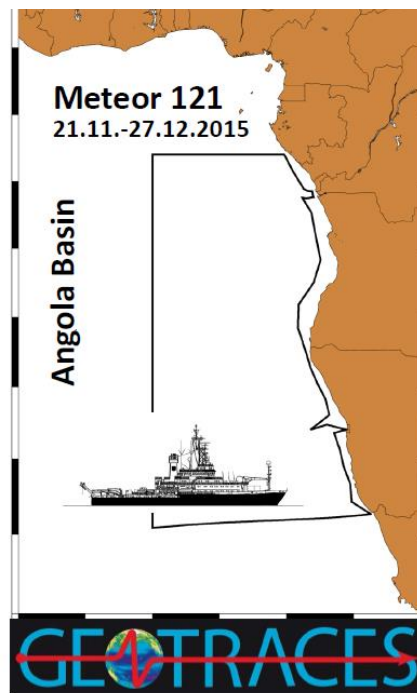


METEOR-Berichte
***Trace Metal Chemistry in the Water Column of the Angola Basin -
A Contribution to the International GEOTRACES Program***

Cruise No. M121

November 22, – December 27, 2015
Walvis Bay (Namibia) – Walvis Bay (Namibia)



**M. Frank, E. Achterberg, L. Bristow, T. Browning, F.-F. Deng, P. Handmann,
E. Hathorne, M. Hopwood, P. Lodeiro, J.-L. Menzel-Barraqueta, G. Merschel,
S. Meyer, J. Pampin Baro, P. Rahlf, W. Rath, C. Schlosser, A. Stippkugel,
L. H. Vieira, R. Zitoun, A. Raeke**

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MARUM – Zentrum für Marine Umweltwissenschaften der Universität Bremen

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Editor:

DFG-Senatskommission für Ozeanographie
c/o MARUM – Zentrum für Marine Umweltwissenschaften
Universität Bremen
Leobener Strasse
28359 Bremen

Author:

Prof. Dr. Martin Frank
GEOMAR
Helmholtz-Zentrum für
Ozeanforschung Kiel
Standort Ostufer
Wischhofstraße 1-3
24148 Kiel, Germany

Telefon: +49-431-600-2218
Telefax: +49-431-600-2925
e-mail: mfrank@geomar.de

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1 Summary

Meteor Cruise M121 was dedicated to the investigation of the distribution of dissolved and particulate trace metals and their isotopic compositions (TEIs) in the full water column of the Angola Basin and the northernmost Cape Basin. A key aim was to determine the driving factors for the observed distributions, which includes the main external inputs, as well as internal cycling and ocean circulation. The research program of the cruise is official part of the international GEOTRACES program (www.geotraces.org) and cruise M121 corresponds to GEOTRACES cruise GA11. Subject of the cruise was the trace metal clean and contamination-free sampling of waters and particulates for subsequent analyses of the TEIs in the home laboratories of the national and international participants. Besides a standard rosette for the less contaminant prone metals, trace metal clean sampling was realized by using for the first time a new dedicated, coated trace metal clean rosette equipped with Teflon-coated GO-FLO bottles operated via a plastic coated cable from a mobile winch of GEOMAR Kiel. The particulate samples were collected under trace metal clean conditions using established in-situ pump systems operated from Meteor's Aramid line. The cruise track led from Walvis Bay northwards along the West African margin until 3°S, then turned west until the Zero Meridian, which was followed southwards until 30°S. Then the cruise track turned east again until the Namibian margin was reached and then completed the near shore track northwards until Walvis Bay. The track crossed areas of major external inputs including dust from the Namib Desert and exchange with the west African continental margin and with the oxygen depleted shelf sediments of the Benguela upwelling, as well as with the plume of the Congo outflow, that was followed from its mouth northwards. Our investigations of internal cycling included the extremely high productivity associated with the Benguela Upwelling and the elevated productivity of the Congo plume contrasting with the extremely oligotrophic waters of the southeastern Atlantic Gyre. The links between TEI biogeochemistry and the nitrogen cycle forms an important aspect of our study. The major water masses contributing the Atlantic Meridional Overturning Circulation were sampled in order to investigate if particular TEI signatures are suitable as water mass tracers, in particular near the ocean margin and in the restricted deep Angola Basin. A total of 51 full water column stations were sampled for the different dissolved TEIs, which were in most cases accompanied by sampling for particulates and radium isotopes using the in-situ pumps. In addition, surface waters were continuously sampled under trace metal clean conditions using a towed fish and aerosol and rain samples were continuously collected.

Zusammenfassung

Die Forschungsreise Meteor 121 hatte die Untersuchung der Verteilung der Konzentrationen gelöster und partikulärer Spurenmetalle sowie deren Isotopie (TEIs) in der gesamten Wassersäule des Angolabeckens und des nördlichen Kapbeckens zum Ziel. Insbesondere sollten deren steuernde Faktoren wie externe Einträge, die internen Kreisläufe und die Ozeanzirkulation erfasst werden. Dieses Forschungsprogramm der Ausfahrt ist offizieller Bestandteil des internationalen GEOTRACES-Programms (www.geotraces.org) und die Ausfahrt M121 wird als GEOTRACES-Fahrt GA08 geführt. Hauptschwerpunkt der Fahrt war die spurenmetalldaubere, kontaminationsfreien Beprobung des Wassers und der Partikel zur nachfolgenden Messung in den landbasierten Laboren der nationalen und internationalen Partner. Neben einem Standard-

