MARIA S. MERIAN - Berichte

Climate induced changes of the subpolar and polar Atlantic: Water mass formation and spreading, ice coverage and sea level

PART 5

Cruise No 05, Leg 5

July 18 - August 10 2007, Reykjavik (Iceland) – Longyearbyen (Norway)

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5.1 Participants

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Longyearbyen - Longyearbyen

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IFM-GEOMAR) Leibniz-Institut für Meereswissenschaften , Kiel, Germany

NPI Norsk Polar Institut, Tromsoe / Norway

UAB Universitat Autonoma de Barcelona, Spain

Uni Bergen University of Bergen, Norway

Uni Tromsö University of Tromsö , Norway

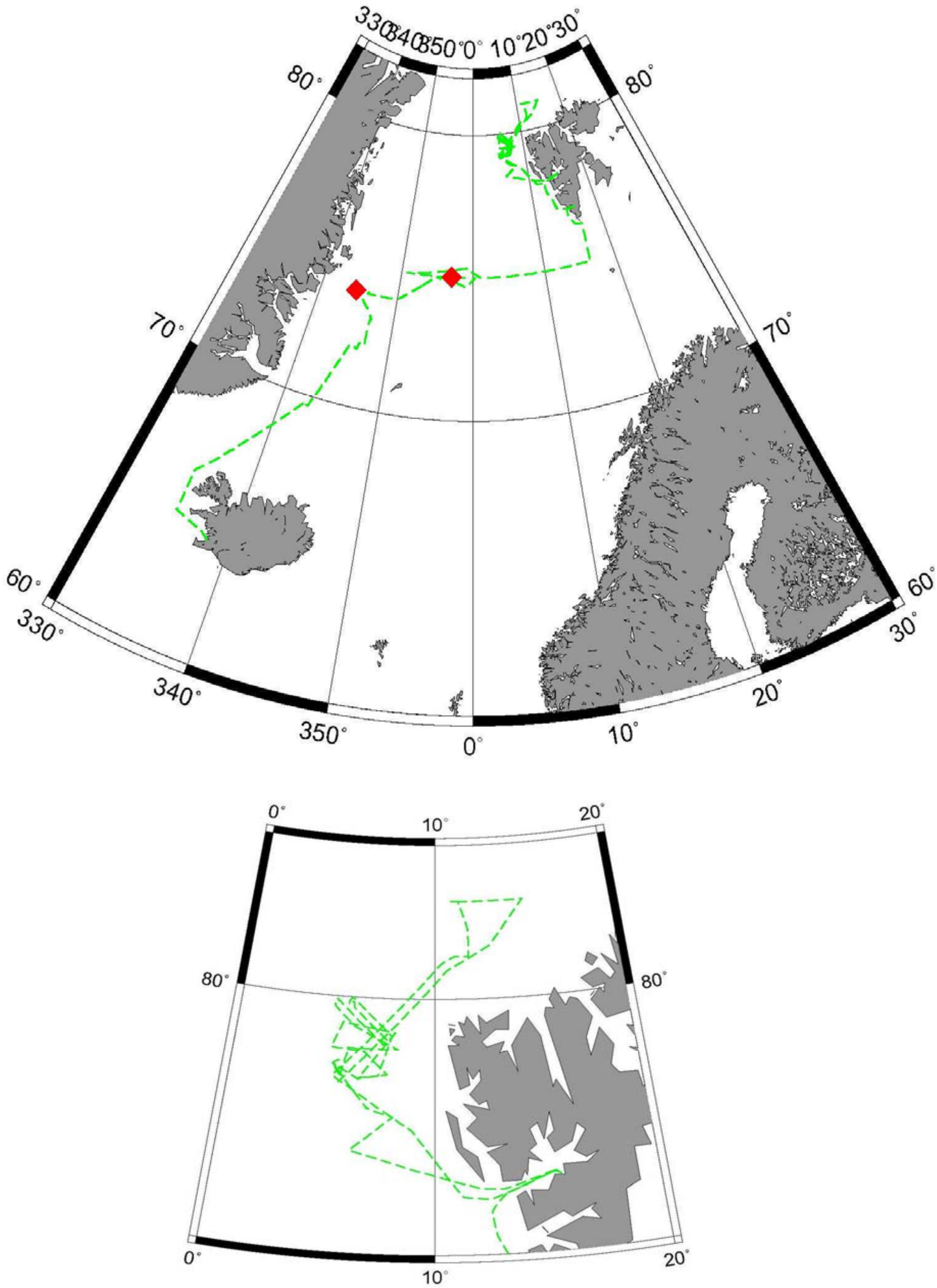


Fig. 5.1: Cruise track and mooring sites (red diamonds) a) total, b) marine geology part in detail

5.2 Research Program

The cruise leg MSM 05/05 consisted of three scientific programmes: An oceanographic programme in the Greenland Sea Gyre (G. Budéus, Alfred-Wegener-Institute for Polar and Marine Research, Bremerhaven, Germany), an oceanographic programme in the East Greenland Current (D. Quadfasel, Centre for Marine and Atmospheric Sciences of the University of Hamburg, Germany), and a marine geological one (R. Spielhagen, Leibniz Institute of Marine Sciences at the University of Kiel) at the Yermak-Plateau. Scientists and students from the Geofysisk Institutt, University of Bergen, Norway; the Universitat Autònoma de Barcelona, Spain; the University of Tromso, Norway; the Norsk Polarinstitutt, Tromso, Norway; the Scottish Association for Marine Science, Oban, United Kingdom also participated in the cruise as well as a french photographer and a german teacher of the IPY programme.

The measurements mainly contributed to the following projects
- Long term variability of the hydrographic structure, convection and transports in the Greenland Sea (LOTEVA-GS, IPY)
- Sonderforschungsbereiche 512 „Tiefdruckgebiete und Klimasystem des Nordatlantiks“
- Arctic Gateways, high latitude thermohaline circulation, sediment transport pathways and ice sheet dynamics (SEDARC, IPY)
- Holocene Variability in the Arctic Gateway (HOVAG, DFG)

The main objectives of the cruise were to
- exchange tube moorings in the East Greenland Sea
- perform a hydrographic/chemical transect across the Greenland Gyre
- exchange autonomously profiling deep sea moorings (EP/CC-Jojo) and install an autonomous underwater winch for near surface measurments (Sea-Elevator) in the Greenland Gyre
- deploy drifters for the ARGO programme
- deploy a Sea Glider for DAMOCLES in Fram Strait
- undertake a paleo multi-proxy calibration against in-situ sea surface temperature and salinity in arctic and polar domain waters
- perform Parasound tracks on the Yermak Plateau
- carry our various sediment samplings in the eastern Fram Strait and on the Yermak Plateau

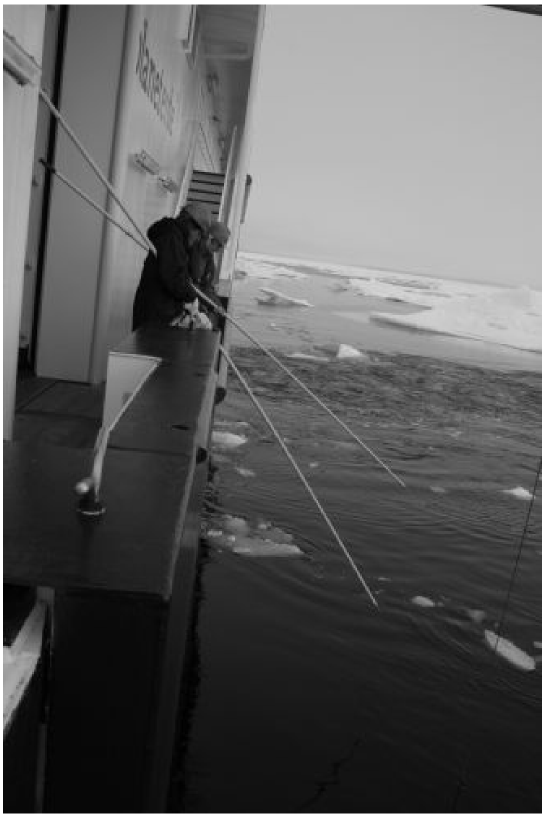
All work was carried out successfully without failures or losses with the exception of the Sea Glider deployment which was postponed.

5.3 Narrative of the Cruise

Embarkment was perfectly in time, but our departure was not. A delay of about eight hours had to be accepted because the luggage of six participants got stuck in Amsterdam and did not arrive at Reykjavik with the passengers. With only one flight per day from Amsterdam we were lucky to depart on the 18th of July with such a small delay.

First ice contact was encountered already at 4am during July, 20th at 70°N, somewhat east of Scoresby Sound, where the satellite images displayed no ice at all. This was a first warning that the attempt to enter the ice at 74°N might take more effort and time than originally expected. This was indeed the case. The recovery and redeployment of three moorings belonging to ZMAW Hamburg went well, nevertheless. The first of these moorings was exchanged on July, 21st and the last late on July, 22nd. All three were situated in dense pack ice with little space to move the ship (Foto O. Zenk). Patience was needed partially to wait for ice floes to drift off from the mooring's position or to surround large ice floes in the foggy conditions that were prevailing.

It became quickly evident that a second trip into the ice would consume too much time to be feasible and consequently the trip's schedule was modified. Instead of moving to 75°N and start a hydrographic transect there, as was originally planned, the way out of the ice at 74°N was used to perform a $CTDO_2$ transect. Again, dense pack ice reduced the ship's speed effectively. At 10°W, now in open waters, we changed from the zonal eastern direction to a heading in the direction of the central Greenland Basin, where the autonomously profiling deep sea moorings (EP/CC-Jojos) of AWI were located.



We reached these moorings while performing the hydrographic/chemical transect on July, 26th and recovered and deployed three systems successfully without any loss or damage. Position accuracies are so exact nowadays, that the foggy conditions, which were combined to the low wind situation, did not hinder the work at all. A few moments after the acoustic release of the moorings, the top buoys appeared at the surface exactly at the expected positions where they had been moored with MARIA S. MERIAN during the previous year. The update of the mooring winch to a speed of 1 m/s facilitated the mooring works greatly. The Sea-Elevator system, as the last mooring to be handled, was deployed on July, 28th.

The zonal hydrographic/chemical transect was then continued along 75°N heading eastward. Finally, the sea showed us that it can be rough when we were sailing close to Bear Island. After two weeks of calm winds, wind force 8 and up to 9 in gales hit us during the last $CTDO_2$ stations on the large zonal transect at 75°N. The ship behaved well, and all stations could be done. Overall results are excellent. We finished the transect close to midnight on August, 1st.

On our way to Longyearbyen we planned to deploy the Sea Glider. Despite considerable efforts, it was not possible to deploy this instrument due to software and hardware problems. This was the first serious failure we experienced during our cruise. The performance control of this fish is done remotely via Iridium from Seattle, USA, and the search for failures was hindered by the slow and individual email transfers between the Seattle lab and MARIA S. MERIAN. The glider was brought home and will be serviced on land.

Our 'touch down' at Longyearbyen on August, 3rd, necessary to exchange scientific personell, was scheduled to last only one or two hours, but took some more time as a diver had to inspect the propellers. This time was appreciated much by the new scientific crew members. The geologists had to put up their equipment under great time stress, as the sailing time to their investigation sites was extremely short. The small delay took off a bit of this stress. We had to deviate from our original plans which included sampling in regions, where 100% ice cover inhibited our visit of these areas. During the attempt to reach them, we certainly reached the northernmost point MARIA S. MERIAN has approached up to now: We stayed only three miles south of 81°N. However, we gave up quickly and switched over to an alternative sampling scheme in the ice free waters north of Spitzbergen. Here, a variety of Parasound profiles was performed and sediment samples were taken using the gravity corer, giant box corer, and kastenlot. Disembarkation was on Friday, August, 10th in Longyearbyen.

