilla and (2) over the side of the Meteor using a customized research device near the mouth of the Orinoco River. In both cases, the bottom water depths precluded the use of the rosette.

Tab. 5.1: Interested parties in water sampling.

Name	Analyses to be made	Purpose of water sampling	Volume
Flögel, Dullo, Garlichs	Oxygen, Stable Isotopes ($\delta^{18}O$, $\delta^{13}C$ DIC)	Instrument calibration (CTD), water mass identification	0.1 litre
Haley	Radiogenic isotopes (Nd), trace metals (REEs)	Water mass identification and circulation studies	20 litres
Nürnberg	Stable Isotopes ($\delta^{18}O$, $\delta^{13}C$), Mg/Ca	Calibration of paleoproxies, water mass identification	1 litre
Troccoli	Phytoplankton	Planktonic systems and productivity	4 litres

5.2 Plankton Sampling

5.2.1 Plankton Net

(Margret Bayer, Michal Kucera, Christopher Beer)

Planktonic foraminifera for molecular genetic investigation, geochemical proxy development and studies of population structure and calcite flux were collected from stratified vertical net hauls with a Hydrobios MultiNet Midi multiple opening-closing plankton net with aperture size of 50 x 50 cm and five net bags with mesh size of 0.1 mm. The opening depths were controlled remotely and determined on the basis of information from the pressure sensor integrated in the plankton net. A standard set of nine depth intervals was used for genetic sampling and for calcite flux sampling. On several occasions, deep (up to 2500 m) net hauls for calcite flux determination were carried out. For geochemical proxy development, a customised depth interval scheme has been used, based on local salinity structure and chlorophyll distribution. In shallow regions, the sampling intervals were adjusted to the actual water depth. Slacking and hoisting was done at 0.5 m/s for genetic and calcite flux sampling and 0.3 m/s for geochemical sampling. After each haul, the net bags were washed thoroughly with sea water from the ship's fire pump and the cups' mesh cloth was washed and rinsed in filtered sea water and cleaned in ultrasonic bath after each second or third haul. Samples for geochemical analyses have been washed from the net cups with filtered sea water, settled, decanted and filled with 98% alcohol to a concentration of ~ 50%; all samples were stained with Rose Bengal solution of 2 g/l, except of the uppermost sample, which was preserved in alcohol only. In order to study bacterial activity on the sinking shells of planktonic foraminifera, a total of 262 specimens, selected on the basis of species, size and depth, were separated from the calcite flux samples immediately after collection on board under a binocular microscope and frozen at -20°C in centrifuge tubes. The rest of the samples were settled and decanted, filled up with 37% formaldehyde to a concentration of 4% and buffered to pH 8.5 by pure solid hexamethylentetramine. The pH has been monitored by a *Knick Portamess 902* pH-meter. The initial measured pH 8.5 is known be experience to decrease to 8.2 within several weeks and stabilise at that level. For genetic analyses, a representative assemblage of planktonic foraminifera with cytoplasm has been extracted from each of the nine depth intervals. Individual foraminifera were photographed using a digital camera attached to a binocular microscope, determined to species level using the taxonomy of Hemleben et al. (1989) and individually transferred into a protective buffer solution in an Eppendorf cup. The cups were subsequently incubated in an orbital shaker while heated to 50°C for 1 hour and then stored at 5°C until onshore laboratory processing. The residues were conserved in the same way as for the calcite flux samples. The complete list of sampling stations, sample depths, sample destinations and species collected is given in the Appendix. An examination of planktonic foraminifera assemblages based on abundances of species taken for genetic analyses reveals a typical highly diverse tropical fauna with well developed deep-dwelling community throughout the sampled region. The dominant species were similar throughout the region, including in the surface layer *G. sacculifer*, *G. ruber* (pink) and *G. glutinata.* The deep-dwelling fauna included *N. dutertrei*, *G. menardii/tumida*, *G. truncatulinoides* and *H. pelagica*. In the eastern part of the Caribbean and in the Orinoco plume, *G. scitula* was additionally abundant among the subthermocline dwellers. The surface layer at that location was dominated strongly by *G. ruber* (pink). Unexpected was the relatively high abundance of mature large *S. dehiscens* in the deep fauna of the western Caribbean and the Gulf of Mexico.

5.2.2 Phytoplankton Taxonomy and Chlorophyll

(Luis Troccoli)

Sixty-eight samples for phytoplankton taxonomy and for Chlorophyll determination were collected along the cruise at 36 stations in the Caribbean Sea. At 15 stations, the samples were collected from NISKIN Bottles at CTD stations (Appendix 5.2.2). The rest of 23 samples were collected using a pump located at 5 m depth. The samples (500 ml) as collected from NISKIN

Bottles (CTD) or from the pump were filled into plastic vials and fixed with 4% formalin to analyze taxonomy by using an inverted microscope (Hasle, 1978). For the chlorophyll analysis, samples were filtered with WHATMAN GF/F (0.47 µm) membranes (2 L in CTD samples and 3 L in pump samples) and they were kept frozen at -20º C until analysis according to the LORENZEN-Method as described by Parsons et al. (1984).

5.2.3 Zooplankton Filtering

(Joachim Schönfeld, Julia Langenbacher, Bernhard Bannert)

Zooplankton samples from specific areas and well-constrained depths were collected by using the ship's pumps and a KC-Denmark plankton pump. The filtered seawater volume was measured to assess the population density. In-situ temperature and salinity were recorded with the vessel's thermosalinograph and an RBR XR-420 CTD mounted to the plankton pump. We will investigate the planktonic foraminiferal assemblages from the zooplankton samples.

A special filtering device has been constructed at IFM-GEOMAR to collect plankton from the surface water to be supplied by a tap or fire hose. The apparatus consisted of a solid-state vertical PVC tube of 40 cm length and 10 cm diameter into which a removable 63-µm mesh was inserted. The filter was installed in the Universal Laboratory. Water from 3.5 m depth was supplied by the ship's pure seawater system. A water meter with a precision of ± 1 litre was set between the tap and the filter in order to record the volume. The filtered plankton was washed with seawater into 200 ml PVC vials. Each sample was divided into two aliquots by using a seesaw plankton splitter. One split was for faunal analysis, it was handed to Chris Beer (NOCS) and fixed with formalin. The other split was designated for isotopic and chemical analyses. It was conserved with 98 % ethanol and remained with Joachim Schönfeld (IFM-GEOMAR). Zooplankton filtering was performed 34 times in the working areas, mostly during transit. We filtered 0.3 to 8.5 m^3 which took 22 minutes to more than 10 hours. In the southern Caribbean, the filter clogged after about half an hour due to the higher abundances of algae or cyanobacterial filaments. Occasionally, it spilled over when the device was unattended and we had to discard the sample. We then switched from the laboratory tap to the fire hose on deck, which provided a higher pressure and thus prevented the mesh from clogging.

The KC-Denmark plankton pump was operated at 4 stations at depths ranging from 40 to 140 m. The plankton pump is equipped with a 60-µm mesh and a digital flow meter to determine the filtered volume. The device was slacked to the centre of the deep chlorophyll maximum and to a level distinctively below in order to collect deep-dwelling planktonic foraminifera at their habitats. The power cable was guided along the wire and fixed to it with cable straps every 2 or 3 metres. The pump is driven by a GRUNDFOS MS4000 motor which was operated with an input power of 70 % that refers to 2.7 kVA. Operation times were 20 to 55 minutes, the yields were 2.0 to 8.8 m^3. After filtering, the pump was hoisted on deck, the net bag was carefully rinsed with seawater from outside in order to wash particles that still adhered to the netbag into the collector cup. The collector cup was removed quickly so that the residue could not fall dry. The sample was then washed with filtered seawater into 300 ml PVC vials. The sample was preserved and stained with a Rose Bengal – ethanol solution (2g/l) immediately after it was taken. The staining will allow to discern planktonic foraminifera living at the depth and time of sampling from empty tests settling from higher levels in the water column.

5.3 Seafloor Observations and Monitoring

5.3.1 OFOS Observations

(Jürgen Titschack, Bernhard Bannert, Christian Dullo, Sascha Flögel, Nina Joseph)

Direct seafloor observations during Meteor cruise M78/1 were obtained with the Ocean Floor Observation System (OFOS) from IFM-GEOMAR. OFOS deployments focused on three areas where cold-water coral growth was expected: (i) the Yucatan Strait, (ii) the W Florida Slope, and (iii) the Florida Strait. Real time observations with OFOS were done with an OKTOPUS UW-Video camera and a 50W Xenon-floodlight. The employment of a digital Nikon D80 camera combined with two flashlights from Ocean Imaging System allowed a high quality documentation of the video observations. Digital images were done automatically every minute during dive M78/1-165-1. In all other dives the digital images were done manually triggered. For scaling three triangular-oriented laser pointers with a distance of 50 cm between each and a weight, 20 cm wide and positioned 1.6 m below OFOS, were employed. OFOS was further equipped with a data-storage CTD of RBR (R-420 CTDm) combined with a SEAPOINT turbidity sensor and two AANDERAA oxygen optodes 3830, and the positioning system POSIDONIA. Additional ground truthing was performed with the giant box corer, REINECK box corer and a VAN VEEN grab.

On Saturday, 28th of February 2009, three OFOS deployments were carried out on the western slope of the Yucatan Strait in water depths ranging from 400 m (M78/1-165-1), 650 - 750 m (M78/1-165-2) and 950 - 1100 m (M78/1-165-3). The first OFOS deployment (M78/1-165-1) had to be abandoned due to strong currents after a few minutes. All three OFOS deployments revealed heavily bioturbated hemipelagic muds as dominant facies. Fishes were common.

On Friday, 6th of March 2009, two OFOS deployments were undertaken on the western continental slope of Florida in water depths ranging from 500 to 650 m (M78/1-189-1) and 450 to 550 m (M78/1-189-2) (Fig. 5.4). Both OFOS deployments concentrated on areas where mounded elongate sediment complexes (MESCs) were identified in the PARASOUND and multibeam map. The direct sea floor observations revealed that the MESCs, constituted of chaotic sedimentary rock boulders, which formed mound-like structures several meters in height. The sedimentary rocks were partly interrupted by fissures that were filled with black material. Locally fractured platy black hardgrounds occurred. The MESCs were partly colonised by cold-water corals (abundantly *Lophelia pertusa*). The spatial coral distributions points to their preferential occurrence on the southern slopes of the MESCs. Areas of living colonies were commonly surrounded by dead coral rubble fields. It is important to note that the mound-like structures were not build by the cold-water corals but that the corals just colonised a very irregular mound-like substrate consisting of sedimentary rock boulders. The MESCs were surrounded by hemipelagic sediments. Subordinately to a preliminary facies classification based on the digital still images each identified facies was sampled with a REINECK box core (M78/1-192; M78/1-193; M78/1-195; M78/1-197).

On Monday, 9th of March 2009, two OFOS deployments were performed in the Florida Straits at water depths ranging from 560 to 460 m (M78/1-202-1) and from 465 to 445 m (M78/1-202-3) (Fig. 5.4). Additional ground truthing was performed with a VAN VEEN grab. Both deployments allowed the differentiation of three major facies:

i. Hardground surfaces represented the dominant facies and were commonly colonised by octocorals, stylasterids and sponges (M78/1-217-1). Subordinately volcanic pebbles were associated with the hardgrounds. The sponges showed abundantly a vertical half-circular concave-convex growth form with typically the concave side oriented into the current. On the leeward side of the sponges small cones of coarse bioclastic sand deposited. Small colonies of *L. pertusa* were mainly observed in front of large sponges on their current exposed side. Crinoids occurred frequently attached to the sponges also on their current exposed side. Subordinately anemones, fishes, sea cucumbers, sea stars, crustaceans, and octopuses could be observed. Rarely volcanic dykes occurred that penetrated the hardgrounds.

ii. Coarse carbonate sands to fine gravels, which locally exhibited ripples (M78/1-213-1) or were partly associated with volcanic pebbles (M78/1-214-1). The vagile benthos was more or less comparable to the hardground facies.

iii. Pavements of volcanic clasts and boulder occurred preferentially in sea floor depressions and on small ridges (M78/1-215-2; M78/1-215-2). Only a few occurrences of volcanic basement rock outcrops could be detected. Pebbles, boulders and basement rock were commonly colonised by octocorals, stylasterids and sponges. Also crinoids occurred attached to it.