Kranzwasserschöpfer für die weniger kontaminationsanfälligen Metalle wurde die spurenmethallsaubere Beprobung mittels eines speziell entwickelten neuen, beschichteten Kranzwasserschöpfers umgesetzt, der mit teflonbeschichteten GO-FLO-Flaschen bestückt war und mittels eines plastikummantelten Kabels und einer mobilen Winde des GEOMAR betrieben wurde. Die partikulären Proben wurden ebenfalls unter spurenmethallsauberen Bedingungen mittels etablierter In-Situ-Pumpensysteme entnommen, die am Aramidseil der Meteor eingesetzt wurden. Die Fahrtroute führte von Walvis Bay auf dem Schelf von Westafrika nach Norden bis 3°S und bog dann nach Westen ab, bis der Nullmeridian erreicht wurde und folgte diesem dann nach Süden bis 30°S. Dort bog die Fahrt wieder nach Osten ab bis die namibianische Küste erreicht wurde und komplettierte dann nach Norden den Schnitt auf dem Schelf bis Walvis Bay. Die Route überquerte Gebiete erhöhten externen Eintrags wie dem Staub aus der Namib-Wüste und dem Austausch mit dem afrikanischen Kontinentalrand, sowie dem Einstrom des Kongo, dem die Fahrt nach Norden folgte. Schwerpunkte der Untersuchung der internen Kreisläufe waren die extreme biologische Hochproduktivitätszone des Benguela Auftriebs und seiner ausgeprägten Sauerstoffminimumzone, sowie die erhöhte Produktivität, die durch den Kongoeinstrom gesteuert wird. Alle Hauptwassermassen die Teil der Umwälzzirkulation im Atlantik sind, wurden beprobt, um zu untersuchen in wie weit bestimmte TEIs als Wassermassentracer dienen können, insbesondere nahe des Ozeanrands und im teilweise abgeschlossenen, tiefen Angolabecken. Insgesamt wurden 51 Stationen für die gelösten Spurenmethalle beprobt, an denen in den meisten Fällen auch partikuläre Proben entnommen wurden. Zusätzlich wurde das Oberflächenwasser kontinuierlich ebenfalls unter spurenmethallsauberen Bedingungen mittels eines Schleppfischs beprobt und es wurden ebenfalls kontinuierlich Aerosol- und Niederschlagsproben gesammelt.

2 Participants

Name	Discipline	Institution
Frank, Martin, Prof.	Paleo-Oceanography / Chief Scientist	GEOMAR
Achterberg, Eric, Prof.	Chemical Oceanography	GEOMAR
Bristow, Laura, Dr.	Marine Biogeochemistry	MPI Bremen
Browning, Thomas, Dr.	Chemical Oceanography	GEOMAR
Dausmann, Veit	Paleo-Oceanography	GEOMAR
Deng, Feifei, Dr.	Chemical Oceanography	Univ. Oxford
Evers, Florian	Winch-Technician	GEOMAR
Handmann, Patricia	Physical Oceanography	GEOMAR
Hathorne, Edmund Charles, Dr.	Paleo-Oceanography	GEOMAR
Heinze, Jutta	Technician	GEOMAR
Hopwood, Mark, Dr.	Chemical Oceanography	GEOMAR
Koesling, Sabrina	Geology	CAU Kiel
Kunde, Korinna	Chemical Oceanography	JUB
Langer, Julia	Paleo-Oceanography	GEOMAR
Fernandez Lodeiro, Pablo, Dr.	Chemical Oceanography	GEOMAR
Menzel, Jan-Lukas	Chemical Oceanography	GEOMAR

Merschel, Gila	Chemical Oceanography	JUB
Meyer, Steffi	Marine Biogeochemistry	MPI Bremen
Pampin Baro, Joaquin	Technician	GEOMAR
Rahlf, Peer	Paleo-Oceanography	GEOMAR
Rath, Willi, Dr.	Physical Oceanography	GEOMAR
Schlosser, Christian, Dr.	Chemical Oceanography	GEOMAR
Stippkugel, Angela	Chemical Oceanography	GEOMAR
Vieira, Lucia Helena	Chemical Oceanography	GEOMAR
Yong, Jaw Chuen	Chemical Oceanography	GEOMAR
Zitoun, Rebecca	Chemical Oceanography	JUB
Camalandua, Rocha, Dr.	Marine Zoology/Observer Angola	INIP
Andre, Florêncio Estevão	Student/Observer Angola	INIP
Raeke, Andreas	Meteorologist	DWD

GEOMAR	Helmholtz-Zentrum für Ozeanforschung Kiel, Kiel
MPI Bremen	Max-Planck-Institut für Marine Mikrobiologie, Bremen
JUB	Jacobs University Bremen
Univ. Oxford	Department of Earth Sciences, University of Oxford, United Kingdom
CAU Kiel	Institut für Geowissenschaften, Christian Albrechts Universität Kiel
INIP	Instituto Nacional de Investigação Pesqueira, Luanda, Angola
DWD	Deutscher Wetterdienst, Geschäftsfeld Seeschifffahrt