5.4 Preliminary Results

5.4.1 Technical Information

5.4.1.1 CTD system

105 CTD casts were completed on this cruise using Sea-Bird equipment. Together with a 12 bottle frame it was configured in the following way:

SBE 9/11 plus CTD, AWI
SBE 32, 12 position carousel 12 x 2.5 L "Niskin" bottles

The configuration of AWI CTD was:
SBE 9+ underwater unit
SBE 3 temperature primary sensor s/n 1491, calibrated 28-nov-2006
SBE 3 temperature secondary sensor s/n 1338, calibrated 28-nov-2006
SBE 4 Conductivity sensor primary, 1198, calibrated 28-nov-2006
SBE 4 Conductivity sensor secondary, 1199, calibrated 28-nov-2006
SBE 43 Oxygen sensor SN: 48, calibrated 09-jan-2007
Digiquartz temperature compensated pressure sensor s/n 53962
SBE 5T submersible pump
Benthos Altimeter
SBE 32 carousel, 12 position
SBE 11+ deck unit
Casts were initiated and terminated on deck. Between 0 and 4 water samples were taken per cast for calibration of the conductivity sensor at carefully selected locations where in situ calibration is allowed. It has not yet been decided which sensor set has to be assigned as the valid set.

5.4.1.2 ADCP

The Acoustic Doppler Current Profiler (ADCP) had been running almost constantly during the cruise without any problems. The instrument, which has been manufactured by RD Instruments (Poway, Ca., USA), has a working frequency of 75 kHz, ping rate of
0.7 Hz, and is specified for a maximal ship speed of 22 kn.

5.4.1.3 Thermosalinograph

The Thermosalinograph is permanently flushed by sea water. The manufacturers are Sea & Sun Technology GmbH (salinity sensor, type: CT 48) and Isotech (temperature sensor, type: PT100-1509). These sensors have a working range of 0-65 mS/cm and –3° C to 36° C.

5.4.1.4 Data Logging

Numerous sensors, which collect scientific relevant data at different locations on the ship, send their data via the ship's network into a central data base with a frequency of 1 Hz. Furthermore, also ship specific data like cruise direction and speed over ground are integrated into the data base. In total, roughly 250 single sensors contribute to the date base, ranging from meteorological data, like air temperature, wind speed and direction, over oceanographic data, like surface water temperature and salinity, to water column thickness data, like echo sounding. The actual hardware hosting the data base is a pair of two SUNFire V.210-Server, which are configured as a fail-over pair working in loadsharing operation.

The data of the data base can be extracted easily through a web interface from all computers attached to the ships network from all cabins or laboratories. The result of guided data base queries are stored as ASCII text files, which can be downloaded after the query has been proceeded. The here described data base service is only a small part of an integrated data collecting, accessing, and storing system, which is called DavisShip (Datensammel-, -verteilungs- und speichersystem).

5.4.2 Scientific programme - preliminary results

5.4.2.1 Long term variability of the hydrographic structure, convection and transports in the Greenland Sea (LOTEVA-GS)

G. Budéus

The Greenland Sea is one of the few open ocean sites worldwide where waters which have recently been in contact with the atmosphere can sink to great depth or to the ocean bottom. These sites, including the Weddell Sea, the Labrador Sea, and the European Mediterranean, supply most of the deep waters of the world ocean and receive increasing interest with the focus of earth sciences on climate changes because of their role with respect to the global oceanic conveyor belt.

Physical processes in the Polar Oceans receive increased attention also because of their high sensibility and positive feedback mechanisms against climatic changes. This includes the hydrographic development in the Greenland Sea, where parent end members (in the TS-space) of a number of Arctic water masses are found. Oceanic field work in the Greenland Sea has long been conducted only sporadically because the dynamic nature of changes in the Arctic had not been recognized. Since the late 80s, field observations have been performed on a more regular basis (GSP, EU-projects ESOP I and II, CONVECTION, TRACTOR) revealing unexpected results with respect to most initial assumptions.

The classical view had to be altered with respect to the regularity of the ventilation events in the late eighties, when it became evident that deep reaching convection did not occur since the early eighties. Later, namely during the late nineties, also the concept of a vertically homogeneous deep water dome reaching close to the surface had to be skipped because observations showed a prevailing density stratification at intermediate depth. The vertical structure is now dominated by an intermediate temperature maximum which is combined with an enhanced salinity and density gradient. Observations show that this density gradient is not static but is slowly displaced vertically. It was found at about 900 m in 1993 and descended to roughly 1800 m in 2005. This interface between the upper and lower layer of the two-parted structure limits convection depths by the increased stability associated with the enhanced density/salinity gradient.

With this situation, the main modification processes in the upper layer are winter convection, succeeded by lateral exchange for which the most important constituents are the import of Atlantic Waters, Return Atlantic Waters, and Polar Waters. These inputs are then distributed vertically during the next winter convection phase.

It is clear from this cycle, that a correct determination of winter convection depths is essential in order to attribute observed modifications to the related process. Often used simple consideration like homogeneous profiles or input of colder waters do not suffice for this determination. A criteria catalogue has to be used (see Ronski et al., 2006). Changes in the deep waters can be explained by the combined action of lateral exchange (responsible for a salinity increase due to the input of deep Arctic Waters which are introduced from the rims surroundig the Greenland Basin) and vertical processes. It is proposed that a vertical shift of the water column is the main cause for the deep water changes in temperature.

Winter convection in the 'background', i.e. in the prevailing hydrographic conditions of the basin, is contrasted by convection within so called Submesoscale Coherent Vortices (SCVs). These are remarkably small eddies with diameters of only about 20 km, so that their size is adverse to their easy detection, but they severely spoil averaged profiles when accidentally met by a station or two. First indications of their occurance stem from drifter data, floating in about 1000 m depth and showing long periods of constant speed rotations (Gascard, 2002). Subsequent CTD investigations showed their hydrographic structure which departs largely from the background (Wadhams 2002, Budéus 2004). The interiour is outstandingly homogeneous with respect to all measured physical, biological and chemical properties in the upper part (i.e.: above the pycnocline) of the eddy (Budéus 2004, Wadhams 2004). This part extends to depths considerably below the level of the pycnocline in the background. Typical recent depth levels of the pycnocline are 1800 m for the background versus 2700 m for the SCV.

Due to the large spatial gradients and relatively small spatial scales involved (Rossby radius about 20 km) it is indispensable to perform measurements with a small station spacing. Otherwise spatial and temporal differences cannot be distinguished and any derived trend is most likely heavily biased. According to this, the transects are performed with a station spacing of 10 natical miles or less.

Zonal transect at 75ºN

The CTD data have to be finally calibrated for a precise evaluation. Due to the high primary data quality, preliminary conclusions can be stated already to date. The distribution of temperature is shown below, complemented by the oxygen distribution (uncorrected sensor values).

To start with the oxygen distribution, there are three features which are immediately evident. The first is the slow sensor time drift which is evident from the gradient in the deep sea, which is artificial (note station schedule from centre to west, then from centre to east). Chemical analysis will be used to correct for the drift. As it is smooth and shows no jumps this poses no problem. The second is the
pool of waters with high oxygen contents between 1ºE and, though subducted, 7ºW, which might be indicative for past winter convection. This has to be verified yet. The third, and most important, feature is the two layer structure with an efficient vertical isolation of the deeper layer (below 2000 m). In opposite to the classical dome structure, the interface between the upper and lower layer shows a depression to date.

The temperature distribution shows no evidence of winter convection. The waters in the upper layer (down to about 2000 m) show increasing temperatures to such a degree, that the persistent temperature maximum at the interface between the upper and the lower layer cannot be discerned in the contour plot. This is no sign of a lacking winter convection, as this may result in an input of warmer waters to the ventilated water volumes.

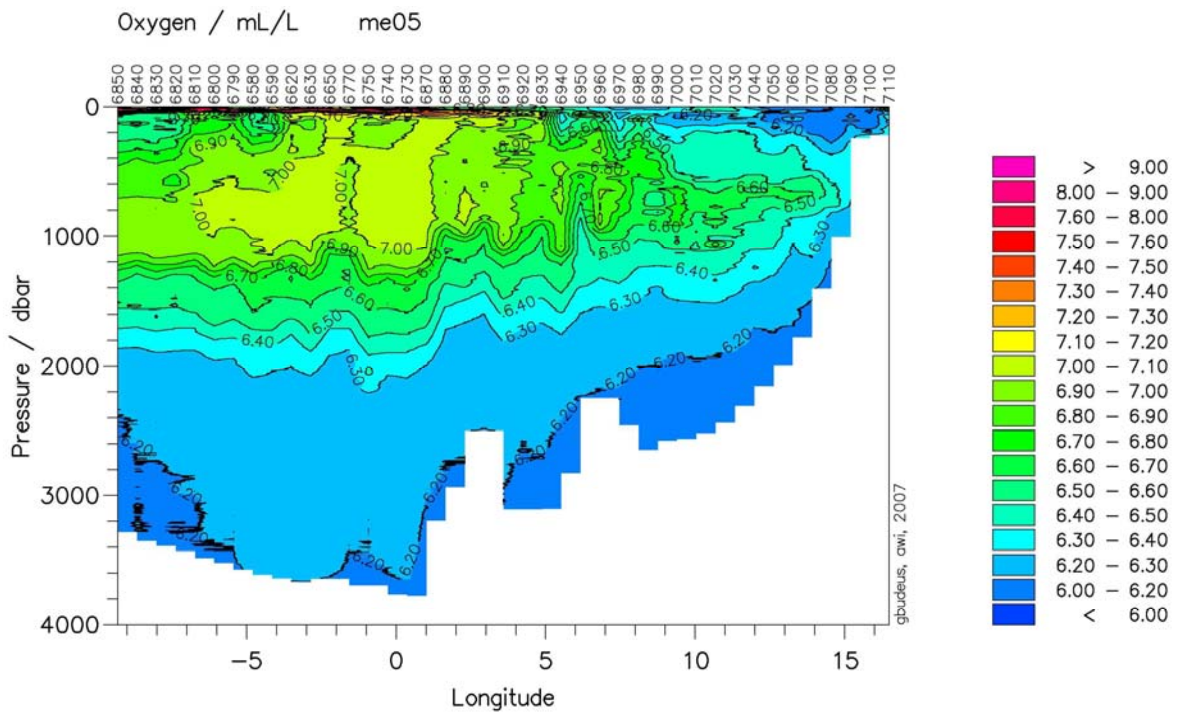


Fig. 5.2: a) Oxygen content (raw data) and b) potential temperature on the zonal transect at 75ºN