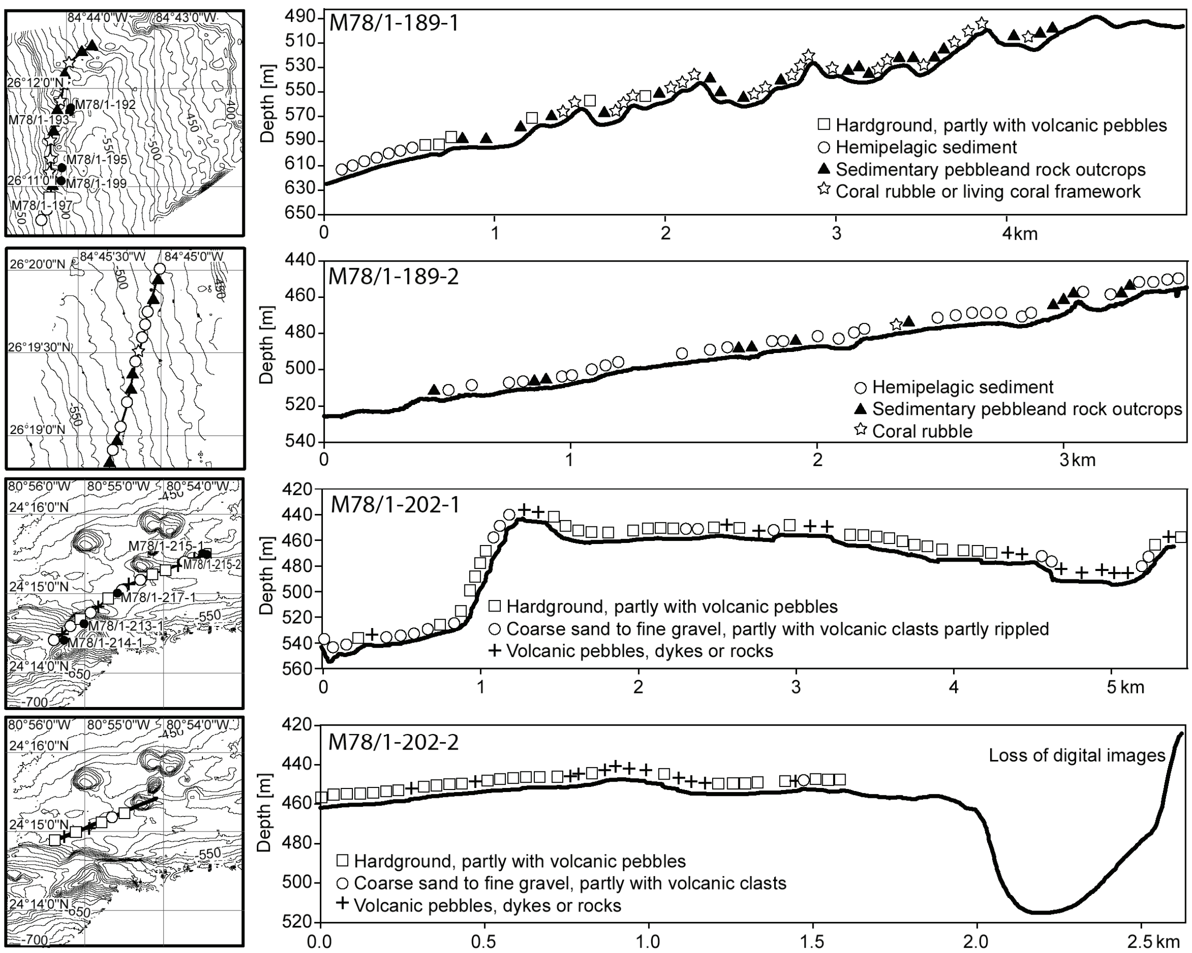

Fig. 5.4 OFOS deployments during Meteor cruise M78/1. Upper 2 panels: western Florida slope, lower 2 panels: Florida Straits. Colour figures are available in Appendix 5.3.1.

5.3.2 POZ-Lander Deployments

(Sascha Flögel, Christian Dullo, Bernhard Bannert, Asmus Petersen)

Cold-water corals are an ideal natural laboratory to study the impact of climate variability. The corals record short-term to decadal changes in the ambient hydrography such as temperature, salinity, oxygen availability, and current regime. For the past years, our group has investigated the dynamics of cold-water corals along the European continental margin. Our results showed that it is indispensable to measure present day oceanographic properties around sampling sites in high resolution and on various time scales of days to months to understand the high variability of geochemical parameters recorded in the calcareous coral skeletons. Until now we have used single CTD measurements and occasionally lander deployments to get assess the properties of water masses bathing cold-water coral habitats. The need for a specific observatory and advanced instrument package targeting on high-resolution data acquisition at the seafloor became evident. To promote this idea, we have designed and built a small lander system, which was constructed by K.U.M. Umwelt- und Meerestechnik GmbH, Kiel. On cruise M78/1, we successfully tested the new system, named ”POZ-Lander”, for the first time (Fig. 5.5).

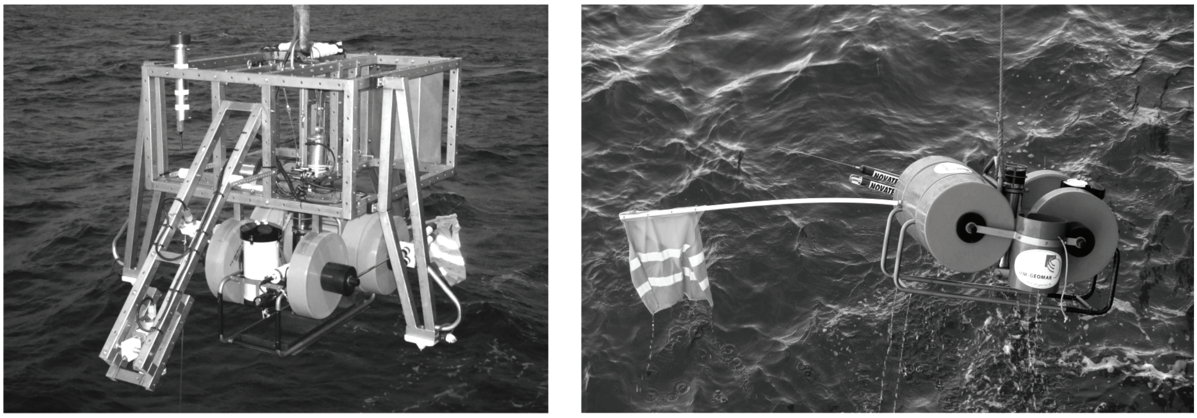

Fig. 5.5 Video guided deployment and recovery of POZ-Lander system which is equipped with a CTD, an ADCP, and a high precision digiquartz for pressure/depth measurements.

The POZ-Lander is equipped with a RBR XR-420CTm Conductivity-Temperature-Depth (CTD) profiler and a high precision PAROSCIENTIFIC INTELLIGENT pressure sensor with an accuracy of 0.015%. The system also carried a RDI WORKHORSE SENTINEL 300 ADCP. To release the system we used a K/MT 562 Releaser from K.U.M. Umwelt- und Meerestechnik GmbH, Kiel. We deployed the system three times during the cruise for two days at each locality, at the West Florida Slope, in the Florida Straits and south of Tobago.

As an example we show pressure (depth), temperature, and salinity data from the first 36-hour deployment at the West Florida slope (station M78/1-190-2). The bottom waters on the West Florida Slope are characterized by a strong tidal signal that is expressed by a 12-hour cycle of depth with an amplitude of about 60 cm between high- and low tide. This is accompanied by changes in temperature and salinity, which obviously do not correlate to the pressure measurements. At this time we speculate that these data are rather influenced by internal waves in the lower water column which have a higher frequency (Fig. 5.6).

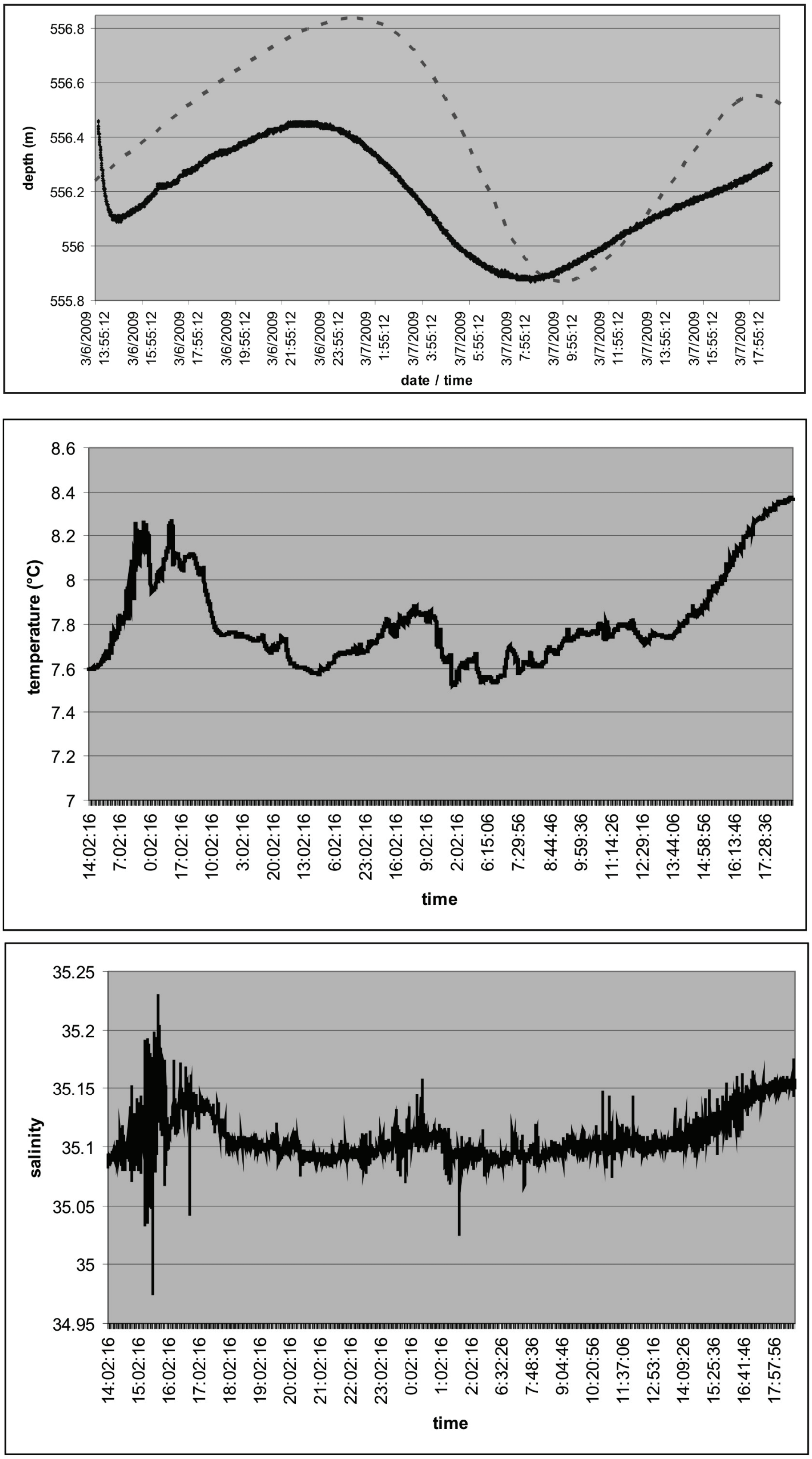

Fig. 5.6 Results of POZ-Lander deployment at station M78/1-190-2, West Florida Slope. Shown are pressure measurements, temperature, and salinity variation during the 36 hours of deployment. The upper panel nicely illustrates the strong correlation of pressure variation at station M78/1-190-2 being linked to tidal effects as recorded on Captiva Island, West Florida (dashed line).