3 Research Program

The core of the research program of Meteor cruise M121 (GEOTRACES cruise GA08; Fig. 3.1) was a detailed sampling of the water column for trace metals and their isotopes (TEIs) along two N-S sections in the Angola Basin and the northernmost Cape Basin in the southeastern Atlantic Ocean, one near the shoreline in the shallow waters of the shelf and one offshore in the open Angola Basin. These sections were complemented by two E-W sections perpendicular to the shore line at 3°S and near 29°S. The cruise was officially part of the international GEOTRACES program (e.g. SCOR working group, 2007). The scientific goal of the cruise was to obtain an improved understanding of the sources, sinks, speciation, and biogeochemical cycling of TEIs, which actively control ocean productivity and carbon and nitrogen cycles, as is the case for the essential micronutrients Fe, Cd, or Zn. On the other hand, the distributions of TEIs are also influenced by biogeochemical and physical processes such as scavenging, mixing, dissolution of particles or dust from land, which is the reason why many of these TEIs are used as proxy indicators of past seawater variability. The goal of the GEOTRACES program is to better understand the processes that govern the distribution of TEIs in the ocean and to establish the sensitivity of these distributions to changing environmental conditions. GEOTRACES was officially launched in February 2010 and is projected to run last for at least 5 more years. The GEOTRACES programme is mainly achieved by a coordinated international effort to carry out ocean sections across the main ocean basins, along which the dissolved and particulate distributions of the TEIs are measured at high resolution in full depth water column profiles. Internationally established sampling protocols are applied and these guarantee the full

comparability of data acquired during different cruises carried out by different nations. Combining the results of the sections from the up now 83 GEOTRACES cruises will ultimately result in a three-dimensional picture of the distributions of TEIs in the global ocean which will allow to better constrain sources, such as dust, rivers, exchange with the continental landmasses and shelves, or hydrothermal activity, as well as the biogeochemical cycling of the TEIs and, importantly, their distribution in relation to the global circulation system.

The main goals of the sample collection during M121 were the investigation of the relationships between the distributions of the TEIs and the large and small scale ocean circulation processes in the southeastern Atlantic Ocean, in particular we will study how particular dissolved TEIs can be used quantitatively to track the main deep water masses and their mixing. This goal was achieved through detailed sampling of the cores of distinct subsurface, intermediate and deep water masses determined by their hydrographic parameters. We will determine the influence of external particulate and dissolved inputs on the distributions of the TEIs, and this study will include an assessment of the influence of particulate inputs from the Namibian desert and the particulate and dissolved inputs from the Congo River. Another focus is the biogeochemical cycling at the continental margin of West Africa influenced by the Benguela Upwelling system and the associated high biological productivity and low oxygen levels. This region is of particular interest for a range of TEIs that also serve as micronutrients, and because of the links between the micronutrients and the nitrogen cycle. Finally, the nutrient cycling in the oceans will be subject to investigation by utilizing innovative stable isotope compositions, such as those of iron, cadmium, and nitrogen, for which partly also the trace metal clean rosette system was used.

How, where, when and in which quantities are TEIs supplied to the surface waters and in which way are they recycled? These questions were tackled by a combined sampling for dissolved and particulate trace metals. The samples for dissolved trace metals were obtained by using for the first time a dedicated trace metal clean rosette and CTD system operated with a plastic coated conducting cable from a mobile winch that was recently acquired by GEOMAR and allows the collection of surface and deep water samples under reliable and contamination-free, trace metal clean conditions. For sampling of the corresponding particulate concentrations and distributions, waters collected using the trace metal clean Go Flo bottles were filtered, and in addition, autonomously operating situ pumping systems were used, while aerosols and wet precipitation were collected at the top of the vessel. In order to be able to handle, filter, and acidify the dissolved and particulate samples under contamination free conditions on board, a mobile clean laboratory container of GEOMAR was installed on the ship and used during the cruise. Contamination-free sampling of surface waters was achieved using a towed fish, from which the water was directly pumped in the clean laboratory. In addition to these activities, two new surface and deep water reference samples were collected using a specifically designed device of the laboratory of Ken Bruland, University of California, Santa Cruz, USA, from which a total of more than 1,000 0.5 l filtered seawater samples were filled into bottles in an overpressured plastic bubble.

Essentially all the trace metal parameters can only be measured in the home laboratories on land, which is the reason why the major focus of cruise M121 was contamination-free sampling of sea water and particulate samples. The sample analysis will therefore be conducted following the return of the samples to the laboratories. The only exceptions were preliminary

determinations of the dissolved Al and Fe(II) distributions (5.3, 5.4) and preliminary radium observations (5.10). It is therefore not possible to show significant amounts of preliminary results but we thus rather use section 5 to describe the scientific goals and applications of the different trace metals and isotopes to be analysed.

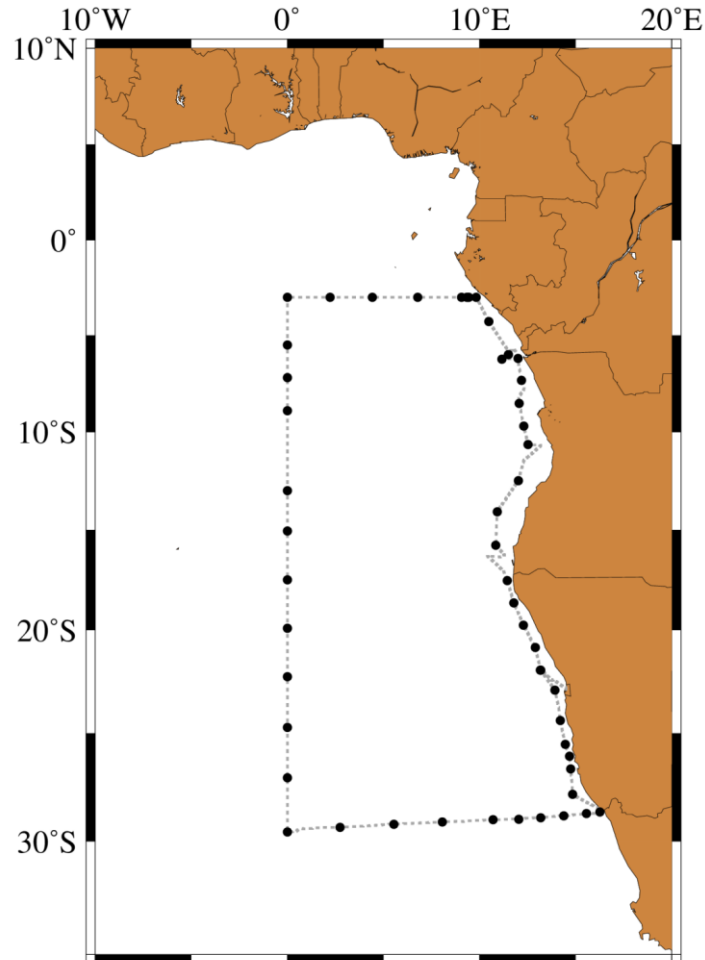


Fig. 3.1 Cruise track of R/V METEOR Cruise M121 and locations of sampled stations provided as black dots.