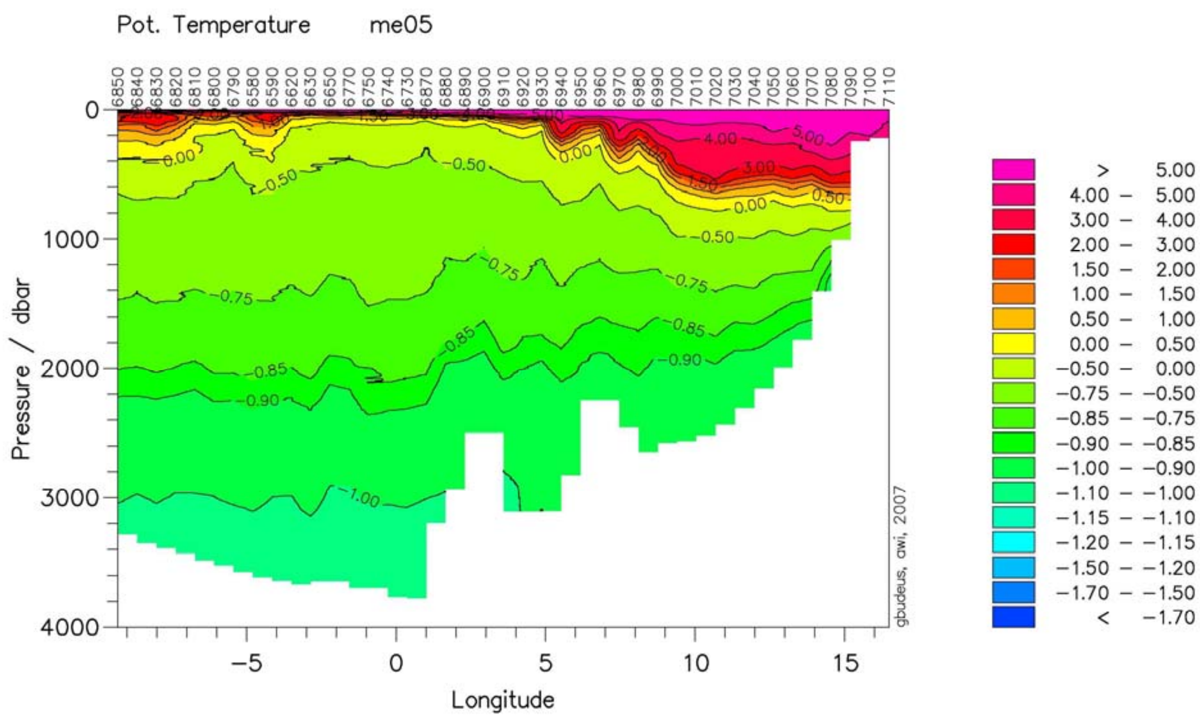
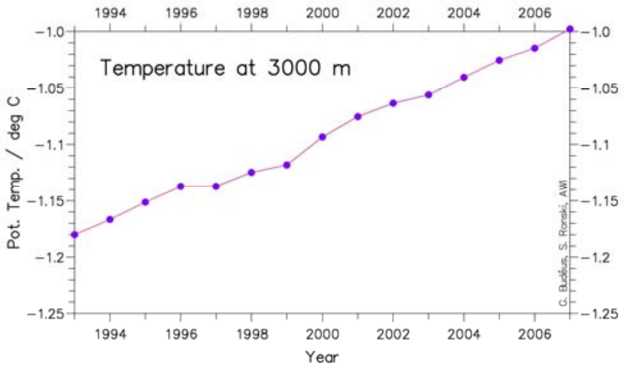


Fig. 2 continued



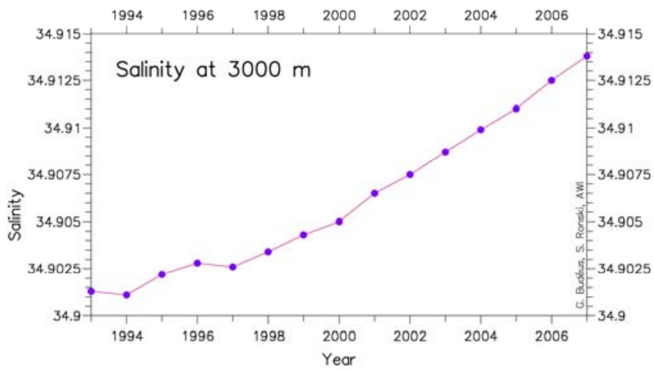


Fig. 5.3: Long term salinity and temperature development at 3000 m

The long term increase of temperature and salinity continues to date. These trends as well as the properties of the Atlantic Water domain and the East Greenland Current area contribute annually to the ICES ocean climate report. Also included there are the convection depths, which are indicated in 2007 by stability considerations. A mixed layer type convection was effective, which seems typical if low amounts of Polar Waters are present in the area.

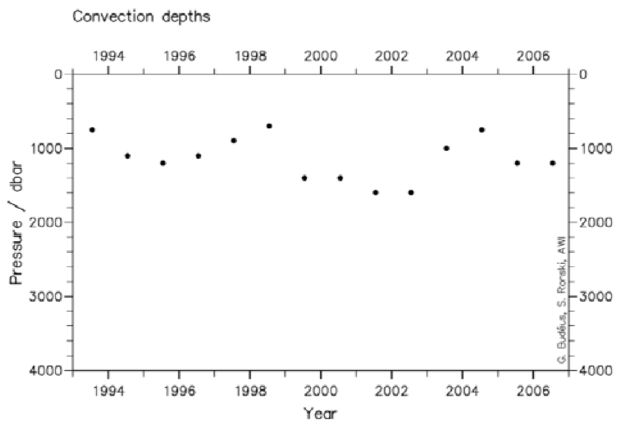


Fig. 5.4: Long term time series of winter convection depths

An issue of increasing interest in physical oceanography is representativeness of field data, since assimilation techniques are used more routinely to control numerical models. The question how close a model result should resemble a single field datum or a set of data has to be decided in order to write the model code. But also within the scope of sea going physical oceanography itself the issue is important. As long as general large scale phenomena are investigated, as e.g. along which boundary the Atlantic Water (AW) enters the Arctic, there is little concern about the issue. But as soon as mean values of a region are requested, water mass censi are aspired or budgets like fresh water or heat contents are needed, the representativeness of collected data must be judged. More often than not the problem is ignored because it seems that little can be done to solve it. Generally it is implicitely assumed that station data are representative for a volume which covers half the distance to the next data point. The distances between stations are set according to tradition, previous cruises, time constraints et cetera but rarely according to such abstract principles like the sampling theorem or statistical considerations. Most of the time there is indeed no other choice, as the scales of a parameter structure have to be known beforehand if such principles shall be observed.

We attempt to gain a certain level of insight into local variability of the Greenland Gyre region by performing a multitude of stations where usually just one or two are assumed to be representative, and by investigating parameter ranges and standard deviations, exemplarily shown here for temperature.

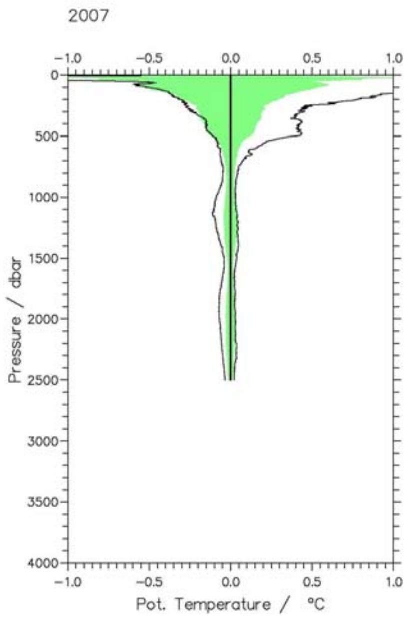


Fig. 5.5: Range and standard deviation of temperature profiles between 7°W and 3°E (normalized to the mean)

The normalized profiles show largest ranges close to the surface which reduce towards the bottom. Neither ranges nor standard deviations do so in a steady fashion. Dispersion extremes occur at about 1200 m (negative) and 2000 m (negative), and standard deviation has a local minima at 1000 m but increases again below this level and shows a second minimum at 1600 m. Standard deviations and ranges exceeding 0.5 K occur in the upper few hundred meters, and ranges smaller than 0.1 K are hardly observed anywhere within the upper 1200 m. At 2400 m, what is below the interface between upper and lower large scale layer, and thus in the isolalted deeper layer, ranges still exceed measurement accuracies (of 1 mK) by a factor of 40.

It is evident that it is extremely difficult to arrive at a reliable budget from field measurements even in this presumably homogeneous part of the global ocean. In reality, the spatial variability in the discussed region amounts to a magnitude which is similar to the seasonal signal. As the involved spatial scales are roughly estimated to 15 to 30 km, a single hydrographic profile is representative for a region of this order.

In order to exemplarily assess the sensitivity of the heat content of a water column against the temperature range, we use a simple calculation with a conservatively small value of 0.2 K for the difference between the maximum and minimum profile over a depth range of 1000 m. The above figure shows that this difference is usually larger. The deltaQ from this scenario amounts to 0.8 10**9 J. When distributed over the time span of one month, a heat flux of 309 W/m**2 across the surface would be needed to accomplish this difference. If distributed over a year, the average heat flux would be roughly 1/10 of this value and thus still be of the order of the annual mean in the Greenland gyre. This result illustrates that great care is needed to assure that measured profile sets represent the mean hydrographic state before budget considerations can be executed reasonably. Data sets of the central gyre which show a smaller range than presented in Fig. 5 certainly miss important information.

EP/CC Moorings

The autonomously profiling EP/CC moorings are equipped with modified SBE-16 CTDs with Digiquartz pressure sensors. They deliver complete profiles every other day, traveling between the parking position at roughly 100 m and the ocean bottom at 3700m. Vertical speed is about 1 m/s during the downcast and much less during the upcast. Measurements are recorded during the downcast only. The demand for profiling instruments in the ocean has increased in recognition that the description of oceanic processses based on only a few instruments located at fixed depths in the water column is not adequate to most problems investigated today. While some 15 years ago there were few attempts to construct and utilize autonomous profiling instruments, there exists a large variety of designs today. Applications range from infrequently profiling drifters (e.g. ARGOS floats) and futile attempts to combine these with mooring ropes or tethered platforms to dedicated instruments intended originally for moorings. Deep sea applications frequently dictate a particular design. Small depth ranges can be covered by designs which incorporate a winch or which are driven by near surface forcings (like the Seahorse moored profiler). Profilers for deep sea applications make use of bouyance changes or propell themselves along the mooring line (WHOI/McLane moored profiler). All solutions have different advantages and shortcomings, but when thinking in terms of many profiles (typically 200-400) to great depths (typically 3000 to 6000 m) a problem common to all designs is energy consumption. The mutual tradeoffs are immediately apparent, as, e.g., more energy carried along inside the profiling vehicle implies greater vehicle volumes in order to balance the additional weight, and this in turn implies smaller velocities for the same applied force, leading to higher energy consumption. We use here a design for an autonomous deep sea profiler which is intended for many fast and deep casts and departs substantially from previous solutions with respect to the energy management. It is designed and built by AWI.

One of the particular properties of the instrument is its high velocity during the downcast which is achieved by the smallest cross section area possible. This dimension is determined mainly by the SBE-16 diameter of 99mm. When thinking about a design for an autonomous deep sea profiler, we considered it somewhat impractical to store the whole energy needed for all of the up- and downcasts of the profiler within the vehicle and carry it along on the many profiles up and down. A considerable amount of additional energy is needed when doing so. The weight of the batteries (as the common storing means of energy) implies an increase of required buoyancy through a bigger volume, which in turn increases the flow resistance. With a given force to drive the movement, this reduces the velocity of the vehicle and results therefore in a a longer profiling time to span the water column which increases the necessary battery power. To alternatively remain at the same speed while increasing the flow resistance also requires more battery power. Consequently, much care has been applied to the design to realize a slim, low drag, and low mass device.