5.4 Hydroacoustics

5.4.1 System Overview and Operations

(Christian Hübscher, Pia Pulm)

The hydroacoustic instruments encompassed two parametric sediment sub-bottom profilers and two swath sounders. Except for the working area south of the Mississippi delta, where technical malfunctions impeded Parasound measurements, all systems were continuously operated in all working areas.

The hull mounted PARASOUND system sediment echosounder (Atlas Hydrographics) represent a narrow beam sediment sub-bottom profiler that has been described first by Grant and Schreiber (1990) and Spieß (1993). Two frequencies (18 kHz and 22 kHz) are emitted from hull-mounted transducers. Due to the parametric effect a 4 kHz signal is generated in the water column within an emitting cone of ca. 4°, which results in a foot print with a diameter of 7% of the water depth. The signal penetration depth strongly depends on the lithology, grain size and gas load. The received data are digitised and stored in a SEG-Y like format. Data processing and visualisation has been carried out by means of the SESuit software package developed at the University of Bremen by Volkhard Spieß and co-workers. Processing mainly included frequency filtering and gain control.

Most of the profiles stroke (almost) perpendicular to the bathymetric contour in order to image water depth dependent deposition pattern or downslope sediment transport. On board processing and preliminary interpretation of the Parasound data enabled us to carefully determine bottom sampling sites and OFOS tracks.

In the Gulf of Paria we operated additionally the SES-2000 (INNOMAR) parametric sub-bottom profiler with a frequency of 8 kHz. The transducer was installed within METEOR'S moon pool. For the compensation of the ship's pitch, roll and heave movements we used a KONGSBERG motion sensor. These data have not been processed yet.

Bathymetric measurements have been carried out mainly with the hull mounted EM120 swath sounder. A swath of 256 preformed beams is emitted periodically with signal frequencies of 12 kHz. The usable foot print of a single emitted swath perpendicular to the ship's heading has a width of more than three times of the water depth.

5.4.2 Swath mapping

(Christian Hübscher, Pia Pulm)

The EM120 was operated continuously in all working areas. In order to produce spatially extended bathymetric maps of particular working areas swath mapping has been carried out along parallel profiles with distances of twice the water depth. We used the on board NAUTILUS software for editing and removal of overlapping pings. Gridding and visualisation has been done by means of the

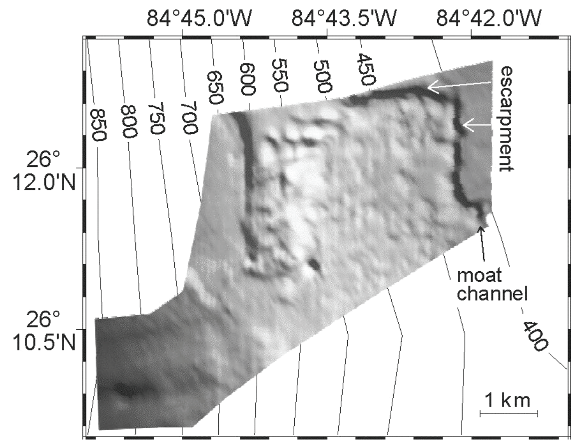

Fig. 5.7 Bathymetry of the western Florida Slope working area. Data gaps have been filled with ETOPO02 V2 data.

Generic Mapping Tool software (GMT). Particular maps have been produced for the working areas off northwestern Campeche Bank, off western Florida (Fig. 5.7), in the southern Straits of Florida and at the Orinoco Fan. The data further supported the selection of OFOS-tracks and core sites throughout the cruise. Data gaps were filled with public domain ETOPO2 V2 data.

5.4.3 Parasound

(Christian Hübscher, Pia Pulm)

Owing to the outstanding support of M78/1 scientific party PARASOUND shifts were on duty on a 24/7 schedule in all working areas (Fig. 1.9). In the Gulf of Mexico (GoM), the hydroacoustic profile networks were designed to investigate the impact of the Loop Current on the geometry of sediment deposits. The four working areas were located in the Gulf's gateways (Yucatan Strait and southern Straits of Florida) and on the upper slopes of the Campeche Bank as well as off western Florida. The observed reflection and sedimentation pattern along the slopes of the gateways of the GoM reflect the bottom current velocities which have been determined by other authors. Between 500 and 800 m, deposition takes place under the influence of the northbound Loop Current. Sedimentation rate is highest at 800 m where bottom velocity has its minimum. Southbound along slope bottom currents control sediment accumulation beneath.

Sediment accumulation on the northern slope of the southern Straits of Florida reflects the decrease of bottom current velocities with depth. A decreasing current velocity enabled the accumulation of a prograding sediment drift in depth between 470 m and 600 m.

Mounded elongate drift complexes have been observed in the eastern Gulf, e.g., between 520 m and 600 m on the Campeche Bank (Fig. 5.8) and between 400 and 550 m off western Florida. Under the assumption that the uppermost drift complexes evolved contemporaneously in both areas, the causative bottom currents at the upper Florida slope were active more than 100 m shallower than at the Campeche Bank (Hübscher et al., in press).

On the Orinoco Shelf, the PARASOUND profiles cover the fore- and bottomset deposits of the Orinoco prodelta slope as well as the outer shelf. The rugged topography and the reflection pattern of outer shelf deposits which is typical of winnowed sediments reflect the strong contour currents in this realm. In a water depth of about 100 m an escarpment of about 20 m height may result from carbonate cementation of the Late-Pleistocene land surface as it was observed, e.g., for the Amazon Shelf (Hübscher et al., 2002). In front of the escarpment, wavy drift deposits and truncated reflections are further evidences for the coast parallel current. Several so far unknown channel-levee systems have been discovered in greater water depth. We state that none of these observations are consistent with the sparse literature, which are mainly some decades old.

A dense profile grid has been shot in the Golf of Paria between Trinidad and north-eastern Venezuela. The Golf represents one of the gateways through which Amazonas and Orinoco sediments flow into the Caribbean Sea. Shallow gas hampers partly imaging of deposits within the Gulf. Interestingly, southward prograding clinoforms have been discovered close to the northern exit of the Gulf.

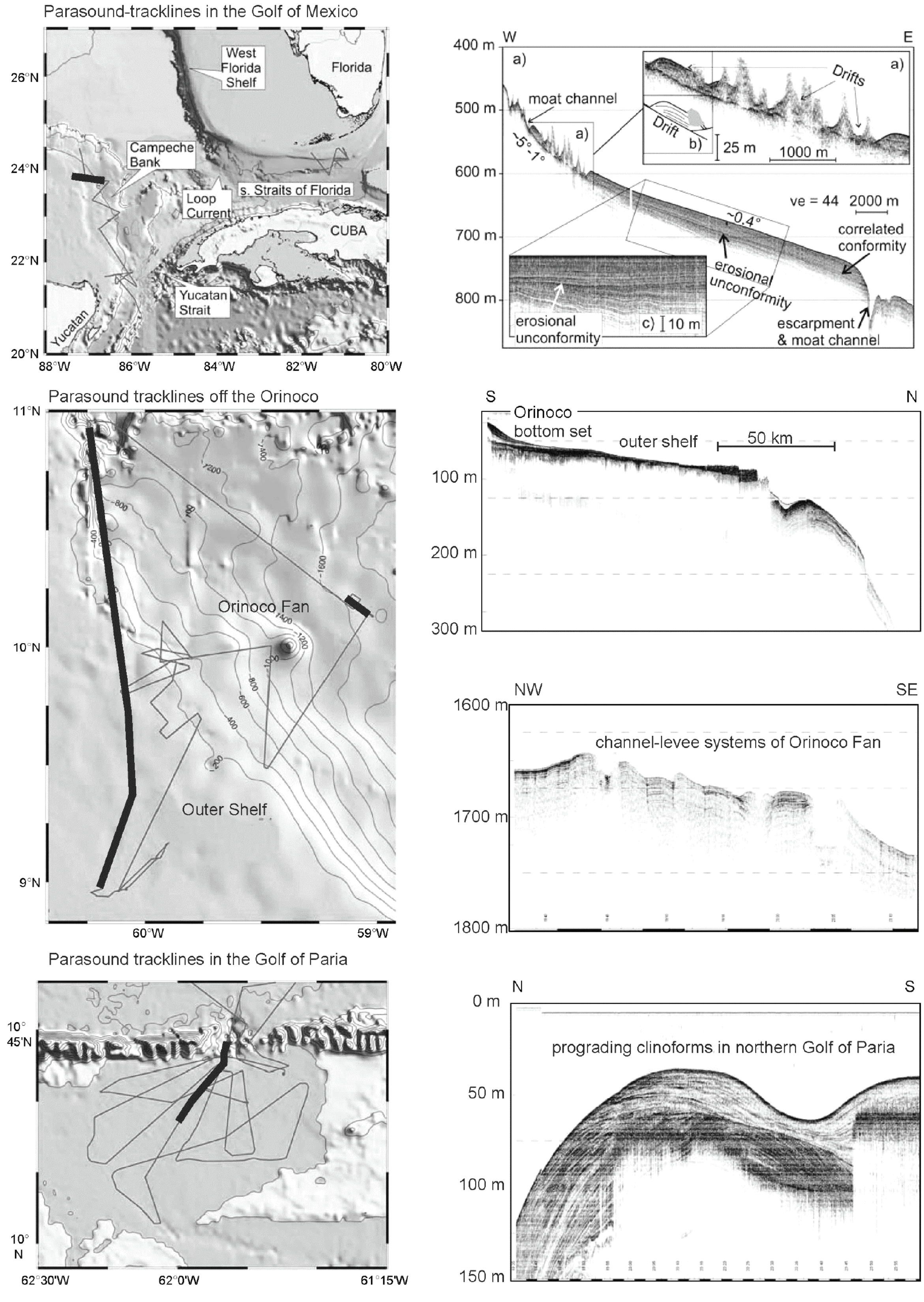

Fig. 5.8 Bathymetry (ETOPO2 v2) of working areas in the Gulf of Mexico (upper part), off the Orinoco (middle part), and in the Gulf of Paria (lower part). Hydroacoustic data are available along the red lines mark the ship tracks. Profile locations of PARASOUND data examples are marked by thick black lines. Data processing of PARASOUND data has been carried out with the SESuit developed by V. Spieß and co-workers (University of Bremen). The examples elucidate the data quality for all major working areas.

5.5 Surface Sediment Sampling

5.5.1 Devices and Operations

(Joachim Schönfeld, Thomas Blanz, Nina Joseph, Dirk Nürnberg, Jürgen Titschack)

Surface sediment sampling was performed with a Multicorer (MUC), USNEL giant box corer (GKG), REINECK box corer (BC), VAN VEEN grab (BG), and a hand-held grab sampler (MBG). The pilot corer (MGC), which is the piston corer trigger weight, and a RUMOHR corer (MIC) was also used.

The Multicorer was deployed on the same locations where gravity or piston cores were retrieved or where soft sediments were expected. The purpose was to recover a reliable sediment surface for proxy calibration and an undisturbed sediment sequence as late Holocene archive for palaeoclimatic, palaeoceanographical, and environmental studies. The MUC was equipped with eight tubes of 60 cm length and 10 cm diameter. Slacking velocity was 0.3 cm/s, the core recovery varied from 12 to 51 cm. One complete core was frozen for organic compounds. The other cores were sliced in 1-cm intervals, and the sediment composition, colour and structures were noted. A sample series to be analysed for biomarker and another series for pore-water geochemistry and clay mineralogy was immediately frozen at –20°C. A series for foraminiferal proxies and a series for trace metal geochemistry was stored in PETRIE dishes at 4°C. One 0-1 cm surface sample was collected in a PVC bottle and preserved with ethanol/Rose Bengal solution for benthic foraminiferal studies. If available, another core was washed through 0.5, 1, and 2 mm screens in order to collect macroinvertebrates.