4 Narrative of the Cruise

Cruise M121 started in Walvis Bay, Namibia. A first group of 13 scientists from GEOMAR, Kiel and the University of Kiel arrived in Walvis Bay on the 18th November 2015 and started to prepare for the cruise, in particular setting up the trace metal clean winch and the laboratories on the Meteor in the afternoon of the 19th November. All containers from Germany had already arrived and thus the installation of the trace metal clean CTD-rosette equipped with 24 x 12 litre GO-FLO water samplers and the newly acquired mobile winch with an 8 km plastic coated conducting cable of GEOMAR started immediately. These devices were essential for contamination-free sampling of seawater. The clean lab container of GEOMAR served as clean laboratory space. Glove boxes for contamination free working environments were set up in the isotope container and one other laboratory to guarantee clean laboratory handling of contamination-prone TEIs. The remaining scientists from GEOMAR, the University of Kiel, the Jacobs University, Bremen, the Max Planck-Institute for Marine Microbiology, Bremen, the

University of Oxford, United Kingdom, and the Instituto Nacional de Investigação Pesqueira (INIP), Luanda, Angola arrived on the 19th November in Walvis Bay. All scientists boarded Meteor in the morning of the 20th November. Unpacking of the equipment from the containers started immediately and continued on 21st November accompanied by continuous strong winds blowing dust from the Namibian desert onto the vessel, and it took several days at sea to get rid of the dust. This was the day initially scheduled for leaving port but due to delays, in particular the delivery and spooling of a new cable for one of the winches, which finally turned out not to be usable, delayed departure for one day so that M121 in the end started in the morning of the 22nd November.

The ship then steamed north to the first station on the Namibian Shelf where the sampling of the water column started on the evening of the same day at 22°58.5'S, 13°11'E. In order to perform sampling of the surface waters near the vessel, a towed fish for pumping water under trace metal-clean conditions, which is towed by the vessel while it is steaming and allows continuous pumping directly into the clean laboratory container, was deployed via one of the ship's cranes immediately after the start of the cruise and left. Main focus of the work along the Namibian shelf, that was covered by a total of six stations until 16°45.4'S, 11°13'E was the investigation of the behavior of the trace metals and their isotopes in the water column of the Benguela Upwelling system. Given the relatively high swell of 4-5 m the trace metal clean CTD rosette and winch were not used at the first two stations but instead single GOFLO bottles were deployed on the aramid line to collect coarse resolution water profiles. On Monday the 23rd the swell had gone down and the new CTD rosette system could be used. At each station the normal stainless steel CTD rosette was used to collect samples for less contaminant prone trace elements, nutrients, nitrate isotopes, DIC, and others. This was accompanied by sampling of the particles from discrete depths in the water column using in situ pumps, which at the same time also pumped water across Mn fibres to adsorb the dissolved radium that will be applied as a tracer for the last contact of the respective waters with the ocean margin. In addition to the trace metal samples extensive amounts of samples were taken for experiments investigating the nitrogen cycle in the oxygen depleted subsurface waters of the upwelling region. On the 24th and 25th November two autonomous gliders were successfully recovered that had been released by previous cruise M120 and that had investigated the upper water column for different hydrographic properties along sections perpendicular to the coast for approximately 4 weeks.

Continuing northwards we carried out the first stations in deeper waters of up to 3000 m. This was started by a mobile winch test station with a weight in order to adjust the spooling of the new winch when for the first used in deep waters. At the deep station at 14°11.3'S, 10°53'E on Thursday 26th November technical problems with the new winch system were encountered that forced us to carry out sampling with the GOFLO bottles on the aramid line again. The problems could finally be overcome after one day with the help of the ship's chief engineer and electrician. Trace metal clean sampling was from then on performed with the new sampling system without further problems. A third glider was successfully recovered near the Angolan coast at 10°40'S, 10°53'E on Friday 27th although it turned out that the glider must have had a collision during which some of the sensors were damaged.

After a total of seven stations in Angolan waters at different depths we encountered the freshwater plume of the Congo River on the shallow shelf south of its mouth. A total of 3 more stations and intense surface water sampling with the towed fish were performed across the main

salinity gradient reaching values as low as 24 psu. We then followed the Congo plume in northerly direction until 3°S on the shallow shelf of Gabon, where the salinity was still markedly decreased with values of 32 and 33 psu.

On Tuesday 1st December the cruise continued westwards along 3°S with a high resolution profiles perpendicular to the continental slope, where intense sampling at 4 closely spaced stations until a water depth of 1000 m took place in order to obtain samples for combined radium isotope and trace metal concentrations in order to be able to quantify the amount of trace metals released from the continental margin sediments to the open ocean. Further offshore along the 3°S section at 6°46.5'E systematic deep water sampling down to depths below 4000 m at a spacing of approximately 2° started and continued with a total of 4 stations until the Zero Meridian, where the cruise turned south on the 5th December and followed the Zero Meridian southward until 30°S. The spacing between the deep stations reaching up to 5800 water depth was approximately 2.5° and the end of the section was reached on the 15th December after a total of 12 deep stations.