It is indeed not really necessary to carry more energy along with the vehicle than is needed for one single profile. The only complication in comparison to a self contained internally powered design is the transfer of energy from an energy storage unit to the profiling vehicle. While this problem is not easily solved under subsurface ocean conditions as long as one thinks in terms of electricity, a mechanical solution provides little difficulty. In addition, gravity serves as a highly reliable driving means.

Therefore, a vehicle/control unit-pair has been constructed which consists of a bouyant vehicle that is ballasted by a weight which is supplied by the control unit, one weight for each profiling cast. With this weight, the downcast is performed with the potential energy of the weight providing the driving means. At the bottom, the weight is detached from the vehicle and the latter moves back to the surface, driven by its own buoyancy. Back at the control unit, the vehicle waits for the next supply of a weight which is dispensed according to the chosen time schedule. It is immediately apparent that this method is particularly well suited for deep-sea applications since the size of the driving weights needs no alteration for increasingly deeper dives because the available energy increases automatically with greater depths.

With this design, only one electrical consumer exists in the vehicle, namely the measuring instrument. Its total electrical consumption for one profile is directly dependent on the profile duration and hence on the profiling speed. A high profiling speed is therefore desirable in order to maximize the number of possible profiles for a given on-board battery. As measurements are taken only during the downcast, the use of mechanical force available for driving the vehicle can be optimized. Specifically, a larger force can be used for the downcast than for the upcast (which will be correspondingly slower). When thinking of daily profiles with a time period of about 1.5 h for a downcast to 4000 m, 22.5 hours would in principal be available for the upcast. For deep sea applications, it is very advantageous to adjust the vehicle's overall compressibility to compensate for the in situ density stratification in the ocean, and consequently this has been done.

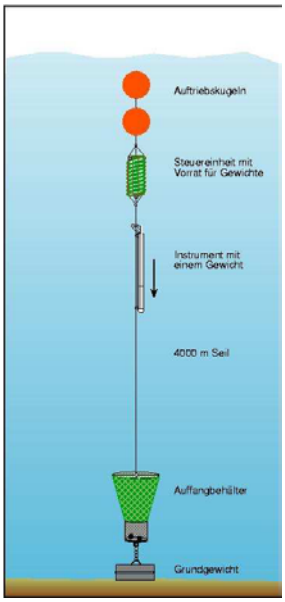


Fig. 5.6: The EP/CC-Jojo principal configuration

The instrument works with a 1 Hz sampling rate. With 1 dbar bins, the noise is larger than for the pumped ship based CTDs but overall accuracy is high, in part due to the precision pressure sensor. It has been recognised that drifts of all sensors are extremely small, partly due to the quality of the instrument, partly due to the parking position below the euphotic zone.

The time series contain detailed information about the prevailing processes which modify the hydrographic situation. The actual data set has to be fully processed and corrected yet. A remarkable signal is the disappearance of the cold water pool above the interface between the upper and lower main layer which is illustrated here by the temperature rise at 1050m in Fig. 7. Each dot marks a full depth profile. The development to higher temperatures is an outstandingly smooth process which shows particular events only during the winter season (i.e. warming by mixed layer type of winter convection).

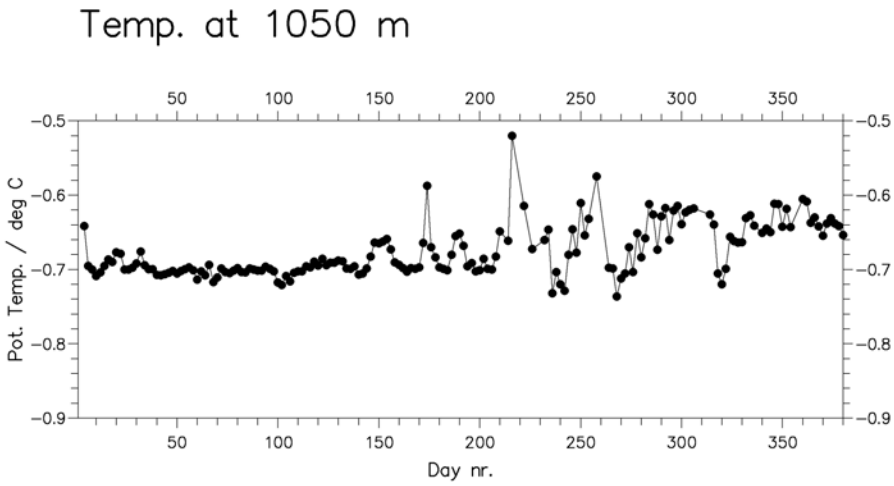


Fig. 5.7: Temperature development from the EP/CC mooring at a level of 1050 m

Drifters

Five drifters have been deployed which contribute to the ARGO programme. The drifters reside at about 1000 m for 10 days, then they perform a CTD profile between 2000 m and the surface, and finally the sampled data are transferred via statellite connection to CORIOLIS in France. As individual instruments they are well suited to identify the atmospheric influence on a water parcel, as they (ideally) track a water parcel in a Lagrangian manner.

5.4.2.2 Paleo multi-proxies

A. Rosell-Melé

The main aim of the sample collection was to obtain suspended matter and plankton samples to derive information to undertake a multi-proxy calibration against in-situ sea surface temperature and salinity in arctic and polar domain waters, and assess their transformation during sedimentation. The proxies to investigate are from biomarkers (UK37 and TEX86), coccoliths and foraminifera trace metals (Mg/Ca).

Water samples were collected using two procedures:
a) pumped through (centrifugal pump) the clean seawater system from the ocean surface, whilst the ship was underway between stations. It is retrieved from approximately 6.5 m below the sea surface.
b) using Niskin PVC bottles in the rosette attached to the CTD, fired at certain depths in the water column.

Water from Niskin bottles, and from the ship's clean seawater system for some stations, was then filtered to determine the composition and quantity of coccoliths (acetate cellulose filter) or biomarkers (pre-cleaned GF/F glass fibre filter), employing a filtration ramp and vacuum pump ("off-line" filtration).
Water from the ship clean seawater system, for all stations and at regular time intervals, was filtered "on-line" as it was passed through filter holders (with pre-cleaned GF/F glass fibre filter) connected to the tap of the laboratory clean seawater supply. In this case no vacuum pump was

employed.
Filters for biomarker analysis were stored in the freezer.
Filters for coccoliths analysis, after filtration were rinsed with distilled water buffered with ammonia, dried in an oven at 40 to 60°C for at least one hour, and stored in the freezer.
All samples are stored at the Autonomous University of Barcelona.

Details on the samples filtrated are provided in the table under section 10.

5.4.2.3 Marine geological work

R. Spielhagen

Arctic seas contain geological records that are critical to our understanding of global climatic change and its linkages to global thermohaline circulation. At timescales of millennia and longer, the sedimentary archives found in Arctic seas provide evidence fundamental to our understanding of Arctic palaeoclimate, and hence can inform contemporary studies of high latitude cryospheric, atmospheric and oceanic processes. Contourites are little studied on Arctic continental margins. They are an extremely important but neglected group of deep-water sediments. Being the result of persistent, alongslope thermohaline circulation their study and interpretation is vital to further our understanding of bottom-water circulation and ocean-climate link, with huge potential for providing high-resolution records of the influences of climate change in the deep-sea. Fram Strait forms the only deep oceanic gateway between the Arctic and the World Ocean. This study aims to utilize contouritic sediments as proxies for THC variability in a climatically sensitive, high latitude oceanic gateway setting which includes a region of known deep-water formation of global significance.
The goal of the marine geological work on leg MSM05/5b was the recovery of long, large-volume sediment cores from selected areas on the northwestern continental slope off Svalbard and on the Yermak Plateau, from where high sedimentation rates were known or could be expected. From analyses of the cores by sedimentological, micro palaeoontological and geochemical methods the variability of the ice margin and the advection of Atlantic Water during the last ca. 10 000 years (Holocene) will be reconstructed.

Site survey and coring site selection

Transects for site survey and coring (Fig. 7) were selected based on detailed bathymetric information available from nautical charts. Under consideration of the sediment transport capacity of the northward slope current along the Western Svalbard continental margins, areas had been selected on the leeward side of westward protruding morphological noses. One such site (MSM05-712) had already been visited, surveyed, and successfully sampled during the "Warmpast" expedition of RV "Jan Mayen" (Univ. Tromsø) in October 2006. Site selection on the other transects was carried out based on the results from previous surveys with the onboard parametric sediment echosounder system PARASOUND. The system provides digital, high resolution information on the sediment coverage and the internal structure of the sediments. This can be used to interpret the sedimentary environments and their changes in space and time. During MSM05/5b, the aim of PARASOUND profiling was to select coring locations for gravity cores, box cores, and kastenlot cores. In order to obtain bottom and sub-bottom reflection patterns, the echosounder uses the so-called parametric effect: PARASOUND radiates two primary frequencies in the range of 18 to 23.5 kHz that generate a secondary pulse of lower frequency which provides the signal. This parametric frequency is the difference frequency of the two primary waves transmitted. The parametric frequency can be chosen between 2.5 and 5.5

kHz and is adjusted by varying the primary frequencies. Due to its low secondary frequency and a small emitting angle of 2 degrees, PARASOUND achieves high resolution of the sediment structures and penetrating depths of up to 70 meters with a possible vertical resolution of ca. 30 cm.

Sediment coring and sampling

A total of 6 box cores were retrieved during the MSM5/5 expedition. All box cores were described and sampled immediately (see annex). Sampling included 4 surface samples, 3 tubes and 3 liner boxes. Surface samples were carefully taken from the upper 0.5 cm, and 3 of them were preserved and stained in ethanol with Rose Bengal (2 g/l). One surface sample was frozen. The 3 tubes were gently pushed into the surface and stored cold. The liner boxes were pushed into the front of the box corer. The large box (12 cm wide) was wrapped up and stored cold. The two small boxes (7.5 cm wide) were immediately subsampled.
Two kastenlot cores (9.50 m and 9.53 m long) were taken (Fig. 8). They were opened on board and sampled by 4 parallel liner boxes (two boxes 12 cm wide, two boxes 7.5 cm wide) along the core. From each set, one narrow box was frozed; the other boxes were stored cold. In addition to these archive boxes, samples were taken for various scientific purposes by the working groups from the participating institutions. Due to time limitations, only brief sediment descriptions could be performed (see annex).
Five gravity cores were obtained during the cruise, recovering between 5.03 and 7.21 cm of sediment (Fig. 8). The cores were cut into 1 m long segments and stored cold. To allow core logging in the home laboratory, the cores were not opened on board.

Sediment characteristics

Sediment surfaces consisted of brown silty clays often containing dropstones and evidence of benthic life (brittle stars, bivalves, polychaet tubes). Below this few centemeters thick brown, oxidized surface sediment layer, the sediment color changed to a homogeneous olive gray. Evidence for bioturbation comes from the sediment structure which shows abundant burrowing. The lower parts of the kastenlot cores were dark grayish. Below ca. 2 m sediment depth, the deposits often contained black spots of monosulphides. All the recovered sediments were fine-grained (clay to silty clay), except 3 zones below 4.5 m in kastenlot core MSM05-723-2 which held common to abundant dropstones. From the sediment characteristics it can be concluded that bulk accumulation rates at the core sites were relatively high. Most probably the long kastenlot cores did not penetrate deposits from the penultimate glaciation and are thus <130,000 years old.