The USNEL and REINECK box corer was used to investigate the sediment surface distribution and their structures where sands or fine-grained sediments were expected. The GKG was deployed at greater depths or where archive cores were requested, whereas the REINECK box corer was preferred at shallower depths, insecure grounds, or where light-weighed equipment was needed. The GKG was equipped with boxes of 50 x 50 cm width and 60 cm length, the BC box had boxes of 20 x 20 cm and 25 cm length. Slacking velocity was 0.5 and 0.3 cm/s respectively, the core recovery varied from a few pebbles to 57 cm. The box core surface and the section was described and photographed. Volume-defined surface samples were taken with a frame and preserved with ethanol/Rose Bengal solution for benthic foraminiferal studies. Additional subsamples were taken from the surface with cut-off syringes to analyse carbonate mineralogy and physical properties. A surface bulk sample was taken for coarse-fraction analyses. Push-cores were taken by opportunity for clay mineralogy, alkenone studies, or as archive cores for x-ray tomography. The remaining sediment was washed through 0.5, 1, and 2 mm screens and macroinvertebrates were collected from the residues (Appendix 5.5.1).

The VAN VEEN grab of 35 x 35 cm and small hand-held grab sampler of 16 x 16 cm were used to explore the bottom sediment distribution where pebble lags, hardgrounds or corals were expected. On sufficient recovery, the same documentation and sediment surface sampling scheme was applied as with the box cores (Appendix 5.5.1).

The pilot corer and RUMOHR corer was deployed to recover short sediment sequences from coral mounds or shallow-water muds. The pilot corer operated successfully only on station M78/1-231-1 in the Gulf of Paria.

5.5.2 Sedimentary Facies Distribution

(Nina Joseph)

On Saturday the 28th of February, and on Sunday the 1st of March 2009, we performed a surface sampling transect on the eastern Yucatan shelf and slope (Fig. 5.9 A). The sediments in the shallowest grabs consisted of coarse to middle carbonate sand with bivalve fragments, polychaets, serpulids, gastropods, coral and echinoid fragments, as well as some living rhodoliths and a red-algae branch. Further down slope, where the average current velocity was lower than 70 cm/s (Sheinbaum et al. 2002), the grain size of the surface sediment decreased and silty middle to fine sands were retrieved. Even a couple of gromiid mud balls were recovered at station M78/1-172-2. The surface sediment consisted of silty clay at 750 m depth where the average flow was below 10 cm/s.

From Monday the 9th, to Wednesday the 11th of March, we accomplished the GOLDFLOS surface sample transect between Cay Sal (Bahamas) and Sombrero Key (Florida). The southern part has been sampled during the R/V SONNE cruise SO164 in June 2002 already (Nürnberg et al., 2002). The transect of cruise M78/1 commenced at the American side of the Florida Trough and continued down slope across Pourtales Terrace and beyond (Fig. 5.9 B). REINECK box cores and VAN VEEN grabs recovered only small amounts of coarse to middle sand at the shallowest stations. At station M78/1-208-1, some carbonate clasts encrusted by serpulids and polychaets were recovered. Further organisms like hydrozoans, bryozoans, and a sponge settling on hard substrates as well as coral rubble was recovered from greater depths. Therefore it was concluded that the seabed consists of hardgrounds, which are covered with a thin veneer of pebbles and bioturbated sands. The VAN VEEN grab or REINECK box corer were not able to penetrate the substrate. The highest near-bottom current velocities prevailed in this area (Richardson et al., 1969). Sampling was more successful further down slope between 450 and 550 m. The surface sediments pass into fine carbonate sands but patches of coarse sand or gravel were still present. Pteropods, echinoid fragments, otoliths, bivalves and echinoid spines, some heavily bioeroded corals, possibly *Lophelia*, and volcanic clasts were recovered. From 700 m to the deepest part of the Strait, spiculitic carbonate oozes were retrieved. The average current velocities were markedly lower than 20 cm/s below 700 m depth in this area (Richardson et al., 1969).

From Tuesday the 24th, to Thursday the 26th of March we investigated the surface sediment distribution off the Orinoco mouth (Boca Grande; Fig. 5.9 C). The surface sediments at the entrance of Boca Grande at 14 m depth consisted of very soft dark clay. The clay was interbedded with thin silt layers in places, which is typical for delta sedimentation. The sediments recovered at 60 m depth consisted of sandy clayey silt and contained abundant bivalves and small crabs. The box core taken at 80 m depth retrieved sandy clay at the southern station. Further north and closer to the shelf break, another box core recovered coarse sand with abundant mollusc shell debris. Further down slope, the grain size decreased. The surface sediments consisted of sandy clayey silt at 300 m water depth and of soft clay at 1600 m.

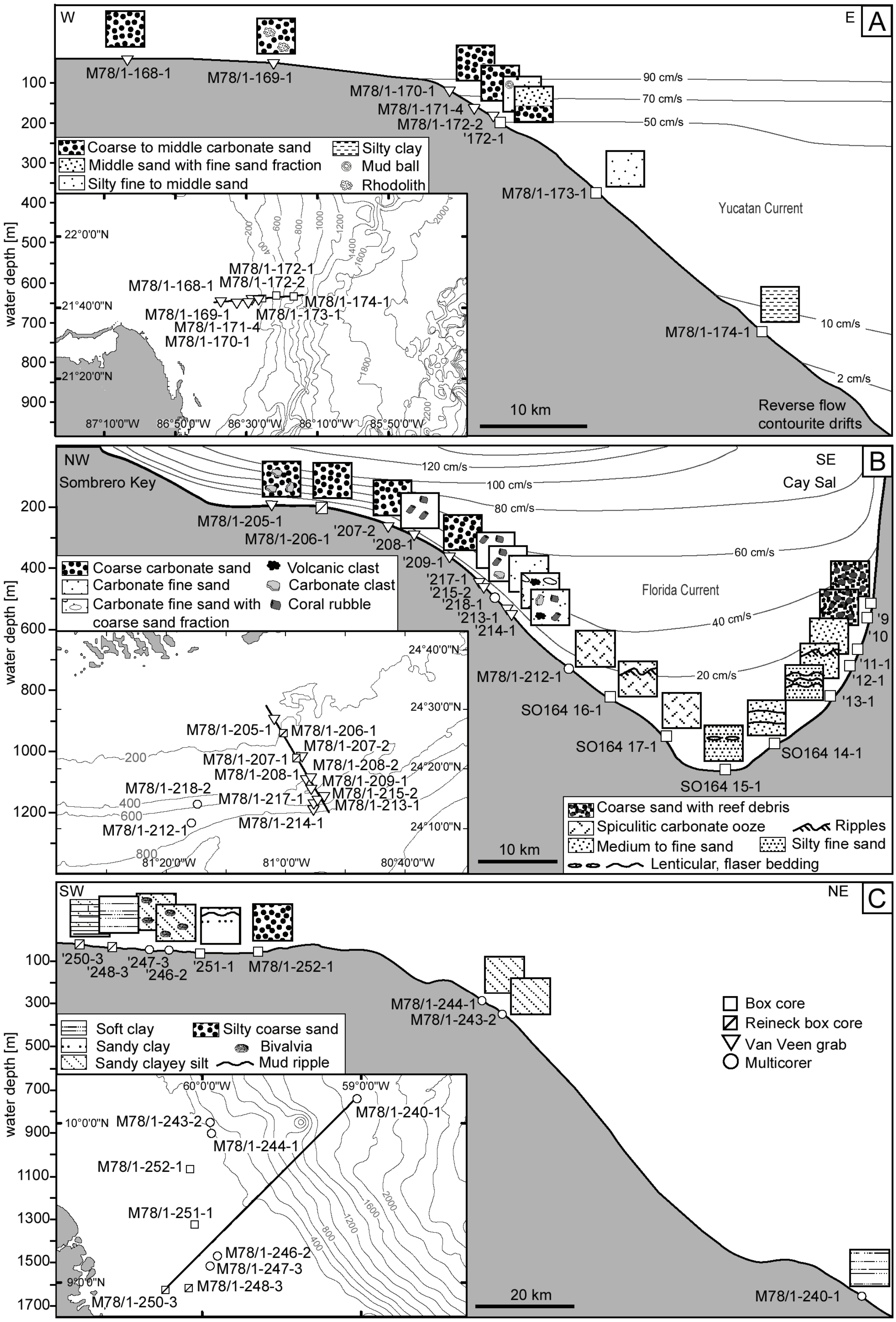

Fig. 5.9 Near-surface sediment distribution on the (A) Yucatan Transect, (B) Strait of Florida Transect and (C) Orinoco Transect.

5.6 Sediment Coring

5.6.1 Coring Devices and Operations

(Dirk Nürnberg, André Bahr, Asmus Petersen)

A "Hydrowerkstätten” gravity corer (GC) with 12.5 cm inner diameter and a head weight of 1.5 tons was used at 9 stations. With the exception of one station in the Gulf of Paria where a 11.5-m core barrel was used, the GC was mounted with a 5.75 m tube. The device was slacked with a speed of 1 m/s to ca. 50 m above sea floor. After attenuation for approximately 5 minutes, the GC was driven into the sediment with 0.8 m/s. Heaving was initially done with 0.3 m/s until the rope tension indicated the release of the device from the sea floor, then with 1.0 m/s on deck. Recoveries ranged from 0.43 m to 5.55 m (Appendix 5.6.1), which was higher than during R/V Sonne cruise SO164 where 4.3 m were retrieved at maximum with a 6-m core barrel.

To recover deeper and older sediment sequences, a "Marinetechnik Kawohl” advanced piston corer (PC) with 12.5 cm inner diameter, a core barrel length of 15 m, and a head weight of 2.5 tons was used at 9 stations. Slacking velocity was 1 m/s until 50 m over ground, followed by 5 minutes attenuation time, and final slacking with 0.3 m/s until release. The PC was hoisted with 0.3 m/s until the device departed from the seabed, and with 1.0 m/s on deck. Recoveries range from 6.26 m to 13.65 m (Appendix 5.6.1), which was approximately to the same range as on R/V Sonne cruise SO164, where 11.76 to 13.16 m were retrieved with the same 15-m core barrel.

5.6.2 Core Analyses and Sampling

(André Bahr, Dirk Nürnberg)

Prior to deploying the gravity and piston core, liners were marked lengthways with a straight line to facilitate oriented cutting of the liners. Segments of 1 m length were numbered consecutively and signed with arrows pointing downcore to retain the orientation of the sediment core after retrieval. After successful deployment, the sediment cores were cut in 1 meter sections, capped and labelled according to a standard scheme.

Whole segments were analysed for magnetic susceptibility in 2 cm steps (cores M78-1 175-1 and, partly, M78-1 180-1 in 1 cm intervals) with a PC-controlled GEOTEK® core logger. Prior to measuring a segment, an in-house standard has been analysed manually. Zeroing the instrument was done before each measuring session and occasionally between sections. The values obtained on the standard have been used during subsequent data processing for drift-correction and normalisation of the data. The first 3 to 4 centimetres at the ends of each section were discarded since they show low magnetic intensities due to the lowered amount of material the loop sensor is integrating over close to segment ends.

Subsequently, cores were cut lengthways in halves, where the working halves were used for sediment sampling, while visual core description and colour spectrophotometry was performed on the archive halves. The results of the core description were documented following the Integrated Ocean Drilling Program scheme using the program APPLECORE® resulting in a graphic visualisation of the lithology, sediment structure, colour, micro and macrofossil content. A MINOLTA CM-508d hand-held spectrophotometer was used to measure the light reflectance of the sediment. For this purpose, the sediment surface was covered with clear polyethylene foil and smoothed in order to avoid the formation of air bubbles on the foil-sediment interface. The spectral reflectance is measured over a wavelength spectrum from 400 to 700 nm at a 10 nm pitch. Routine measurements were made at 1 cm intervals and automatically recorded using the SPECTRAMAGIC® v.2.11 software. The instrument was calibrated before measuring each segment, including the measurement of a reference sample, a plain white sheet of paper. The CIELAB colour coordinates L*, a*, and b* were automatically calculated by the software. Processing of the raw colour scanning data included a correction for outliers and sections where the instrument had poor surface contact due to voids or very coarse sediment. The resulting lightness (L*) and magnetic susceptibility curves were presented together with the lithological columns of the core description (Appendix 5.6.2).