The last station was already somewhat shallower at 4200 m because the cruise track met the Walvis Ridge that was crossed during the eastward continuation of the cruise track on the 17th December and one station was occupied directly above the ridge at 3500 m water depth. During the transit to the latter station, collection of two large volume reference samples (500 litres each) under trace metal clean conditions was performed for the GEOTRACES program (for science plan see: SCOR working group, 2007). For this purpose a tent designed especially for this purpose by the group of K. Bruland, Santa Cruz, U.S. was installed below the hatch of the working deck of Meteor. The tent was supplied by HEPA-filtered air and the surface water was directly pumped into a first acid-cleaned 500 litre tank. The content of the cubitainer was then filled into 500 ml bottles for later distribution to laboratories interested in intercalibration of their measurements and participation in the GEOTRACES program. The second 500 litre tank was filled with water obtained from 2000 m water depth during two extra casts with the trace-metal clean rosette at the first station in the northern Cape Basin.

The cruise continued eastward at 30°S until the Namibian shelf and the Benguela Upwelling was reached, where again a high resolution section between 1000 m and 50 m water depth on the continental slope was sampled for combined radium isotope and trace metal investigations. The cruise track then followed the Namibian shelf northwards where another 7 shallow stations were sampled to complete the near shore north-south section along the West African coast. Immediately offshore Walvis Bay at 22°56.4'S, 13°56.2'E the last glider that had been deployed by previous cruise M120 was recovered with the zodiac. The last station was a revisit of the location of the very first station where it had not been possible to deploy the trace metal clean CTD rosette due to the high swell. The towed fish was taken out of the water and station work was finalized in the night of the 24th December after 190 deployments and 5170 nautical miles. Meteor then went to anchor in Walvis Bay and finally went to the pier in the morning of the 26th of December, where the cruise ended by packing of the containers and the disembarking of all scientists in the morning of the 28th December.

5 Preliminary results and planned work

Most work during the cruise focused on sampling seawater and particulate material under trace metal clean conditions. Only few measurements were actually already carried out on board. In the following we will describe the goals and methods of the sampling for the measurements of the different TEIs.

5.1 Hydrographic Observations and Nutrient Concentrations

5.1.1. Hydrography (W. Rath)

Water mass exchange in the tropical Atlantic Ocean including net northward meridional heat transport across the equator is accomplished by warm Tropical Surface Water (TSW), Atlantic Central Water, Antarctic Intermediate Water (AAIW) and upper Circumpolar Deep Water (uCDW) moving northward in the upper 1200 m of the water column and are compensated by cold and saline North Atlantic Deep Water (NADW) moving southward between ~1200 and ~4000 m. Near the bottom, the northward flow of Antarctic Bottom Water (AABW) carries denser waters formed in the Southern Ocean northwards (cf. Stramma and Schott, 1999). In the eastern south Atlantic and the Angola Basin the direct northward flow of AABW is inhibited by the Walvis Ridge, which acts as a topographic barrier. In contrast, in the western basin AABW flows into the Argentine Basin and transits northward through the Vema and Hunter channels into the Brazil Basin. AABW exits the Brazil Basin at its northern boundary via two routes: One part is diverted to the eastern Atlantic basins through the Romanche Fracture Zone at the equator, while the remainder crosses the equator into the Guiana Basin and further into the western North Atlantic basin.

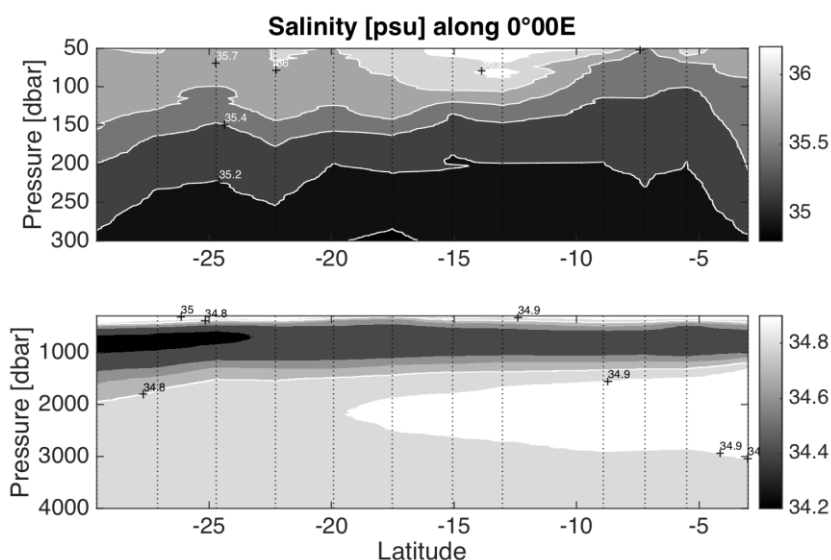
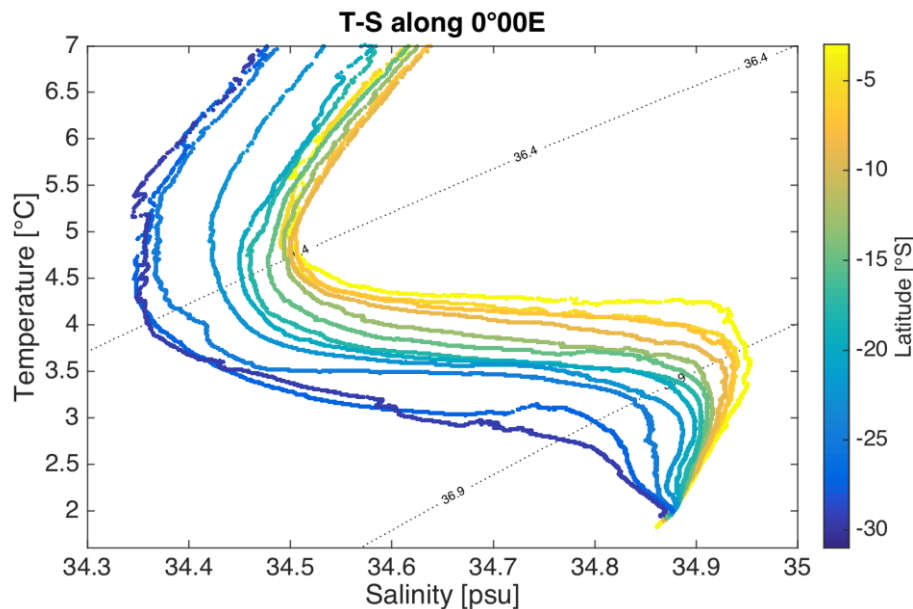