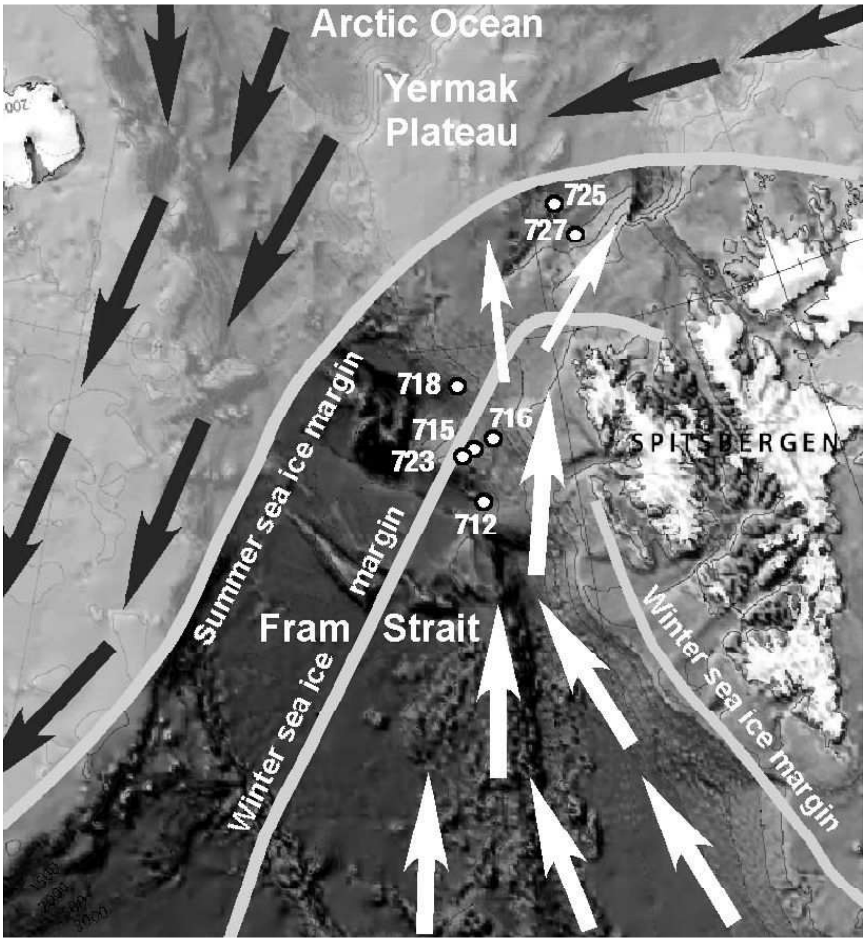


Fig. 5.7: Bathymetric map of the Fram Strait. White arrows show the advection of Atlantic Water; gray arrows show the outflow of Arctic surface water. Labelled dots mark coring locations during leg MSM05/5b.

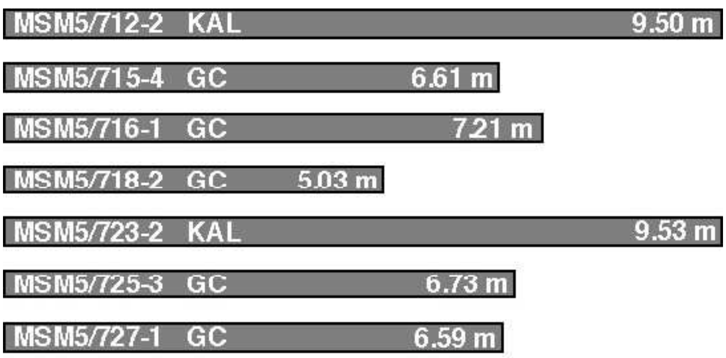


Fig. 5.8: Sediment recovery of long cores during leg MSM05/5b. KAL = kastenlot core; GC = gravity core.

5.4.3. Moorings

Recovery

#Deploym.	Recov.	Descri.	Depth	Lat	Lon
Jul 2006	Jul 2007	AWI-J026 (CTD)	3703m	74°50 N	2°30 W
Jul 2006	Jul 2007	AWI-J027 (CTD)	3683m	75°05 N	3°27 W
Jul 2006	Jul 2007	AWI-J028 (CTD)	3580m	74°55 N	4°37 W
Jul 2006	Jul 2007	HH (ADCP)	201m	74° 02.60 N	015° 38.42 W
Jul 2006	Jul 2007	HH-Rohr27 (CTD)	441m	74° 01.64 N	015° 30.86 W
Jul 2006	Jul 2007	HH-Rohr26 (CTD)	225m	73° 59.98 N	015° 59.03 W

Deployment

27. Jul 2007	Jul 2008	AWI-J029 (CTD)	3703m	74°50 N	2°30 W
27. Jul 2007	Jul 2008	AWI-J030 (CTD)	3683m	75°05 N	3°27 W
26. Jul 2007	Jul 2008	AWI-J031 (CTD)	3580m	74°55 N	4°37 W
28. Jul 2007	Jul 2008	AWI-JP31 (CTD)	3616m	74°56 N	4°37 W
22. Jul 2006	Jul 2007	HH (ADCP)	201m	74° 00.26 N	015° 41.05 W
21. Jul 2006	Jul 2007	HH-Rohr29 (CTD)	441m	74° 01.64 N	015° 30.86 W
22. Jul 2006	Jul 2007	HH-Rohr28 (CTD)	225m	73° 59.98 N	015° 59.03 W

CTD: Conductivity, temperature, pressure measurement, ADCP Acoustic Doppler Current Profiler
Approximate positions (exact positions will be communicated after deployment)

5.4.4 Drifter deployments

Date	S/N	Position Lat	Lon
27.7.2007	3371	75°00 N	2°18 W
27.7.2007	3374	74°40 N	1°00 W
27.7.2007	3379	75°00 N	0°18 E
28.7.2007	3372	75°00 N	1°00 W
30.7.2007	3379	75°20 N	1°00 W

5.5 List of Stations

Station	Date	Time	PositionLat	PositionLon	Gear	Action
MSM5/621-1	7.20.2007	13:46	71°20,28' N	15°27,87' W	CTD	surface
MSM5/621-2	7.20.2007	14:26	71°20,28' N	15°27,88' W	CTD	surface
MSM5/621-3	7.20.2007	15:02	71°20,28' N	15°27,87' W	CTD	surface
MSM5/622-1	7.21.2007	20:58	74°0,76' N	15°29,98' W	Mooring recov. Tube27	action
MSM5/623-1	7.21.2007	23:24	74°1,61' N	15°30,62' W	Mooring depl. Tube32	slipped
MSM5/624-1	7.22.2007	8:07	73°59,90' N	15°59,28' W	CTD	surface
MSM5/624-2	7.22.2007	9:45	73°59,80' N	15°58,46' W	Mooring recov. Tube26	on deck
MSM5/625-1	7.22.2007	11:15	73°59,67' N	15°59,01' W	Mooring depl. Tube31	slipped
MSM5/626-1	7.22.2007	11:26	73°59,53' N	15°58,78' W	CTD	surface

MSM5/627-1	7.22.2007	19:24	74°2,24' N	15°38,82' W	Mooring recov. ADCP	at surface
MSM5/628-1	7.22.2007	20:15	74°1,60' N	15°39,58' W	CTD	surface
MSM5/629-1	7.22.2007	21:15	74°0,85' N	15°41,01' W	CTD	surface
MSM5/630-1	7.22.2007	22:00	74°0,26' N	15°41,05' W	Bottom depl. ADCP	Deployment finished
MSM5/631-1	7.23.2007	1:27	73°58,55' N	15°15,53' W	CTD	surface
MSM5/632-1	7.23.2007	4:44	74°0,08' N	14°58,41' W	CTD	surface
MSM5/633-1	7.23.2007	8:12	73°59,31' N	14°44,76' W	CTD	surface
MSM5/634-1	7.23.2007	11:24	73°59,64' N	14°29,80' W	CTD	surface
MSM5/635-1	7.23.2007	14:36	73°59,94' N	14°14,41' W	CTD	surface
MSM5/636-1	7.23.2007	17:02	74°0,00' N	13°59,36' W	CTD	surface
MSM5/637-1	7.23.2007	20:24	74°0,25' N	13°45,10' W	CTD	surface
MSM5/638-1	7.23.2007	21:41	73°58,91' N	13°36,22' W	CTD	surface
MSM5/639-1	7.24.2007	1:06	74°0,16' N	13°15,58' W	CTD	surface
MSM5/640-1	7.24.2007	3:54	74°0,00' N	12°59,95' W	CTD	surface
MSM5/641-1	7.24.2007	6:28	74°0,01' N	12°44,83' W	CTD	surface
MSM5/642-1	7.24.2007	8:57	74°0,09' N	12°29,85' W	CTD	surface
MSM5/643-1	7.24.2007	11:28	73°59,51' N	12°15,47' W	CTD	surface
MSM5/644-1	7.24.2007	13:44	74°0,00' N	11°59,99' W	CTD	surface
MSM5/645-1	7.24.2007	16:14	73°59,96' N	11°29,75' W	CTD	surface
MSM5/646-1	7.24.2007	19:12	74°0,00' N	10°59,99' W	CTD	surface
MSM5/647-1	7.24.2007	21:52	74°0,02' N	10°29,66' W	CTD	surface
MSM5/648-1	7.25.2007	0:53	74°0,00' N	10°0,05' W	CTD	surface
MSM5/649-1	7.25.2007	3:47	74°6,02' N	9°31,44' W	CTD	surface
MSM5/650-1	7.25.2007	6:49	74°12,02' N	9°2,20' W	CTD	surface
MSM5/651-1	7.25.2007	9:49	74°17,96' N	8°32,80' W	CTD	surface
MSM5/652-1	7.25.2007	12:43	74°23,89' N	8°3,62' W	CTD	surface
MSM5/653-1	7.25.2007	15:30	74°29,88' N	7°33,92' W	CTD	surface
MSM5/654-1	7.25.2007	18:30	74°35,83' N	7°4,20' W	CTD	surface
MSM5/655-1	7.25.2007	21:31	74°41,85' N	6°34,14' W	CTD	surface
MSM5/656-1	7.26.2007	0:29	74°47,70' N	6°4,12' W	CTD	surface
MSM5/657-1	7.26.2007	3:28	74°53,62' N	5°33,60' W	CTD	surface
MSM5/658-1	7.26.2007	6:53	74°59,99' N	4°46,90' W	CTD	surface
MSM5/659-1	7.26.2007	10:28	74°59,96' N	4°8,01' W	CTD	surface
MSM5/660-1	7.26.2007	13:34	74°55,10' N	4°37,45' W	Mooring recov. AWI-J028	start heaving on deck
MSM5/661-1	7.26.2007	17:23	74°55,03' N	4°36,99' W	Mooring depl. AWI-J031	released
MSM5/662-1	7.26.2007	18:59	75°0,01' N	3°29,75' W	CTD	surface
MSM5/663-1	7.26.2007	22:19	74°59,99' N	2°50,92' W	CTD	surface
MSM5/664-1	7.27.2007	1:15	74°59,99' N	2°17,69' W	Drifter S/N 3371	surface
MSM5/665-1	7.27.2007	1:35	74°59,97' N	2°12,84' W	CTD	surface
MSM5/666-1	7.27.2007	4:23	75°6,98' N	2°30,08' W	CTD	surface
MSM5/667-1	7.27.2007	7:12	75°4,84' N	3°26,97' W	Mooring recov. AWI-J027	start heaving on deck
MSM5/668-1	7.27.2007	10:40	75°5,02' N	3°26,96' W	Mooring depl. AWI-J030	released
MSM5/669-1	7.27.2007	13:21	74°49,74' N	2°29,50' W	Mooring recov. AWI-J026	start heaving on deck
MSM5/670-1	7.27.2007	17:02	74°49,73' N	2°29,28' W	Mooring depl. AWI-J029	released
MSM5/671-1	7.27.2007	19:08	74°40,03' N	1°0,02' W	Drifter S/N 3374	surface
MSM5/672-1	7.27.2007	21:36	75°0,01' N	0°17,51' E	Drifter, longterm	surface
MSM5/673-1	7.27.2007	21:55	75°0,00' N	0°20,88' E	CTD	surface
MSM5/674-1	7.28.2007	1:15	74°59,95' N	0°17,93' W	CTD	surface
MSM5/675-1	7.28.2007	4:34	75°0,01' N	0°56,03' W	CTD	surface
MSM5/676-1	7.28.2007	8:01	75°0,00' N	1°0,01' W	Drifter S/N 3372	surface
MSM5/677-1	7.28.2007	8:59	74°59,94' N	1°35,08' W	CTD	surface
MSM5/678-1	7.28.2007	17:47	74°56,01' N	4°36,91' W	Mooring depl. AWI-	released