Sediment sampling was performed using cut-off 10 ml syringes. For most of the cores, three series of 10 ml samples were taken in 5-cm intervals, starting at 3 cm core depth. These series comprise one for foraminiferal analyses (D. Nürnberg, IFM-GEOMAR, stored at 4°C), one for lipid biomarker analyses (R. Schneider, CAU, stored at -20°C), and one for bulk geochemical analyses (D. Nürnberg, IFM-GEOMAR, stored at 4°C). Additionally, 1 series of syringes in 20 cm intervals was taken for on-board carbonate analyses (see chapter 5.7.2). Core M78/1-218-1 was sampled with a fourth syringe series in 5 cm intervals for Jean Lynch-Stieglitz (Georgia Institute of Technology, U.S.A.). After sampling and logging, the core halves were separately stored in D-tubes at 4°C.

5.6.3 Preliminary Stratigraphy and Correlation

(André Bahr, Dirk Nürnberg)

The colour scanning and magnetic susceptibility profiles were used to infer preliminary stratigraphies for the recovered gravity and piston cores by tuning the scanner data to existing, well dated records. However, it turned out that even close-by records such as those from Florida Strait (M78/1-212-3, M78/1-218-1 compared to the dated record SO164-17-2) exhibited a pronounced variability that prohibits a reliable stratigraphic correlation between the different sites. In the case of the Florida Strait, locally variable sedimentary processes apparently lead to a spatially heterogeneous lithology. The same difficulties arised for the cores from the Orinoco Delta and off Tobago.

A better constrained, although tentative correlation has been achieved for the cores recovered from the Gulf of Mexico, in particular stations M78/1-180-1 from Campeche Bank north of the Yucatan Channel, M78/1-181-3 located close to the Mississippi Delta, and M78/1-186-2 from the western Florida Slope. While neither reflectance nor spectral ratios such as red/blue provided sound correlations between the records, magnetic susceptibility data seemed to be most promising for tying these records to the dated record of core MD02-2576 from Desoto Canyon, which is very close to station M78/1-181-3 (Fig. 5.10). A pronounced maximum in the magnetic susceptibility of MD02-2576 was hereby correlative to the Last Glacial Maximum, inferring a high terrigenous input during cold stages. This maximum was also visible in the records from Campeche Bank and Western Florida slope indicating that both records had a fairly condensed Holocene section but experienced increased glacial sedimentation. The total penetration of both cores was difficult to assess but both should at least reach Marine Isotope Stage 6. The correlation of the susceptibility signal between the cores close to the Mississippi was more dubious, although both are located close to the present Mississippi delta and were, judging from the sediment dominated by siliciclastic material, primarily influenced by variations in the Mississippi river discharge.

Based on our preliminary correlation we propose that core M78/1-181-3 is characterised by a comparatively high sedimentation rate, explaining that the usually quite distinct peak in the magnetic susceptibility is more flattened-out and its base is not reached. Thus, this core might represent a high-resolution succession of Holocene to Last Glacial Maximum sediments. However, to further constrain the age models and inter-core correlations further analyses, e.g. XRF scanning and in particular the construction of benthic stable oxygen isotope stratigraphies are necessary.

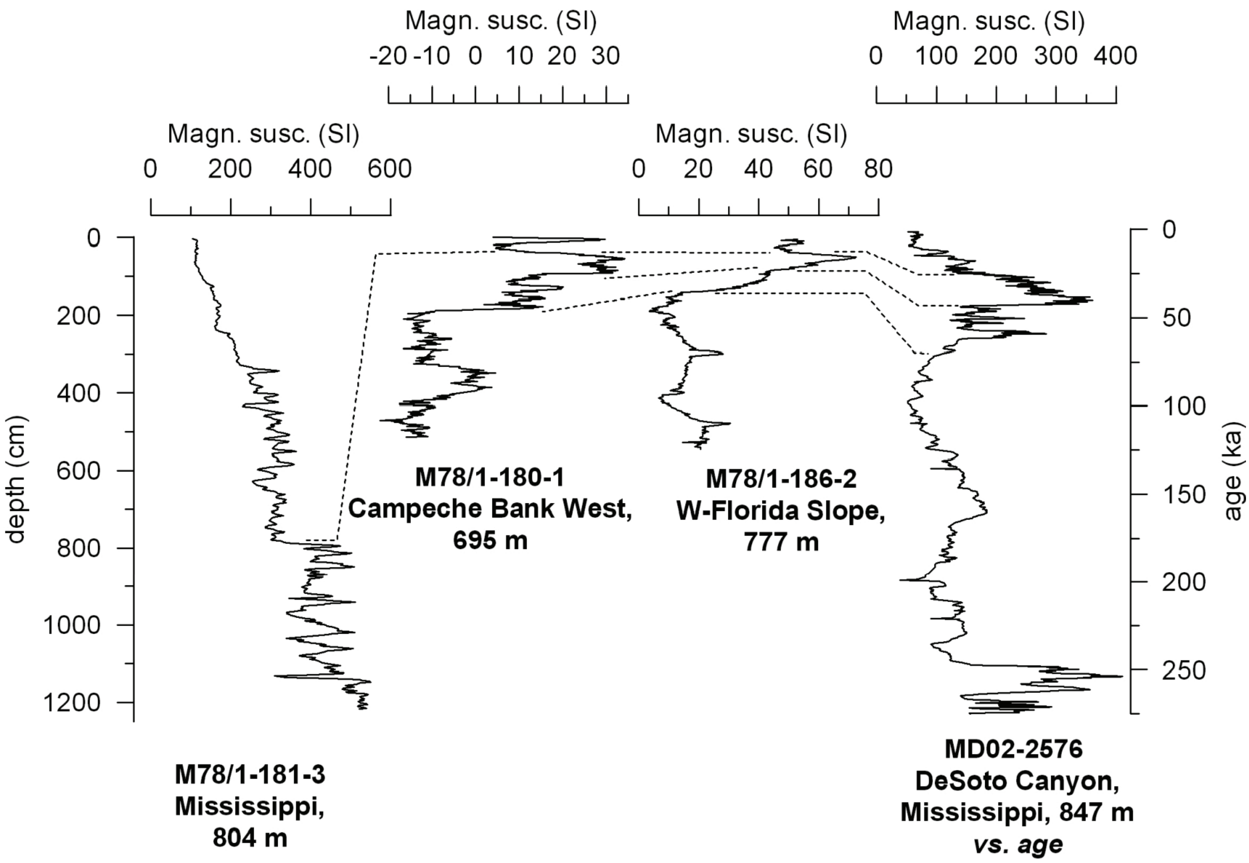

Fig. 5.10 Tentative correlation of cores from the Gulf of Mexico retrieved during the M78/1 cruise with the dated core MD02-2576 from DeSoto Canyon close to the Mississippi Delta. Note that MD02-2576 is plotted *vs.* age, the other records *vs.* depth.

5.7 Shipboard Analyses

5.7.1 Seawater Oxygen Analyses

(Thorsten Garlichs)

The measurements of the CTD oxygen sensors were validated on board with water samples by iodometric WINKLER-Titration after Graßhoff (1983). The measurements were performed on 12 of 40 CTD casts. Water samples were taken on upcast only. When a designated sampler bottle was released, the oxygen sensor readings were noted and later compared to the titration results.

Immediately after collection, the water samples were filled into volume-calibrated WINKLER-bottles. Two parallel samples were taken, and I paid particular attention of not having any air in the WINKLER -bottles. The oxygen was fixed with 0.5 cm^3 manganese-II-chloride and 0.5 cm^3 alkaline iodide. Then the bottles were shaken and stored cool for several hours. Before titration, the manganese hydroxide was solved with 1 cm^3 H_2SO_4 (9M) and the bottles were shaken again. The samples were each transferred into a 250 ml beaker, where they were titrated with 0.02 M sodium thiosulfate until the solution turned into yellow. After adding 1 cm^3 of zinc iodide solution, the titration was continued until the blue colour of the sample disappeared. The factor of the thiosulfate solution was determined with a standard, which was performed after every CTD station. The oxygen content was calculated from the thiosulfate consumption by using the following standard formula:

$$O_2 = (a * f * 0.112 * 103) / (b-1) \quad [ml/l]$$

where a is the consumption of thiosulfate solution [ml], b is the volume of the WINKLER bottle [ml], and f is the factor of the thiosulfate solution.

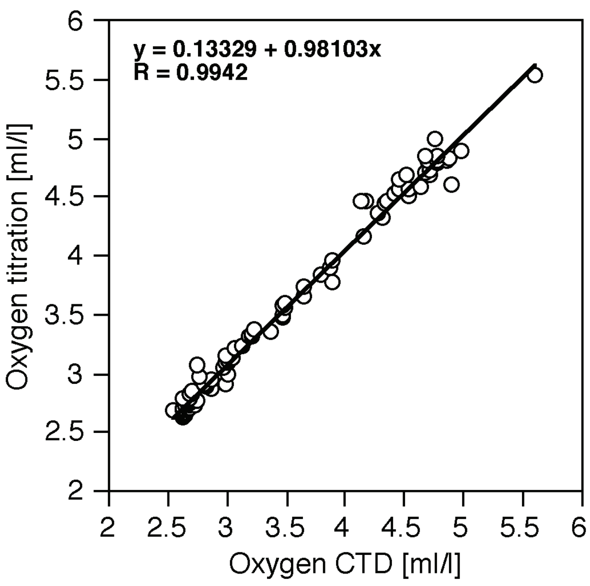

Figure 5.11 Comparison between dissolved oxygen contents of CTD and Winkler-Titration for all measurements during cruise M78/1. The regression equation was used to calibrate the CTD data.

A total number of 182 titrations were performed. The oxygen contents range from 2.62 to 5.60 ml/l. The differences between parallel measurements range from 0 to 0.41 ml/l, on average 0.029 ml/l. The accuracy of our titrations is considered as 0.5%, which is in the range of values reported in the literature (0.06 to 0.89 %; Furuya and Harada, 1995). The two oxygen sensors of the CTD transmitted slightly different oxygen contents at depth. The comparison of sensor readings and titration results revealed that sensor no.1 indicated oxygen contents lower by 0.38 ml/l whereas sensor no.2 showed concentrations lower by 0.13 ml/l on average as compared to the values obtained by WINKLER-titration. Therefore, we considered sensor no. 2 as reliable and corrected the measured values according to the regression equation (Fig. 5.11).

5.7.2 Carbonate Analyses

(Thorsten Garlichs)

The carbonate analyses were performed with a "carbonate bomb“ described by Müller and Gastner (1971). A carbonate bomb measures the CO_2 pressure that is generated after dissolving $CaCO_3$ in a sediment sample with hydrochloric acid. The manometer scale is designed accordingly and already displays carbonate percentages. As the gas volume also depends on temperature and atmospheric pressure, the values have to be corrected.. A calibration series of 7 measurements with 126 to 732 mg pure carbonate corresponding to 15 to 100 % $CaCO_3$. was carried out before measuring regular samples. The stability of the carbonate bomb was determined routinely every 30 measurements with pure carbonate. These replicates arised a mean value of 99.8 % $CaCO_3$ and a standard deviation of ± 0.7 % (1-sigma value).

Syringe samples were taken every 20 cm along selected cores. One to two cm^3 of the samples were dried in the drying cabinet at 60°C for at least 24 hours. They were finely ground in an agate mortar after drying. For each measurement, 732 mg were tared with a small beam balance, transferred into the carbonate bomb and leached with 5 ml of 10 % HCl until the pressure reading was stable. The $CaCO_3$ percentages were calculated by using the following equation:

$$CaCO_3\ (spl) = CaCO_3\ (man) * (100/CaCO_3\ (man\ std)) * (\text{weight}(std) / \text{weight}\ (spl)) \quad [\%]$$

where *man* is the reading from the manometer scale, *man std* is the manometer reading for the standard (99,75 %), *spl* indicates the sample, and *std* refers to the standard.

Twohundred-one carbonate measurements were carried out. The carbonate contents ranged from 70 to 90 % and showed only minor variations in cores from the Gulf of Mexico and Florida Straits. The values were markedly lower in core M78/1-183-3 close to the Mississippi delta. This core showed strong fluctuations in the upper part and a downcore decreasing trend with minor variations below (Figure 5.12).