Figure 5.1: Salinity distribution along the N-S section at 0°E.

During M121, all the above major water masses were encountered and sampled (Figures 5.1 and 5.2): While AABW only prevailed at the deep stations in the northern Cape Basin south of the Walvis Ridge, AAIW was present at all deep stations of the cruise. The core of NADW was clearly distinguishable near 2000 m depth until 20°S (Figure 5.1). The T-S diagram of the deep waters along the North-South section along 0°E (Figure 5.2) clearly shows that mixing causes



the water masses to become systematically colder and fresher towards the South.

Figure 5.2: Temperature, salinity and potential density referenced to 2000m depth along the North-South section at 0°E. Colors indicate latitude.

5.1.2. Oxygen concentrations (A. Stippkugel)

The CTD systems were equipped with two independent optical oxygen sensors (optodes), which continuously measured oxygen concentrations in the water column. To calibrate the optodes, a discrete set of 1200 oxygen samples was analysed using the Winkler (1888) method. For the trace-metal-free CTD, oxygen was sampled and analysed from every available depth (up to 24 depths per cast) while for the standard stainless steel CTD at least two different depths covering relatively high and relatively low oxygen concentrations were sampled and analysed.

Figure 5.3 shows the oxygen concentration in the upper 500m along the westward section at 3°S and along the eastward section at approximately 28°S. In the West-East section at 28°S, the core of the pronounced South-Atlantic Oxygen Minimum Zone forming beneath the Benguela upwelling is visible east of 13°E.