					JP31	
MSM5/679-1	7.28.2007	19:12	75°0,04' N	5°25,22' W	CTD	surface
MSM5/680-1	7.28.2007	22:20	74°59,99' N	6°4,11' W	CTD	surface
MSM5/681-1	7.29.2007	1:26	75°0,02' N	6°42,96' W	CTD	surface
MSM5/682-1	7.29.2007	4:33	75°0,02' N	7°22,00' W	CTD	surface
MSM5/683-1	7.29.2007	7:56	75°0,02' N	8°1,04' W	CTD	surface
MSM5/684-1	7.29.2007	10:58	75°0,03' N	8°40,35' W	CTD	surface
MSM5/685-1	7.29.2007	13:54	75°0,00' N	9°19,02' W	CTD	surface
MSM5/686-1	7.30.2007	3:24	75°20,03' N	1°0,04' W	Drifter, longterm	surface
MSM5/687-1	7.30.2007	6:45	74°59,94' N	0°59,09' E	CTD	surface
MSM5/688-1	7.30.2007	9:59	74°59,98' N	1°37,79' E	CTD	surface
MSM5/689-1	7.30.2007	12:55	75°0,02' N	2°16,49' E	CTD	surface
MSM5/690-1	7.30.2007	15:42	74°59,99' N	2°56,11' E	CTD	surface
MSM5/691-1	7.30.2007	18:25	75°0,01' N	3°34,98' E	CTD	surface
MSM5/692-1	7.30.2007	21:33	74°59,98' N	4°14,05' E	CTD	surface
MSM5/693-1	7.31.2007	0:28	75°0,02' N	4°52,00' E	CTD	surface
MSM5/694-1	7.31.2007	3:32	75°0,01' N	5°29,88' E	CTD	surface
MSM5/695-1	7.31.2007	6:36	74°59,96' N	6°8,10' E	CTD	surface
MSM5/696-1	7.31.2007	9:25	75°0,02' N	6°47,06' E	CTD	surface
MSM5/697-1	7.31.2007	11:54	74°59,98' N	7°25,92' E	CTD	surface
MSM5/698-1	7.31.2007	14:28	74°59,95' N	8°4,79' E	CTD	surface
MSM5/699-1	7.31.2007	17:37	75°0,02' N	8°43,98' E	CTD	surface
MSM5/700-1	7.31.2007	20:20	74°59,98' N	9°21,91' E	CTD	surface
MSM5/701-1	7.31.2007	22:52	75°0,01' N	9°59,66' E	CTD	surface
MSM5/702-1	8.1.2007	1:35	75°0,04' N	10°38,91' E	CTD	surface
MSM5/703-1	8.1.2007	4:19	74°59,99' N	11°17,89' E	CTD	surface
MSM5/704-1	8.1.2007	7:13	74°59,98' N	11°55,91' E	CTD	surface
MSM5/705-1	8.1.2007	9:48	75°0,31' N	12°34,47' E	CTD	surface
MSM5/706-1	8.1.2007	12:12	74°59,97' N	13°12,74' E	CTD	surface
MSM5/707-1	8.1.2007	14:40	75°0,02' N	13°52,05' E	CTD	surface
MSM5/708-1	8.1.2007	16:58	74°59,94' N	14°30,99' E	CTD	surface
MSM5/709-1	8.1.2007	19:14	74°59,99' N	15°9,85' E	CTD	surface
MSM5/710-1	8.1.2007	21:30	74°59,98' N	15°49,46' E	CTD	surface
MSM5/711-1	8.1.2007	23:24	75°0,20' N	16°29,38' E	CTD	surface
MSM5/711-2	8.4.2007	1:28	78°30,00' N	6°5,00' E	Parasound	start of profile
MSM5/711-2	8.4.2007	4:20	78°50,18' N	8°0,78' E	Parasound	end of profile
MSM5/712-1	8.4.2007	6:28	78°54,94' N	6°46,04' E	Box corer	surface
MSM5/712-1	8.4.2007	7:05	78°54,94' N	6°46,04' E	Box corer	at sea bottom
MSM5/712-1	8.4.2007	7:43	78°54,94' N	6°46,04' E	Box corer	on deck
MSM5/712-2	8.4.2007	8:22	78°54,94' N	6°46,03' E	Gravity corer	surface
MSM5/712-2	8.4.2007	8:52	78°54,94' N	6°46,03' E	Gravity corer	at sea bottom
MSM5/712-2	8.4.2007	8:54	78°54,94' N	6°46,04' E	Gravity corer	off ground hoisting
MSM5/712-2	8.4.2007	9:29	78°54,94' N	6°46,04' E	Gravity corer	on deck
MSM5/713-1	8.4.2007	10:03	78°54,66' N	6°46,78' E	CTD	surface
MSM5/714-1	8.4.2007	11:20	78°54,91' N	6°46,07' E	Parasound	start of profile
MSM5/714-1	8.4.2007	14:35	79°18,44' N	5°3,98' E	Parasound	interruption of profile
MSM5/714-1	8.4.2007	15:30	79°14,67' N	5°23,43' E	Parasound	continuation of profile
MSM5/714-1	8.4.2007	16:20	79°19,99' N	4°59,88' E	Parasound	change of course
MSM5/714-1	8.4.2007	16:35	79°19,37' N	5°7,88' E	Parasound	interruption of profile
MSM5/714-1	8.4.2007	17:46	79°20,05' N	4°59,96' E	Parasound	continuation of profile
MSM5/714-1	8.4.2007	19:42	79°12,00' N	6°14,92' E	Parasound	change of course
MSM5/714-1	8.4.2007	21:33	79°15,00' N	7°39,11' E	Parasound	change of course
MSM5/714-1	8.4.2007	23:37	79°28,01' N	6°28,71' E	Parasound	change of course
MSM5/714-1	8.5.2007	1:40	79°30,00' N	4°50,54' E	Parasound	change of course
MSM5/714-1	8.5.2007	3:31	79°45,06' N	5°20,13' E	Parasound	change of course
MSM5/714-1	8.5.2007	6:58	79°40,00' N	7°59,40' E	Parasound	change of course

MSM5/714-1	8.5.2007	10:58	79°11,93' N	6°15,21' E	Parasound	end of profile
MSM5/715-1	8.5.2007	11:08	79°11,98' N	6°15,26' E	Large Box Corer	surface
MSM5/715-1	8.5.2007	11:46	79°11,98' N	6°15,25' E	Large Box Corer	at sea bottom
MSM5/715-1	8.5.2007	12:22	79°11,98' N	6°15,25' E	Large Box Corer	on deck
MSM5/715-2	8.5.2007	12:27	79°11,98' N	6°15,26' E	Large Box Corer	surface
MSM5/715-2	8.5.2007	13:02	79°11,98' N	6°15,25' E	Large Box Corer	at sea bottom
MSM5/715-2	8.5.2007	13:40	79°11,98' N	6°15,25' E	Large Box Corer	on deck
MSM5/715-3	8.5.2007	13:52	79°11,99' N	6°15,26' E	Large Box Corer	surface
MSM5/715-3	8.5.2007	14:29	79°11,98' N	6°15,24' E	Large Box Corer	at sea bottom
MSM5/715-3	8.5.2007	15:07	79°11,98' N	6°15,24' E	Large Box Corer	on deck
MSM5/715-4	8.5.2007	15:32	79°11,99' N	6°15,25' E	Gravity corer	surface
MSM5/715-4	8.5.2007	16:01	79°11,99' N	6°15,25' E	Gravity corer	at sea bottom
MSM5/715-4	8.5.2007	16:35	79°11,99' N	6°15,25' E	Gravity corer	on deck
MSM5/716-1	8.5.2007	17:57	79°14,11' N	7°13,25' E	Gravity corer	surface
MSM5/716-1	8.5.2007	18:22	79°14,11' N	7°13,25' E	Gravity corer	at sea bottom
MSM5/716-1	8.5.2007	18:24	79°14,11' N	7°13,24' E	Gravity corer	off ground hoisting
MSM5/716-1	8.5.2007	18:54	79°14,11' N	7°13,25' E	Gravity corer	on deck
MSM5/716-2	8.5.2007	19:15	79°14,11' N	7°13,26' E	Large Box Corer	surface
MSM5/716-2	8.5.2007	19:45	79°14,11' N	7°13,26' E	Large Box Corer	at sea bottom
MSM5/716-2	8.5.2007	20:18	79°14,11' N	7°13,26' E	Large Box Corer	on deck
MSM5/717-1	8.5.2007	23:16	79°38,02' N	7°49,98' E	Parasound	start of profile
MSM5/717-1	8.6.2007	2:49	79°59,62' N	5°44,71' E	Parasound	end of profile
MSM5/717-2	8.6.2007	4:03	79°53,22' N	5°54,03' E	Parasound	start of profile
MSM5/717-2	8.6.2007	7:12	79°35,02' N	7°39,39' E	Parasound	end of profile
MSM5/717-3	8.6.2007	7:38	79°32,58' N	7°25,79' E	Parasound	start of profile
MSM5/717-3	8.6.2007	12:56	79°58,37' N	4°54,72' E	Parasound	end of profile
MSM5/717-4	8.6.2007	12:57	79°58,36' N	4°54,53' E	Parasound	start of profile
MSM5/717-4	8.6.2007	16:15	79°43,79' N	5°51,70' E	Parasound	end of profile
MSM5/718-1	8.6.2007	16:41	79°42,92' N	5°56,52' E	Large Box Corer	surface
MSM5/718-1	8.6.2007	17:13	79°42,92' N	5°56,52' E	Large Box Corer	at sea bottom
MSM5/718-1	8.6.2007	17:49	79°42,92' N	5°56,52' E	Large Box Corer	on deck
MSM5/718-2	8.6.2007	18:03	79°42,92' N	5°56,52' E	Gravity corer	surface
MSM5/718-2	8.6.2007	18:30	79°42,92' N	5°56,52' E	Gravity corer	at sea bottom
MSM5/718-2	8.6.2007	18:31	79°42,92' N	5°56,52' E	Gravity corer	off ground hoisting
MSM5/718-2	8.6.2007	18:59	79°42,92' N	5°56,52' E	Gravity corer	on deck
MSM5/719-1	8.6.2007	22:17	79°30,01' N	8°9,79' E	CTD	surface
MSM5/720-1	8.7.2007	0:06	79°30,09' N	7°10,34' E	CTD	surface
MSM5/720-2	8.7.2007	1:04	79°30,09' N	7°10,34' E	CTD	surface
MSM5/721-1	8.7.2007	2:27	79°29,98' N	6°14,81' E	CTD	surface
MSM5/722-1	8.7.2007	4:24	79°30,00' N	5°40,00' E	CTD	surface
MSM5/723-1	8.7.2007	8:09	79°9,66' N	5°20,27' E	Large Box Corer	surface
MSM5/723-1	8.7.2007	8:41	79°9,66' N	5°20,27' E	Large Box Corer	at sea bottom
MSM5/723-1	8.7.2007	9:16	79°9,66' N	5°20,27' E	Large Box Corer	on deck
MSM5/723-2	8.7.2007	9:29	79°9,66' N	5°20,27' E	Gravity corer	surface
MSM5/723-2	8.7.2007	9:57	79°9,66' N	5°20,27' E	Gravity corer	at sea bottom
MSM5/723-2	8.7.2007	10:35	79°9,66' N	5°20,27' E	Gravity corer	on deck
MSM5/724-1	8.7.2007	20:51	80°16,96' N	10°39,37' E	Parasound	start of profile
MSM5/724-1	8.8.2007	0:08	80°30,91' N	12°57,04' E	Parasound	change of course
MSM5/724-1	8.8.2007	4:16	80°57,16' N	14°59,66' E	Parasound	change of course
MSM5/724-1	8.8.2007	9:35	80°57,00' N	11°8,29' E	Parasound	end of profile
MSM5/725-1	8.8.2007	10:02	80°57,00' N	11°19,37' E	CTD	surface
MSM5/725-2	8.8.2007	11:23	80°57,00' N	11°19,37' E	Large Box Corer	surface
MSM5/725-2	8.8.2007	12:07	80°57,00' N	11°19,37' E	Large Box Corer	at sea bottom
MSM5/725-2	8.8.2007	12:52	80°57,00' N	11°19,36' E	Large Box Corer	on deck
MSM5/725-3	8.8.2007	13:06	80°57,00' N	11°19,35' E	Gravity corer	surface
MSM5/725-3	8.8.2007	13:39	80°57,00' N	11°19,36' E	Gravity corer	at sea bottom