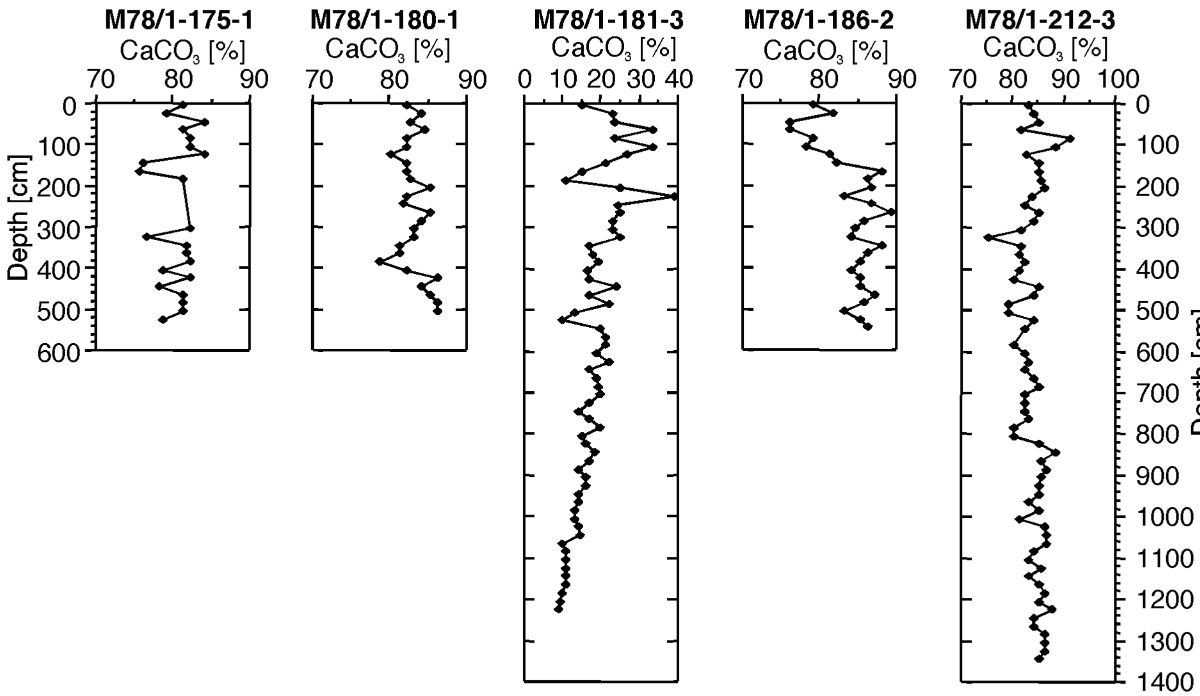

Figure 5.12 Carbonate records of M78/1 sediment cores

6 Ship's Meteorological Station

(Wolf-Thilo Ochsenhirt)

METEOR left the port of Colón (Panama) on 22nd of February 2009 with north-easterly winds of 4 Bft. The wind increased rapidly after departure to 6 Bft. The swell, as well from Northeast as the wind, became 3 metre. To the beginning of the leg METEOR was in the northern area of a low over Colombia south of a high pressure ridge over southern Texas.

On 14th of February METEOR arrived at the first working station near 14.2°N 77.4°W with fair weather and a north-easterly wind of 5 Bft. The north-easterly swell was 2.5 to 3 metre. During the night from 24th to 25th of February the voyage was continued and METEOR headed north-westerly to 18.6°N 83.8°W. The wind from East to Northeast rapidly decreased to 4 Bft and the easterly swell to 1.5 metre. During the further cruise to the Yucatan Channel the weather did not change significantly.

A ridge from a high south-east of Newfoundland extended to southern Mexico and Cuba. In the working area of METEOR the wind came from easterly directions with 4 to 5 Bft and a height of the sea of 1.5 metre. On 28th of February in the area of the Yucatan Channel the mentioned ridge had moved further to the west. The wind however was nearly the same (east 4 to 5).

On 1st of March METEOR arrived at the position of 22.7°N 86.8W in the northern Yucatan Channel. In the rear of a low of gale-force north of Florida the wind increased rapidly during forenoon to Northwest 6 to 7. These winds were possible due to a ridge of a new Canadian high over southern Mexico, which pushed against the mentioned low. On the following day the wind decreased quickly to 4 to 5 Bft. METEOR left the working area in the evening, heading to the Mississippi mouth. Arriving there on 4th of March near 28.4°N 88.5°W METEOR was under the influence of a high pressure ridge, extending until Cuba and the corresponding winds were northerly with 2 to 3 Bft.

During the following days a high with centre over the US-eastcoast affected the weather of the working area. The wind shifted to Southeast, first with 2 to 3 Bft , then on the route to the area near West Florida with 4 to 5 Bft. On 7th of March a new high had established near 31°N 70°W, displaced to Southwest by a developing low on the North Atlantic. On 8th of March METEOR arrived in the Strait of Florida and the easterly wind increased to 5 to 6 Bft. On the next day the wind speed decreased a little and until 11th of March, when leaving that area, the winds were easterly with 4 to 5 Bft.

In the afternoon of 13th of March METEOR arrived at the "Windward Passage". In the evening and during the following night the wind decreased to 3 to 4 Bft. In the morning of 14th March the southern coast of Haiti was passed and the trade winds increased again to 5 to 6 Bft and the swell up to 2 and 3 metre. Sailing easterly, the wind speed did not decrease before 17th of March, then it became 4 to 5 Bft with 2m metre swell. On 18th of March at 14.2°N 63.5°W METEOR was in the trade wind system again with isolated showers but without significant higher wind or gusts. In the afternoon the investigations were finished and METEOR headed southerly to the isle "La Banquilla" (Venezuela) to the position 12.0°N 64.5°W, where the vessel arrived in the next morning. The weather was characterised by easterly winds about 5 again and a sea of 1.5 to 2 metre.

On 21st of March METEOR was on the road of Port of Spain for taking over an observer. The weather was fair and the winds light and variable. South of a ridge of a high near the Azores extending until the northerly Antilles a north-easterly wind blew with about 4 Bft. Caused by a belt of low pressure in the Intertropical Convergence Zone over northern Colombia and northern Venezuela the wind conditions remained very constant for the last days and the shower activity was poor. For the rest of the voyage passing the area east of Trinidad to the Orinoco Delta the situation did not change significantly. The first leg of the voyage M78 ended on 28th of March in the harbour of “Port of Spain”.

7 Station List M78/1

Station M78/1-	Device	Date [UTC]	Time [UTC]	Latitude	Longitude	Depth [m]
Plankton Station 2, Hess Escarpment						
162-1	CTD	24.02.2009	18:57	14° 12.60' N	77° 23.40' W	4033
162-2	MSN	24.02.2009	21:42	14° 12.60' N	77° 23.40' W	4033
162-3	MSN	24.02.2009	22:21	14° 12.60' N	77° 23.40' W	4043
162-4	MSN	24.02.2009	23:01	14° 12.60' N	77° 23.40' W	4035
162-5	MSN	24.02.2009	23:40	14° 12.59' N	77° 23.41' W	4033
163-1	MB-PS start	24.02.2009	23:57	14° 12.61' N	77° 23.43' W	4033
163-1	MB-PS end	25.02.2009	7:42	15° 3.81' N	77° 38.09' W	2030
Plankton Station 1, Misteriosa Bank						
164-1	CTD	26.02.2009	17:50	18° 30.42' N	83° 38.66' W	1172
164-2	MSN	26.02.2009	19:15	18° 30.49' N	83° 38.43' W	1180
164-3	MSN	26.02.2009	20:04	18° 30.51' N	83° 38.02' W	1187
164-4	MSN	26.02.2009	20:50	18° 30.59' N	83° 38.46' W	1184
164-5	MSN	26.02.2009	21:42	18° 30.51' N	83° 38.27' W	1186
164-6	PP	26.02.2009	22:40	18° 30.52' N	83° 38.53' W	1179
164-7	PP	27.02.2009	0:37	18° 30.52' N	83° 38.28' W	1185
164-8	BC	27.02.2009	3:00	18° 30.48' N	83° 37.87' W	1187
Yucatan Strait and Campeche Bank						
165-1	OFOS start	28.02.2009	2:12	21° 41.47' N	86° 21.85' W	412
165-1	OFOS end	28.02.2009	2:30	21° 41.93' N	86° 21.86' W	396
165-2	OFOS start	28.02.2009	4:46	21° 31.83' N	86° 19.55' W	825
165-2	OFOS end	28.02.2009	6:14	21° 33.89' N	86° 18.95' W	665
165-3	OFOS start	28.02.2009	7:37	21° 34.92' N	86° 15.61' W	952
165-3	OFOS end	28.02.2009	9:00	21° 36.61' N	86° 15.02' W	1038
166-1	CTD	28.02.2009	11:20	21° 40.79' N	86° 9.92' W	1541
167-1	MB-PS start	28.02.2009	13:26	21° 46.99' N	85° 58.45' W	1836
167-1	MB-PS end	28.02.2009	19:22	21° 40.99' N	86° 38.21' W	34
168-1	BG	28.02.2009	19:48	21° 41.29' N	86° 37.31' W	34
169-1	BG	28.02.2009	20:50	21° 41.61' N	86° 32.76' W	42
170-1	BG	28.02.2009	21:43	21° 42.54' N	86° 27.89' W	128
171-1	BG	28.02.2009	22:20	21° 42.68' N	86° 26.98' W	164
171-2	BG	28.02.2009	22:36	21° 42.68' N	86° 26.98' W	163
171-3	BG	28.02.2009	22:55	21° 42.68' N	86° 26.98' W	163
171-4	BG	28.02.2009	23:11	21° 42.68' N	86° 26.98' W	164
172-1	GKG	28.02.2009	23:51	21° 42.75' N	86° 26.48' W	180
172-2	BG	01.03.2009	0:19	21° 42.74' N	86° 26.48' W	180
173-1	GKG	01.03.3009	1:55	21° 43.65' N	86° 21.71' W	382
174-1	GKG	01.03.2009	3:18	21° 44.24' N	86° 16.62' W	738
175-1	GC	01.03.2009	8:25	21° 27.49' N	85° 52.51' W	1881
176-1	MB-PS start	01.03.2009	15:54	22° 44.16' N	86° 45.51' W	368
176-1	MB-PS end	01.03.2009	19:15	22° 56.53' N	86° 28.50' W	872
177-1	GC	01.03.2009	20:42	22° 53.86' N	86° 32.94' W	676
178-1	MB-PS start	01.03.2009	22:00	22° 56.77' N	86° 28.39' W	877
178-1	MB-PS end	02.03.2009	0:00	23° 5.12' N	86° 16.69' W	1212
179-1	MB-PS start	02.03.2009	5:47	23° 21.99' N	86° 54.84' W	557