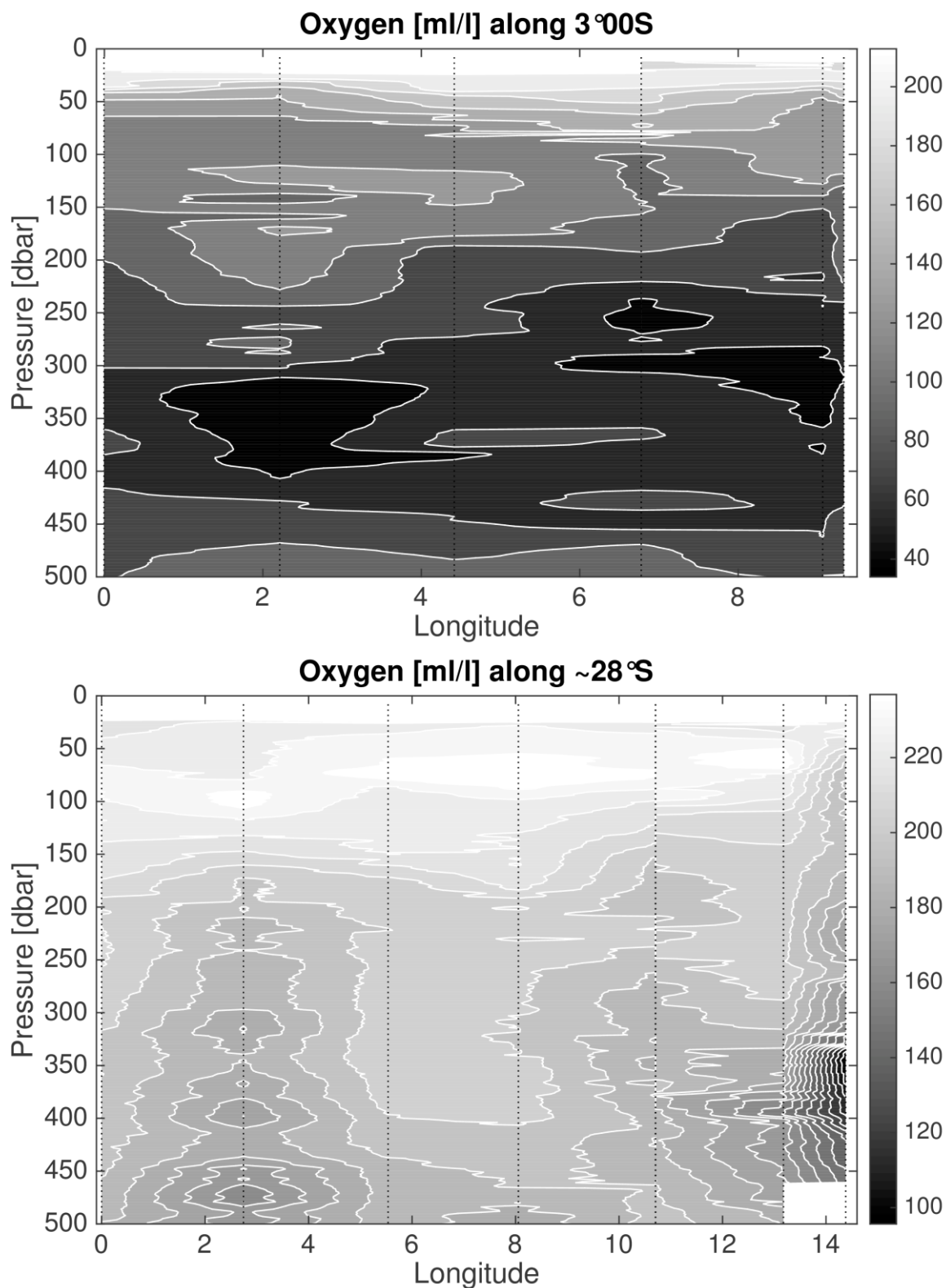


Figure 5.3: Oxygen concentration [ml/l] in the upper 500m at 03°S and near 28°S (note the different scales of the two sections).

5.1.3. Underway current measurements with the vessel-mounted ADCPs (P. Handmann)

Underway measurements of the currents were performed continuously throughout the whole cruise using two vessel mounted Acoustic Doppler Current Profilers (VMADCP). The METEOR

75kHz RDI Ocean Surveyor (OS75) mounted in the ship's hull, and a 38kHz RDI Ocean Surveyor (OS38) placed in the moon pool were used. VmDas Version 1.46 was collecting the data. Both ADCP systems were activated on 22nd November. The OS38 was aligned to zero degrees (relative to the ship's center line) in order to reduce interference with the OS75, which was aligned to 45 degrees. While the 38 kHz ADCP produced reliable data for the duration of the entire cruise the 75kHz ADCP experienced periods of lost velocity data, the reason of which could not readily be detected. The 75kHz ADCP was run in the more precise but less robust broadband (BB) mode whereas the 38kHz ADCP was run in the more robust and less resolving narrowband (NB) mode after the second day of the cruise.

During the entire cruise the SEAPATH navigation data was of high quality. Most shipboard acoustic devices were switched off during the cruise to avoid acoustic interferences. However, the 12kHz echosounder EM122 was in use during the entire cruise and delivered high quality bathymetry data without noticeable interference. Logging for the EM122 data also started on 22nd November. The VMDAS software was used to configure the VMADCPs and to record the VMADCP data as well as the ships navigational data. The data were processed on board and a preliminary data set was used for a number of near real time velocity products. Preliminary processed ADCP data between 0 and 100 m water depth show a turbulent and eddy-rich flow field along the 28°S west-east transect (Figure 5.4), which is related to the Agulhas rings formed further south.

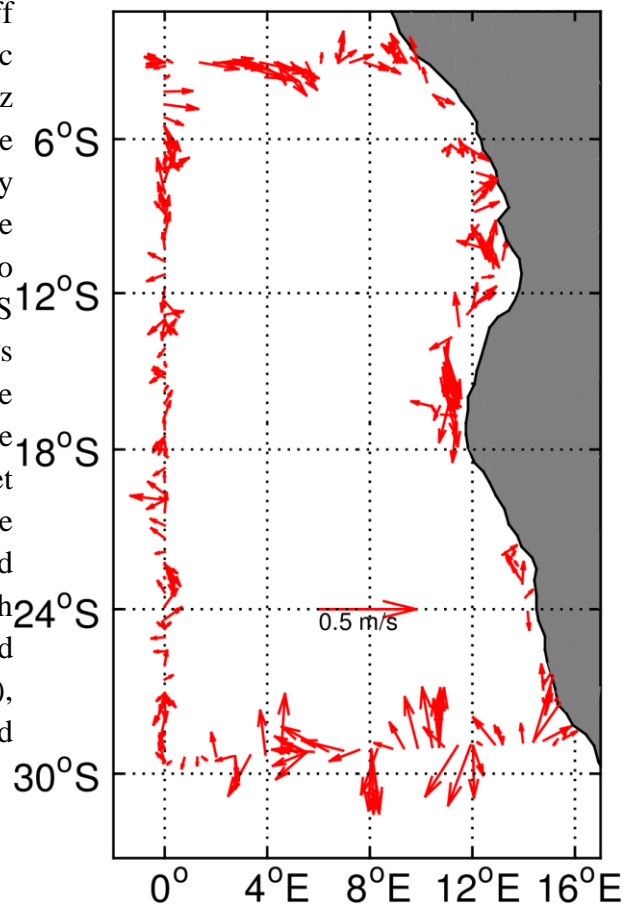


Figure 5.4: Horizontal velocities from the 38kHz ADCP averaged between 0-100m depth along the cruise track.

5.1.4. Nutrient distribution (J. Pampin Baro and J.C. Yong)

The distribution of nutrients in seawater is a key for understanding the biogeochemical processes, and their signatures allow the differentiation between the various water masses in the ocean. In addition, they are used to identify leaking bottles due to their well-defined and oceanographically consistent distributions.

Every single Niskin or Go-Flo bottle fired from every cast was sampled for nutrient analysis onboard. The seawater was collected in acid cleaned (10% HCl) 60 mL polypropylene bottles. Containers and caps were rinsed three times with the water of the sample before the actual sampling. The bottles were completely filled without leaving head space to avoid any gas exchange that may have affected the ammonia measurements.