MSM5/725-3	8.8.2007	14:22	80°57,00' N	11°19,37' E	Gravity corer	on deck
MSM5/726-1	8.8.2007	14:25	80°57,00' N	11°19,36' E	Parasound	start of profile
MSM5/726-1	8.8.2007	16:33	80°40,67' N	11°49,97' E	Parasound	end of profile
MSM5/727-1	8.8.2007	16:43	80°40,56' N	11°49,59' E	Gravity corer	surface
MSM5/727-1	8.8.2007	17:06	80°40,56' N	11°49,59' E	Gravity corer	at sea bottom
MSM5/727-1	8.8.2007	17:35	80°40,56' N	11°49,59' E	Gravity corer	on deck
MSM5/727-2	8.8.2007	17:58	80°40,56' N	11°49,59' E	CTD	surface
MSM5/728-1	8.8.2007	20:49	80°25,00' N	11°49,73' E	CTD	surface
MSM5/729-1	8.8.2007	21:19	80°25,00' N	11°49,74' E	Parasound	start of profile
MSM5/729-1	8.8.2007	22:22	80°24,94' N	11°0,98' E	Parasound	change of course
MSM5/729-1	8.8.2007	23:16	80°20,97' N	10°21,69' E	Parasound	change of course
MSM5/729-1	8.9.2007	9:57	79°13,39' N	5°1,21' E	Parasound	end of profile

5.6 Paleo multi-proxy sampling

Biomarkers **Coccoliths**

Leg 18/07/2007-03/08/2007

Filter No.	online Filtr.	offline Filtr.	CTD No.	Position Lat.	Long.	Depth (m) (m)	Date dd/mm (dd/mm)		S psu	Vol (L)	Coccoliths Filter No.	Vol (L)
1	x			68°45,200 N	19°43,800 W	surface	19-jul	4.10	30.2	40		
				69°2,600 N	19°6,450 W		20-jul	4.80	30.6			
2				69°3,600 N	19°4,200 W	surface	20-jul	4.90	30.5	40		
							20-jul	4.70	30.3			
3				70°19,700 N	16°30,700 W	surface	20-jul	5.8	30.3	100	1	5
				70°41,800 N	16°0,790 W		20-jul	6.20	31.5			
4				71°65,000 N	15°40,000 W	surface	20-jul	6.20	32.6	60	2	5
				71°20,000 N	15°27,000 W		20-jul	5.6	32.3			
5		x	6212	71°20,280 N	15°27,880 W	1464	20-jul	-0.66	34.9	28		
							20-jul					
6	x			71°25,000 N	15°22,000 W	surface	20-jul	5.60	32.6	100		
							20-jul					
7	x			72°5,820 N	14°33,000 W	surface	20-jul	3.20	28.2	100		
				72°14,900 N	13°26,800 W		20-jul	1.80	27.6			
8	x			73°31,000 N	13°36,000 W	surface	20-jul	1.20	27.1	40	3	4
				73°36,000 N	13°57,000 W		20-jul	0.40	26.3			
9	x			73°44,000 N	14°18,000 W	surface	20-jul	-0.10	25.8	20	4	
							20-jul	-0.20	26.3			
10		x		73°45,000 N	14°22,000 W	surface	20-jul	-0.10	25.8	8l, 7l, 5l		
							20-jul					
11	x			73°46,000 N	14°26,000 W	surface	20-jul	-0.60	27.1	20		
				73°48,000 N	14ª39,000 W		20-jul	0.50	26.2			
12	x			73°48,000 N	14°40,000 W	surface	20-jul	0.70	25.9	20		
				73°50,000 N	14°49,000 W		20-jul	0.20	27.1			
13	x			73°51,000 N	14°55,000 W	surface	20-jul	-0.70	27.5	20		
				73°51,000 N	14°58,000 W		20-jul	-0.30	25.9			
14	x			73°58,000 N	15°17,000 W	surface	20-jul	0.40	28.1	20	5	5
				73°59,000 N	15°19,000 W		20-jul	0.40	26.9			
15 a+b		x		73°58,000 N	15°17,000 W	surface	20-jul	0.40	28.1	2 x 10		
16	x			73°59,000 N	15°59,000 W	surface	22-jul	0.20	29.9	20	6	5
				73°59,000 N	15°58,000 W		22-jul					
17		x		73°59,000 N	15°59,000 W	surface	22-jul	0.20	29.9	2 x 10		

18		x	624-2	73º59,000 N	15º58,000 W	100	22-jul	-1.58	33.6	27	7	8
19	x			74º1,400 N	15º47,000 W	surface	22-jul	0.40	27.6	20		
				74º0,600 N	15º42,000 W		22-jul					
20 a+b		x	629-0	74º0,900 N	15º40,800 W	4.4	22-jul	-0.99	30.2	2 x 10	8	5
21		x	634-0	73º59,000 N	14º31,000 W	100	23-jul	1.84	35	10	9	8
22	x			73º59,700 N	13º58,600 W	surface	23-jul	-0.20	28.4	6	10	3
							23-jul					
23		x		73º59,700 N	13º58,600 W	surface	23-jul	-0.20	28.4	4 x 5		
24	x			74º0,400 N	13º46,100 W	surface	23-jul	-0.60	27.1	6		
				74º0,300 N	13º45,000 W		23-jul	-0.40	27.8			
25	x			74º0,600 N	12º30,000 W	surface	24-jul	2.80	29.6	20		
							24-jul	2.50	29.5			
26 a+b		x		74º0,000 N	12º34,000 W	surface	24-jul	2.50	29.4	2 x 10	11 + 12	3,5 each
27	x			74º0,100 N	12º29,900 W	surface	24-jul	2.50	29.5	10		
				at station			24-jul	2.50	29.5			
28	x			74º0,100 N	12º29,900 W	surface	24-jul	2.40	29.5	10		
				at station								
29	x			74º0,000 N	12º0,000 W	surface	24-jul	3.50	30	20		
				74º0,000 N	11º55,270 W		24-jul	3.50	30.5			
30	x			73º59,900 N	11º29,700 W	surface	24-jul	4.10	30.8	20		
				at station								
31 a+b		x		73º59,900 N	11º29,700 W	surface	24-jul	4.10	30.8	2 x 10	13+14	5 each
					at station							
32	x			74º0,000 N	10º29,600 W	surface	24-jul	5.40	32.7	20		
				at station	at station							
33 a+b		x		74º0,000 N	10º29,600 W	surface	24-jul	5.40	32.7	2 x 10	15+16	5 each
				at station	at station							
34	x			74º0,000 N	10º29,600 W	surface	24-jul	5.40	32.7	20		
				at station								
35	x			74º0,000 N	10º29,600 W	surface	24-jul	5.40	32.7	10		
				at station								
36	x			74º12,000 N	9º2,200 W	surface	25-jul	5.40	32.6	10		
				at station								
37 a+b		x		74º12,000 N	9º2,212 W	surface	25-jul	5.40	32.6	2 x 10	17+18	5 each
				at station								
38	x			74º12,000 N	9º2,200 W	surface	25-jul	5.40	32.5	10		
				at station								
39			6520	74º23,880 N	8º3,610 W	3197	25-jul	-0.85	34.9	28	19	
				at station								
40	x			74º23,880 N	8º3,610 W	surface	25-jul	5.50	33.5	10		
				at station								
41 a+b		x		74º23,880 N	8º3,610 W	surface	25-jul	5.50	33.5	2 x 10	20	5
				at station								
42	x			74º35,800 N	7º4,210 W	surface	25-jul	5.90	33.6	10		
				at station								
43		x		74º35,800 N	7º4,210 W	surface	25-jul	5.90	33.6	2 x 10	21	5