Station M78/1-	Device	Date [UTC]	Time [UTC]	Latitude	Longitude	Depth [m]
179-1	MB-PS end	02.03.2009	10:45	23° 45.34' N	86° 31.66' W	1105
180-1	GC	02.03.2009	20:24	23° 49.63' N	87° 4.03' W	695
180-2	MUC	02.03.2009	22:10	23° 49.58' N	87° 4.29' W	691
Mississippi Transekt						
181-1	CTD	04.03.2009	8:17	28° 59.99' N	88° 20.00' W	818
181-2	MUC	04.03.2009	9:34	29° 0.00' N	88° 20.00' W	802
181-3	PC	04.03.2009	11:58	29° 0.00' N	88° 20.00' W	804
182-1	CTD	04.03.2009	16:12	29° 0.00' N	87° 50.00' W	1511
182-2	MUC	04.03.2009	17:56	29° 0.00' N	87° 50.00' W	1518
183-1	MUC	04.03.2009	21:48	29° 0.00' N	87° 20.00' W	1249
184-1	MUC	05.03.2009	1:12	29° 0.01' N	86° 50.00' W	546
185-1	MUC	05.03.2009	4:23	28° 59.93' N	86° 20.18' W	337
185-2	CTD	05.03.2009	5:13	28° 59.84' N	86° 19.69' W	335
West Florida						
186-1	MUC	05.03.2009	20:48	26° 36.30' N	84° 51.81' W	781
186-2	GC	05.03.2009	22:00	26° 36.30' N	84° 51.81' W	778
187-1	MB-PS start	06.03.2009	0:05	26° 21.62' N	84° 44.62' W	385
187-1	MB-PS end	06.03.2009	0:44	26° 18.88' N	84° 45.29' W	544
188-1	MB-PS start	06.03.2009	1:32	26° 12.67' N	84° 41.54' W	353
188-1	MB-PS end	06.03.2009	4:12	26° 9.40' N	84° 46.42' W	962
189-1	OFOS start	06.03.2009	4:54	26° 10.52' N	84° 44.31' W	624
189-1	OFOS end	06.03.2009	7:07	26° 12.50' N	84° 43.42' W	496
189-2	OFOS start	06.03.2009	8:19	26° 18.73' N	84° 45.32' W	525
189-2	OFOS end	06.03.2009	10:28	26° 20.13' N	84° 44.97' W	454
190-1	OFOS start	06.03.2009	11:47	26° 12.19' N	84° 43.84' W	533
190-1	OFOS end	06.03.2009	14:20	26° 12.19' N	84° 43.84' W	534
190-2	POZ	06.03.2009	14:02	26° 12.18' N	84° 43.84' W	531
191-1	MSN, FP	06.03.2009	16:04	26° 12.51' N	84° 46.23' W	855
191-2	MSN	06.03.2009	16:42	26° 12.51' N	84° 46.24' W	850
191-3	MSN	06.03.2009	17:23	26° 12.52' N	84° 46.24' W	850
191-4	MSN	06.03.2009	18:02	26° 12.51' N	84° 46.24' W	849
191-5	PP	06.03.2009	18:36	26° 12.51' N	84° 46.24' W	849
191-6	BC	06.03.2009	20:00	26° 12.52' N	84° 46.24' W	850
192-1	BC	06.03.2009	21:32	26° 11.80' N	84° 43.95' W	549
192-2	BC	06.03.2009	22:14	26° 11.80' N	84° 43.95' W	551
192-3	MGC	06.03.2009	23:10	26° 11.80' N	84° 43.95' W	549
192-4	MGC	06.03.2009	23:43	26° 11.80' N	84° 43.95' W	548
193-1	BC	07.03.2009	0:24	26° 11.78' N	84° 43.97' W	549
193-2	BC	07.03.2009	1:00	26° 11.77' N	84° 43.97' W	549
194-1	CTD	07.03.2009	2:14	26° 12.18' N	84° 43.88' W	538
194-2	CTD	07.03.2009	3:16	26° 12.19' N	84° 43.88' W	539
194-3	CTD	07.03.2009	4:34	26° 12.18' N	84° 43.88' W	538
194-4	CTD	07.03.2009	5:27	26° 12.18' N	84° 43.88' W	538
194-5	CTD	07.03.2009	6:28	26° 12.19' N	84° 43.88' W	538
194-6	CTD	07.03.2009	6:28	26° 12.19' N	84° 43.88' W	538
194-7	CTD	07.03.2009	7:22	26° 12.18' N	84° 43.88' W	538
194-8	CTD	07.03.2009	8:18	26° 12.18' N	84° 43.88' W	538

Station M78/1-	Device	Date [UTC]	Time [UTC]	Latitude	Longitude	Depth [m]
194-9	CTD	07.03.2009	9:20	26° 12.19' N	84° 43.88' W	538
194-10	CTD	07.03.2009	10:29	26° 12.18' N	84° 43.88' W	538
194-11	CTD	07.03.2009	12:19	26° 12.18' N	84° 43.88' W	538
194-12	CTD	07.03.2009	13:24	26° 12.18' N	84° 43.88' W	538
194-13	CTD	07.03.2009	14:26	26° 12.18' N	84° 43.88' W	538
195-1	BC	07.03.2009	15:56	26° 11.20' N	84° 44.05' W	572
196-1	BC	07.03.2009	16:56	26° 11.07' N	84° 44.05' W	580
197-1	BC	07.03.2009	17:55	26° 10.81' N	84° 44.07' W	597
198-1	POZ	07.03.2009	18:59	26° 12,26' N	84° 44,13' W	554
199-1	MGC	07.03.2009	19:44	26° 11.07' N	84° 44.06' W	582
Florida Straits						
200-1	MB-PS start	08.03.2009	16:38	24° 22.12' N	81° 45.68' W	190
200-1	MB-PS end	08.03.2009	22:00	23° 56.45' N	81° 24.09' W	1156
200-2	CTD	08.03.2009	22:54	23° 56.58' N	81° 22.96' W	1143
200-3	MB-PS start	09.03.2009	0:17	23° 57.29' N	81° 24.75' W	1126
200-3	MB-PS end	09.03.2009	1:10	23° 53.48' N	81° 21.33' W	1262
201-1	MB-PS start	09.03.2009	6:43	24° 15.17' N	80° 54.09' W	469
201-1	MB-PS end	09.03.2009	9:29	24° 15.70' N	80° 55.31' W	434
202-1	OFOS start	09.03.2009	10:43	24° 14.06' N	80° 55.91' W	568
202-1	OFOS end	09.03.2009	13:48	24° 15.68' N	80° 53.13' W	454
202-2	OFOS start	09.03.2009	15:00	24° 14.71' N	80° 55.72' W	521
202-2	OFOS end	09.03.2009	17:04	24° 15.64' N	80° 53.69' W	453
203-1	POZ	09.03.2009	18:24	24° 15,04' N	80° 54,94' W	452
204-1	MB-PS start	09.03.2009	18:45	24° 15.32' N	80° 54.46' W	464
204-1	MB-PS end	09.03.2009	20:20	24° 28.63' N	81° 1.84' W	186
205-1	BG	09.03.2009	20:41	24° 28.55' N	81° 2.04' W	195
206-1	BC	09.03.2009	21:40	24° 26.15' N	81° 0.40' W	201
206-2	BG	09.03.2009	22:02	24° 26.26' N	80° 59.81' W	213
207-1	BC	09.03.2009	23:10	24° 21.95' N	80° 58.04' W	269
207-2	BG	09.03.2009	23:35	24° 22.22' N	80° 57.34' W	260
208-1	BG	09.03.2009	0:35	24° 18.50' N	80° 56.46' W	313
208-2	BG	09.03.2009	1:02	24° 18.79' N	80° 55.70' W	320
209-1	BG	09.03.2009	2:12	24° 16.75' N	80° 55.67' W	381
210-1	CTD	10.03.2009	3:34	24° 14.94' N	80° 55.11' W	459
210-2	CTD	10.03.2009	4:30	24° 15.06' N	80° 54.99' W	452
210-3	CTD	10.03.2009	5:23	24° 15.04' N	80° 55.00' W	454
210-4	CTD	10.03.2009	6:18	24° 15.12' N	80° 54.87' W	457
210-5	CTD	10.03.2009	7:15	24° 15.08' N	80° 54.89' W	453
210-6	CTD	10.03.2009	8:17	24° 15.09' N	80° 54.83' W	458
210-7	CTD	10.03.2009	9:15	24° 15.08' N	80° 54.86' W	457
210-8	CTD	10.03.2009	10:17	24° 15.23' N	80° 54.69' W	458
210-9	CTD	10.03.2009	11:15	24° 14.99' N	80° 54.94' W	456
210-10	CTD	10.03.2009	12:13	24° 15.10' N	80° 54.82' W	459
210-11	CTD	10.03.2009	13:30	24° 15.07' N	80° 54.90' W	454
210-12	CTD	10.03.2009	14:22	24° 15.19' N	80° 54.78' W	457
210-13	CTD	10.03.2009	15:20	24° 15.17' N	80° 54.82' W	457
211-1	MSN, FP	10.03.2009	16:34	24° 15.24' N	80° 54.72' W	454
211-2	MSN	10.03.2009	17:16	24° 14.90' N	80° 55.08' W	453

Station M78/1-	Device	Date [UTC]	Time [UTC]	Latitude	Longitude	Depth [m]
211-3	MSN, CTD	10.03.2009	17:54	24° 15.19' N	80° 54.70' W	457
211-4	MSN, CTD	10.03.2009	18:42	24° 15.27' N	80° 55.09' W	447
211-5	MSN, CTD	10.03.2009	19:19	24° 15.50' N	80° 54.81' W	456
211-6	MSN, CTD	10.03.2009	20:18	24° 15.30' N	80° 54.69' W	453
212-1	MUC	10.03.2009	0:05	24° 11.10' N	81° 15.74' W	723
212-2	PC	11.03.2009	1:20	24° 10.92' N	81° 15.84' W	729
212-3	PC	11.03.2009	5:12	24° 11.06' N	81° 15.89' W	722
213-1	BG	11.03.2009	9:17	24° 14.61' N	80° 55.07' W	540
214-1	BG	11.03.2009	10:46	24° 14.41' N	80° 55.26' W	544
215-1	BG	11.03.2009	11:45	24° 15.50' N	80° 53.48' W	468
215-2	BG	11.03.2009	12:46	24° 15.50' N	80° 53.52' W	476
216-1	POZ	11.03.2009	13:58	24° 15,23' N	80° 54,81' W	457
217-1	BG	11.03.2009	15:40	24° 15.00' N	80° 54.60' W	461
218-1	PC	11.03.2009	18:55	24° 14.21' N	81° 14.82' W	547
218-2	MUC	11.03.2009	20:14	24° 14.21' N	81° 14.83' W	547
Plankton Station 3						
219-1	CTD	15.03.2009	3:40	15° 18.30' N	72° 47.06' W	2961
219-2	MSN, FP	15.03.2009	5:54	15° 18.30' N	72° 47.06' W	2962
219-3	MSN	15.03.2009	6:40	15° 18.30' N	72° 47.06' W	2961
219-4	MSN	15.03.2009	7:19	15° 18.30' N	72° 47.06' W	2961
219-5	MSN	15.03.2009	8:00	15° 18.30' N	72° 47.06' W	2960
219-6	MSN	15.03.2009	9:54	15° 18.30' N	72° 47.06' W	2962
219-7	MSN	15.03.2009	11:48	15° 18.30' N	72° 47.06' W	2960
219-8	MSN	15.03.2009	12:26	15° 18.30' N	72° 47.06' W	2960
Plankton Station 4						
220-1	CTD	16.03.2009	19:21	15° 24.00' N	68° 12.00' W	4484
220-2	CTD	16.03.2009	22:12	15° 23.99' N	68° 12.00' W	4481
220-3	MSN, FP	17.03.2009	0:52	15° 23.99' N	68° 12.00' W	4479
220-4	MSN	17.03.2009	1:32	15° 23.99' N	68° 12.00' W	4481
220-5	MSN	17.03.2009	2:12	15° 23.99' N	68° 12.00' W	4481
220-6	MSN	17.03.2009	2:47	15° 23.99' N	68° 12.00' W	4482
220-7	MSN	17.03.2009	4:26	15° 23.99' N	68° 12.00' W	4487
220-8	MSN	17.03.2009	6:23	15° 23.99' N	68° 12.00' W	4481
220-9	MSN	17.03.2009	7:03	15° 23.99' N	68° 12.00' W	4482
Plankton Station 6						
221-1	CTD	18.03.2009	12:14	14° 11.90' N	63° 25.45' W	1533
221-2	CTD	18.03.2009	13:28	14° 11.95' N	63° 25.42' W	1536
221-3	MSN, FP	18.03.2009	14:52	14° 11.90' N	63° 25.43' W	1541
221-4	MSN	18.03.2009	15:27	14° 11.90' N	63° 25.43' W	1535
221-5	MSN	18.03.2009	16:03	14° 11.89' N	63° 25.43' W	1535
221-6	MSN	18.03.2009	16:40	14° 11.89' N	63° 25.43' W	1534
221-7	MSN, CTD	18.03.2009	17:11	14° 11.89' N	63° 25.43' W	1533
221-8	MSN, CTD	18.03.2009	17:47	14° 11.89' N	63° 25.43' W	1535
Plankton Station 7						
222-1	CTD	19.03.2009	6:57	12° 1.48' N	64° 28.70' W	1026
222-2	MSN, FP	19.03.2009	8:14	12° 1.55' N	64° 28.70' E	1029