a+b				at station								
44	x			74º59,900 N	4º46,900 W	surface	26-jul	5.90	33.6	20		
				at station								
45		x		74º59,900 N	4º46,900 W	surface	26-jul	5.90	33.6	10	22	5
				at station								
46		x		74º59,900 N	4º46,900 W	surface	26-jul	5.90	33.6	10		
				at station								
47	x			74º59,900 N	4º46,900 W	surface	26-jul	5.90	33.6	10		
				at station								
48 a+b		x		74º59,950 N	4º8,010 W	surface	26-jul	5.50	33.8	2 x 10	23	5
49	x			74º59,950 N	4º8,010 W	surface	26-jul	5.50	33.8	10		
				at station								
50	x			74º59,990 N	2º50,920 W	surface	26-jul	5.70	33.8	20		
				at station								
51 a+b		x		74º59,990 N	2º50,920 W	surface	26-jul	5.70	33.8	2 x 10	24	5
52	x			74º59,960 N	2º12,840 W	surface	27-jul	5.90	34	21		
53 a+b		x		74º59,960 N	2º12,840 W	surface	27-jul	5.90	34	2 x 5	25	4
54			666	75º6,999 N	2º30,050 W	1799	27-jul	-0.74	34.9	27		
55	x			75º0,000 N	0º20,880 E	surface	27-jul	6.40	34	5		
				at station								
56 a+b		x		75º0,000 N	0º20,880 E	surface	27-jul	6.40	34	2 x 5	26	4
57	x			74º59,950 N	0º17,928 W	surface	28-jul	5.70	33.9	8		
				at station								
58	x			75º0,008 N	0º56,026 W	surface	28-jul	5.80	33.9	20		
				at station								
59 a+b		x		75º0,008 N	0º56,026 W	surface	28-jul	5.80	33.9	2 x 10	27	5
60	x			75º0,042 N	5º25,200 W	surface	28-jul	5.90	33.8	10		
				at station								
61 a+b		x		75º0,042 N	5º25,200 W	surface	28-jul	5.90	33.8	2 x 10	28	5
62	x			74º59,990 N	6º4,110 W	surface	28-jul	5.90	33.7	10		
				at station								
63 a+b		x		74º59,990 N	6º4,110 W	surface	28-jul	5.90	33.7	2 x 10	29	4
64	x			75º0,023 N	6º42,957 W	surface	29-jul	5.60	33.6	21		
				at station								
65	x			75º0,200 N	7º22,003 W	surface	29-jul	5.20	33.5	10		
				at station								
66 a+b		x		75º0,200 N	7º22,003 W	surface	29-jul	5.20	33.5	2 x 8		
				at station								
67	x			75º0,018 N	8º1,038 W	surface	29-jul	4.90	32.9	20		
				at station								
68	x			75º0,001 N	9º19,023 W	surface	29-jul	4.50	31.8	20		

				at station									
69 a+b+c		x		75º0,001 N	9º19,023 W	surface	29-jul	4.50	31.8	a:8, b:6, c:6		30	4
70	x			74º59,981 N	1º37,792 E	surface	30-jul	7.00	34	10			
71 a+b		x		74º59,981	1º37,792 E	surface	30-jul	7.00	34	2 x 5		31	3
72	x			74º59,980 N	2º56,110 E	surface	30-jul	6.90	34.1	10			
73 a+b		x		74º59,980 N	2º56,110 E	surface	30-jul	6.90	34.1	2 x 7		32	4
74	x			74º59,975 N	4º14,051 E	surface	30-jul	7.20	34.1	20			
				at station									
75 a+b		x		74º59,975 N	4º14,051 E	surface	30-jul	7.20	34.1	2 x 7			
76	x			75º0,008 N	5º29,885 E	surface	31-jul	7.00	34.2	20			
				at station									
77 a+b		x		75º0,008 N	5º29,885 E	surface	31-jul	7.00	34.2	2 x 7		33	
78	x			75º0,019 N	6º47,075 E	surface	31-jul	7.50	34.2	10			
				at station									
79 a+b		x		75º0,019 N	6º47,075 E	surface	31-jul	7.50	34.2	2 x 7			
80	x			74º59,98 N	8º4,79 E	surface	31-jul	7.50	34.2	20			
				at station									
81 a+b		x		74º59,98 N	8º4,79 E	surface	31-jul	7.50	34.2	2 x 10		34	5
82	x			74º59,970 N	9º21,910 E	surface	31-jul	7.40	34.2	20			
				at station									
83 a+b		x		74º59,970 N	9º21,910 E	surface	31-jul	7.40	34.2	2 x 7		35	4
84	x			75º0,040 N	10º38,900 E	surface	1-ago	7.10	34.2	20			
				at station									
85 a+b		x		75º0,040 N	10º38,900 E	surface	1-ago	7.10	34.2	2 x 5			
86	x			74º59,978 N	11º55,900 E	surface	1-ago	7.80	34.1	20			
				at station									
87 a+b		x		74º59,978 N	11º55,900 E	surface	1-ago	7.80	34.1	2 x 7		36	3
88			705	75º0,300 N	12º34,48 E	199	1-ago	4.70	35.1	27.5			
89	x			74º59,965 N	13º12,758 E	surface	1-ago	8.00	34.1	15			
90	x			74º59,945 N	14º30,975 E	surface	1-ago	7.50	34.1	20			
91 a+b		x		74º59,945 N	14º30,974 E	surface	1-ago	7.50	34.1	2 x 7		37	5
92	x			74º59,847 N	15º48,850 E	surface	1-ago	8.00	34.1	20			

93		x		74º59,847	15º48,850	surface	1-ago	8.00	34.1	2 x 8		
Leg 03/08/2007-10/08/2007				North	East							
#B1	x			78°14,83	10°21,25		3-ago	8.40	33.2	9		
				78°16,17	10°00,40		3-ago	8.37	33			
#B2	x			78°16,99	9°46,23		3-ago	8.48	33	11.5		
				78°20,72	8°41, 2		3-ago	8.56	33.9			
#B3		x		78°14,22	10°30,81		3-ago	8.05	33.6	20	PZ#B 1	8
				78°14,29	10°29,8							
#B4	x			78°21,85	8°24,79		4-ago	8.34	33.9	15.5		
				78°23,83	7°51,77		4-ago	8.63	34			
#B5	x			78°35,106	6°34,165		4-ago	8.62	34	12		
				78°37,6	6°48,15		4-ago	8.62	34			
#B6	x			78°40,228	7°2,6 0		4-ago	6.95	33.7	14.5		
				78°44,617	7°26,968		4-ago	8.79	34.1			
#B7	x			78°45,738	7°33,240		4-ago	8.83	33.9	20		
				78°52,214	7°26,080		4-ago	8.63	33.7			
#B8		x		78°33,78	6°26,75		4-ago	8.64	33.9	9	PZ#B 2	5.2
#B8b				78°33,78	6°26,75		4-ago	8.64	33.9	9		
#B9	x			78°57,22	6°36,64		4-ago	8.08	34	20		
				79°0,64	6°22, 0		4-ago	7.02	33.8			
#B10	x			79,8,86	5°47,07		4-ago	3.98	32.9	20		
				79°14,95	5°21,64		4-ago	2.52	32.6			
#B11	x			79°16,22	5°16,115		4-ago	2.89	32.8	20		
				79°15,113	5°15,724		4-ago	3.12	32.5			
#B12	x			79,14,388	5°20,891		4-ago	2.82	32.5	20		
				79°19,704	5°1,336		4-ago	1.90	31			
#B13		X	713-1	78°54,66	6°46,78	5	4-ago			12		
#B13b		X	713-1			5	4-ago			15		
#B14		x		79°7,97	5°51,00		4-ago	4.09	33.1	15	PZ#B 3	6.5
#B15		x		79°17,594	5°6,8 8		4-ago	2.45	31.6	15	PZ#B 4	13
#B16		x		79°44,125	5°47,887		5-ago	1.39	30.6	15		
#B16b		x		79°44,125	5°47,887		5-ago	1.39	30.6	4		
#B16	x			79°12,911	6°6,496		4-ago	4.98	33.2	18.5		
				79°12,481	6°28,113		4-ago	6.60	33.5			
#B17	x			79°43,893	5°54,894		5-ago	1.87	30.9	20		
				79°43,014	6°22,976		5-ago	2.52	31.5			
#B18	x			79°41,969	7°13,146		5-ago	7.86	33.9	20		
				79°36,474	7°46,067		5-ago	8.26	34			
#B19	x			79°56,5	5°33,91		6-ago	0.40	30.2	20		
				79°55,882	5°55,882		6-ago	0.60	30.3			
#B20	x			79°54,381	5°51,030		4-ago	0.60	30.4	20		

				79°50,398	6°10,79		4-ago	2.89	31.6			
#B21	x			79°49,54	6°15,719		5-ago	2.94	31.7	20		
				79°45,78	6°36,735		5-ago	6.84	33.8			
#B22	x			79°45	6°36		5-ago	6.84	33.8	20		
				79°36,125	7°32,012		5-ago	8.26	34			
#B23	x			79°33,83	7°18,56		6-ago	6.78	33.6	20.5		
				79°42,6	6°28,01		6-ago	5.51	33.2			
#B24		x		79°56,47	5°33,29		4-ago	0.47	20.2	20	PZ#B5	15
#B25		x		79°34,137	7°34,319		6-ago	6.55	33.6	8	PZ#B6	6
#B25	x			79°44,46	6°16,45		6-ago	5.26	33.19	20		
				79°48,36	5°53,83		6-ago	3.29	31.7			
#B26	x			79°49,07	5°50,01		6-ago	3.30	31.6	19.5		
				79°56,17	5°08,48		6-ago	-1.05	29.6			
#B27	x			79°56,48	5°08,00		6-ago	-1.26	29.3	>20		
				79°58,05	4°57,52		6-ago	3.74	29.1			
#B28	x											
#B29	x			79°48,27	5°24,65		6-ago	0.97	30.8	20		
				79°42,92	5°56,52		6-ago	7.59	33.9			
#B30		x		79°49,07	5°50,01		6-ago	3.30	31.6	18	PZ#B7	8
#B31		x		79°51,49	5°36,49		6-ago	-0.10	30.5	16	PZ#B8	6.5
#B32	x			79°31,35	7°56,38		6-ago	8.40	33.9	20		
				79°30,11	7°39,68		7-ago	7.76	33.8			
#B33		x	719-1	79°30,01	8°9,8	430	7-ago			28		
#B34	x			79°30,02	7°31,10		7-ago	6.97	33.7	21		
				79°29,98	6°14,81		7-ago	?	?			
#B35		x	720-1	79°30,01	7°10,34	990	7-ago			27		
#B36		x	721-1	79°30,01	6°14,81	1500	7-ago			26		
#B37	x			79°29,57	6°7,93		7-ago	3.10	30.7	19		
				79°9,66	5°20,22		7-ago	3.93	33			
#B38		x	722-1	79°30,01	5°40,00	2220	7-ago			26		
#B39a		x	720-2	79°30,01	7°10,34	6.50	7-ago			19		
#B39b		x	720-2	79°30,01	7°10,34	6.50	7-ago			7.5		
#B39	x			79°10,891	5°26,24		7-ago	4.56	32.9	20		
				79°18,70	6°0,76		7-ago	3.35	32			
#B40	x			79°30,82	6°56,10		7-ago	6.33	33.2	20		
				79°46,60	8°12,11		7-ago	6.58	33.8			
#B41	x			79°47,23	8°15,04		7-ago	3.94	32.4	23		
				80°1,23	9°22,29		7-ago	6.65	33.4			
#B42	x			80°2,123	9°26,64		7-ago	6.16	33.4	25?		
				80°21,95	11°29,67		7-ago	7.68	33.9			
#B43	x			80°57,00	11°41,73		8-ago	2.10	31.4	14.5		

				80°57,00	11°19,36		8-ago	-0.37	31.8			
#B44a		x		80°57,00	11°41,73		8-ago	2.10	31.4	14	PZ#B9	6
#B44b		x		80°57,00	11°41,73		8-ago	2.10	31.4	6		
#B45		x	725-1	80°57,00	11°19,37	1990+1500	8-ago			5		
#B46		x	725-1	80°57,00	11°19,37	1000+800	8-ago			5		
#B47		x	725-1	80°57,00	11°19,37	400+200	8-ago			5		
#B48		x	725-1	80°57,00	11°19,37	100+150	8-ago			5		
#B49		x	725-1	80°57,00	11°19,37	10+30+60	8-ago			7.5		
#B50	x			80°52,951	11°26,909		8-ago	1.07	30.6	19.50		
				80°40,565	11°49,59		8-ago	3.05	31.3			
#B51	x			80°39,123	11°48,44		8-ago	2.39	31.2	21.5		

5.7 Acknowledgements

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