Station M78/1-	**Device**	**Date [UTC]**	**Time [UTC]**	**Latitude**	**Longitude**	**Depth [m]**
222-3	MSN	19.03.2009	9:01	12° 1.50' N	64° 28.59' W	1023
222-4	MSN	19.03.2009	9:40	12° 1.56' N	64° 28.80' W	1029
222-5	MSN	19.03.2009	10:28	12° 1.52' N	64° 28.60' W	1024
222-6	MSN, CTD	19.03.2009	10:58	12° 1.57' N	64° 28.80' W	1031
222-7	MSN-CTD	19.03.2009	11:45	12° 1.55' N	64° 28.80' W	1028
222-8	GKG	19.03.2009	12:49	12° 1.48' N	64° 28.50' W	1019
222-9	GC	19.03.2009	14:07	12° 1.49' N	64° 28.50' W	1018
Isla de Blanquilla						
223-1	MBG	19.03.2009	18:13	11° 48.90' N	64° 35.84' W	15
223-2	MBG	19.03.2009	18:15	11° 48.90' N	64° 35.84' W	15
224-1	MBG	19.03.2009	18:27	11° 49.06' N	64° 35.94' W	5
225-1	MBG	19.03.2009	18:45	11° 48.94' N	64° 35.97' W	35
226-1	MBG	19.03.2009	19:10	11° 48.95' N	64° 35.95' W	27
226-2	MBG	19.03.2009	19:13	11° 48.91' N	64° 35.97' W	40
226-3	CTD	19.03.2009	19:16	11° 48.91' N	64° 35.97' W	40
226-4	WSB	19.03.2009	19:20	11° 48.68' N	64° 35.99' W	200
Grenada Basin						
227-1	MB-PS start	20.03.2009	10:03	11° 47.54' N	62° 36.51' W	1029
227-1	MB-PS end	20.03.2009	17:12	11° 32.84' N	62° 39.92' W	281
228-1	MUC	20.03.2009	18:14	11° 37.78' N	62° 39.51' W	447
228-2	MUC	20.03.2009	19:10	11° 37.78' N	62° 39.51' W	447
228-3	PC	20.03.2009	20:45	11° 37.79' N	62° 39.51' W	447
229-1	MUC	20.03.2009	23:30	11° 47.54' N	62° 38.60' W	878
229-2	GC	21.03.2009	0:40	11° 47.54' N	62° 38.60' W	881
Paria Peninsula						
230-1	GKG	21.03.2009	7:12	11° 1.84' N	62° 5.61' W	100
Port-of-Span Anchorage						
231-1	MGC	21.03.2009	14:29	10° 37.49' N	61° 36.23' W	10
North Trinidad						
232-1	GKG	21.03.2009	17:53	10° 59.00' N	61° 31.49' W	122
Tobago Basin						
233-1	MB-PS start	22.03.2009	23:00	11° 31.41' N	60° 54.93' W	470
233-1	MB-PS end	22.03.2009	9:09	11° 24.57' N	61° 1.15' W	211
234-1	MUC	22.03.2009	10:01	11° 24.32' N	61° 2.96' W	200
234-2	PC	22.03.2009	11:15	11° 24.32' N	61° 2.96' W	201
235-1	PC	22.03.2009	14:54	11° 36.53' N	60° 57.86' W	852
235-2	MUC	22.03.2009	16:31	11° 36.53' N	60° 57.85' W	852
Eastern Tobago, Plankton Station 8						
236-1	CTD	22.03.2009	0:15	11° 0.80' N	60° 12.08' W	1587
237-1	MB-PS start	23.03.2009	1:42	10° 59.95' N	60° 11.74' W	1571
237-1	MB-PS end	23.03.2009	4:02	10° 57.04' N	60° 12.73' W	1390
238-1	POZ	23.03.2009	5:41	10° 56,97' N	60° 14,91' W	827
238-2	CTD	23.03.2009	7:03	10° 56.98' N	60° 14.91' W	822
238-3	MSN+FP	23.03.2009	8:18	10° 57.11' N	60° 14.87' W	900
238-4	MSN	23.03.2009	9:00	10° 57.92' N	60° 14.94' W	1095

Station M78/1-	Device	Date [UTC]	Time [UTC]	Latitude	Longitude	Depth [m]
238-5	MSN	23.03.2009	10:03	10° 56.95' N	60° 14.86' W	846
238-6	MSN	23.03.2009	10:41	10° 57.70' N	60° 14.92' W	1077
Orinoco Fan						
239-1	MB-PS start	23.03.2009	18:34	10° 9.78' N	59° 6.29' W	1612
239-1	MB-PS end	23.03.2009	20:11	10° 8.03' N	59° 1.08' W	1738
240-1	MUC	23.03.2009	21:24	10° 8.88' N	59° 2.31' W	1674
240-2	GC	23.03.2009	23:18	10° 8.88' N	59° 2.32' W	1672
241-1	MB-PS start	24.03.2009	0:30	10° 7.61' N	59° 2.96' W	1669
241-1	MB-PS end	24.03.2009	12:18	10° 6,50' N	59° 55,43' W	587
242-1	MUC	24.03.2009	14:00	9° 57.32' N	59° 48.12' W	591
242-2	PC	24.03.2009	15:15	9° 57.35' N	59° 48.11' W	596
243-1	PC	24.03.2009	17:44	9° 59.49' N	59° 56.93' W	341
243-2	MUC	24.03.2009	18:58	9° 59.50' N	59° 56.91' W	341
244-1	MUC	24.03.2009	20:54	9° 56.93' N	59° 56.11' W	278
244-2	GC	24.03.2009	21:48	9° 56.93' N	59° 56.11' W	278
245-1	MB-PS start	25.03.2009	22:15	9° 56.82' N	59° 55.80' W	285
245-1	MB-PS end	25.03.2009	10:27	8° 57.79' N	60° 6.92' W	27
Boca Grande						
246-1	CTD	25.03.2009	12:31	9° 10.01' N	59° 54.04' W	64
246-2	MUC	25.03.2009	13:00	9° 10.00' N	59° 54.00' W	64
247-1	CTD	25.03.2009	14:04	9° 6.01' N	59° 57.00' W	58
247-2	PP	25.03.2009	14:24	9° 6.01' N	59° 57.00' W	58
247-3	MUC	25.03.2009	15:33	9° 6.01' N	59° 57.00' W	59
248-1	CTD	25.03.2009	17:24	8° 58.00' N	60° 5.00' W	55
248-2	BC	25.03.2009	17:56	8° 58.00' N	60° 5.00' W	37
248-3	BC	25.03.2009	18:17	8° 58.00' N	60° 5.00' W	51
248-4	RL	25.03.2009	18:40	8° 58.00' N	60° 5.03' W	52
249-1	BUCKET	25.03.2009	19:50	8° 56,49' N	60° 12,66' W	14
250-1	CTD	25.03.2009	20:28	8° 57.38' N	60° 14.00' W	15
250-2	BC	25.03.2009	20:48	8° 57.37' N	60° 13.97' W	15
250-3	BC	25.03.2009	20:55	8° 57.37' N	60° 13.95' W	14
250-4	BC	25.03.2009	21:09	8° 57.38' N	60° 13.93' W	14
Orinoco Delta						
251-1	GKG	26.03.2009	0:08	9° 22.00' N	60° 2.98' W	68
252-1	GKG	26.03.2009	2:34	9° 43.00' N	60° 4.01' W	81
Eastern Tobago						
253-1	POZ	26.03.2009	9:39	10° 57.42' N	60° 14.72' W	332
Gulf of Paria						
254-1	MB-PS start	26.03.2009	17:57	10° 54.03' N	61° 45.97' W	113
254-1	MB-PS end	27.03.2009	13:38	10° 32.00' N	61° 52.96' W	19
255-1	GC	27.03.2009	14:24	10° 31.95' N	61° 52.84' W	19
256-1	MB-PS start	27.03.2009	14:40	10° 31.86' N	61° 52.53' W	19
256-1	MB-PS end	27.03.2009	16:00	10° 35.26' N	61° 45.85' W	47

Devices: BC: REINECK box corer, BG: grab sampler, CTD: CTD with caroussel water sampler, FP: fluorometer , GC: gravity corer , GKG: USNEL giant box corer , MB: swathsounder, PS: PARASOUND, MBG: hand-held grab sampler, MGC: pilot corer, RL: RUMOHR corer, MSN: multiclosure plankton net, MUC: multicorer , OFOS: ocean floor observation system , PC: piston corer, POZ: deep-sea observatory, PP: plankton pump, WSB: water sampler.

8 Data and Sample Storage and Availability

Station list, cruise track and bathymetric data obtained during R/V METEOR cruise M78/1 are archived at German Oceanographic Data Centre, Bundesamt für Seeschiffahrt und Hydrographie (BSH), Hamburg (http://www.seadata.bsh.de). They are available to the public. Hydroacoustic subsurface profiling data are curated at Institut für Geophysik, Universität Hamburg (Christian Hübscher). Swath mapping bathymetric data are archived at German Oceanographic Data Centre, BSH. They are available to the public upon request by January 2015. The hydrographic data obtained by CTD casts as well as chlorophyll data measured with the Fluorometer are archived at PANGAEA database (http://www.pangaea.de). The seawater oxygen analyses are documented in PANGAEA too. The descriptions of sediment cores are archived at PANGAEA together with magnetic susceptibility and light reflectivity data. The carbonate analyses of sediment core samples are also documented in PANGAEA.

Copies of the station list, cruise track and bathymetric data recorded in the Exclusive Economic Zones of Venezuela and Trinidad and Tobago were given to the scientific observers from Instituto Oceanográfico de Venezuela, and Institute of Marine Affairs, Trinidad and Tobago, as well as to the nautical observer from Dirección de Hidrografía y Navegación, Armada de la República Bolivariana de Venezuela. Copies from all materials, notes and recordings made in the Exclusive Economic Zone of Mexico were forwarded to the Secretaria de Relaciones Exteriores – Dirección General para Europa, México, D.F.

The samples taken on R/V METEOR cruise M78/1 were distributed to the following principle investigators for initial analyses. Seawater samples are analysed by Sascha Flögel, Brian Haley, and Dirk Nürnberg at IFM-GEOMAR. They will characterise the trace metal inventory describe the Orinoco river plume by εNd distribution. Zooplankton samples are analysed by Joachim Schönfeld at IFM-GEOMAR and Ralf Schiebel at the Université de Angers, France. Multinet and Plankton Pump samples are analysed by Michal Kucera, Universität Tübingen, and Joachim Schönfeld, IFM-GEOMAR. These investigations will reveal the population dynamics of planktonic foraminifera, and validate geochemical proxies for reconstructions of surface ocean temperatures and salinities. Phytoplankton samples are analysed by Luis Troccoli, Universidad de Oriente, Venezuela, to assess the phytoplankton associations. Video recordings and seabed images taken during OFOS deployments are examined by Jürgen Titschack, MARUM, Bremen. Sediment surface samples are analysed by André Freiwald, Senckenberg am Meer, Wilhelmshaven, Gregorio Martinez, Instituto Oceanográfico de Venezuela, Dirk Nürnberg and Joachim Schönfeld, IFM-GEOMAR, Julie Richey, University of South Florida, St. Petersburg, U.S.A., and Ralph Schneider, Universität Kiel, to study the sediment composition, pore water geochemistry, microfaunal inventory and trace metals, and organic biomarker for proxy calibration. Sediment cores are analysed by Andre Bahr, Universität Frankfurt, Dirk Nürnberg, IFM-GEOMAR, Ralph Schneider, Universität Kiel, and Jean Lynch-Stieglitz, Georgia Institute of Technology, Atlanta, U.S.A. They will investigate the variability of Orinoco river shedding, and the past near-surface and intermediate water mass dynamics in the Caribbean.

Sediment cores, archive cores from box cores and from Multicorer tubes are archived at Lithothek Core Repository, IFM-GEOMAR, Kiel. Archive samples and sieve residues from box cores, multicorer and grab samples are curated at Senckenberg am Meer, Wilhelmshaven. Subsampleas are available to the public upon request by January 2015.

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