In order to verify that phytoplankton present in the samples did not change nutrient concentration between sampling and analysis, filtered and unfiltered samples were collected from a number of the Niskin bottles and showed that i) phytoplankton activity between sampling and analysis did not affect the measurements (~ 8 h max. in most of the cases), ii) filtering did not affect the measured variables (i.e. ammonia). Samples were placed immediately in the fridge after collection (4°C in darkness) in case they could not be immediately analyzed.

Analysis of nutrients was undertaken on board by segmented flow injection analysis using a QUAATRO (Seal Analytical) auto-analyzer. The system set-up included 5 channels for nitrate + nitrite, silicate, nitrite, phosphate, and ammonia. A total of ~ 220 surface samples collected by the towed fish, and ~ 3500 samples from the different casts were measured. After analysis, samples with concentration lower than ~ 100 nM for mainly nitrate + nitrite were stored at -20°C to be re-analyzed on board following the method of Patey et al. (2008), referred to as ‘Nanomolar FIA’ from here on. Samples were defrosted sufficiently in advanced before analysis. With this method and using the same chemistry the limit of detection is improved by coupling a liquid wave capillary cell (LWCC 220 cm; WPI instruments) to the instrumental setup and measuring the absorbance with a mini spectrophotometer Ocean Optics USB4000. Directly after nanomolar determination, all of them were analyzed with the QUAATRO system again, to make sure that sample storage did not change any parameter.

The analytical methods followed during the M121 GEOTRACES cruise correspond to those described by QuAatro Applications. Low nutrient seawater was used for the calibration during standard preparation and as baseline for all channels with the exception of the fluorometer for the ammonia channel, for which the baseline was set to zero using deionized (MilliQ) water prior to analysis. Certified Reference Material for Nutrients in Seawater (RMNS) was used in order to I) guarantee repeatability and reproducibility between analytical runs and to II) validate the data set in terms of compatibility within the scientific community. Nutrient analysis was validated with KANSO CRM. As an example the preliminary phosphate distribution along most of the Zero Meridian section is shown in Fig. 5.5.

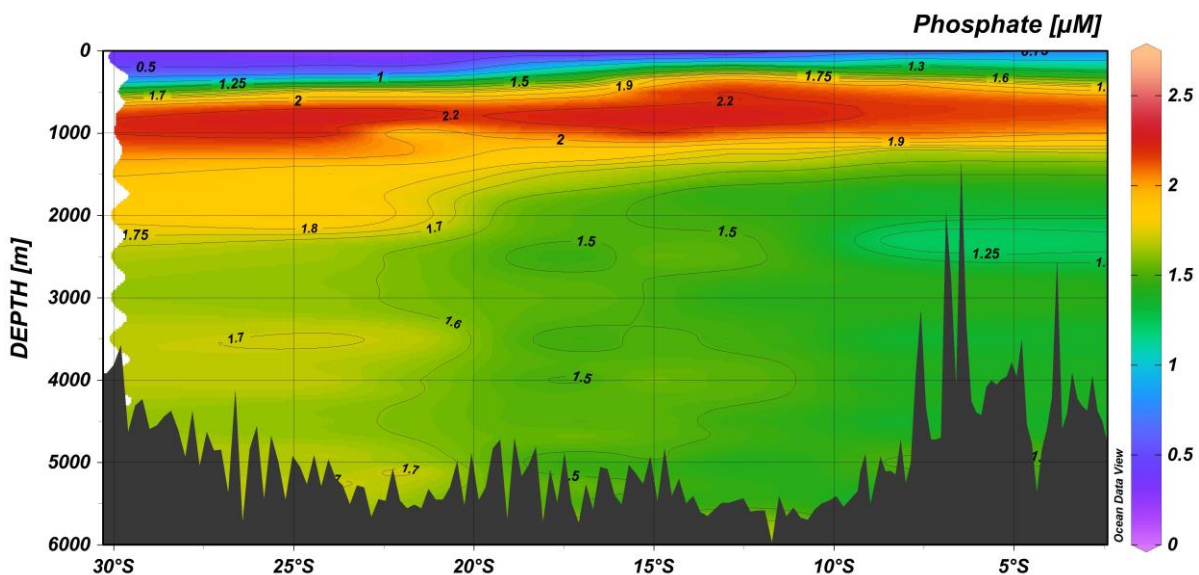


Figure 5.5: Phosphate distribution (μM) along the Zero Meridian section. Clearly visible is the pronounced phosphate maximum associated with the AAIW near 1000 m water depth and southward flowing NADW marked by the phosphate minimum centred near 2200 m water depth, which is eroded during southward advection. The plot was produced using the ODV software (Schlitzer, 2012).

5.2 Water Sampling with the Trace Metal Clean CTD/Rosette

(P. Lodeiro, C. Schlosser)

Iron and other trace metals, including zinc, cobalt, copper, cadmium, can be (co)-limiting nutrients for phytoplankton growth (e.g. Boyd, et al., 2010). A key aim of the GEOTRACES programme is to investigate the processes by which these trace metals are supplied by external sources to the ocean (aeolian dust, river discharge, resuspension of continental shelf sediments and offshore transport processes) and the mechanisms that determine their scavenging/uptake, dissolution of particles, supply by remineralization of organic matter. By examining trace metal distributions along the cruise track, as well as their supply, removal, and physico-chemistry, we will enhance the understanding of key biogeochemical processes. The new results will fill a gap in the global trace metal distribution data set.

Sampling and methods

Along the entire cruise track surface seawater samples (3-4 m water depth) were collected with a trace metal clean towed Fish by direct transfer of waters into the trace metal laboratory container using a Teflon diaphragm pump and an acid-washed braided PVC tube. Samples were filtered in-line through a 0.8/0.2 μm cartridge filter (AcroPak1000™) into acid washed low-density polyethylene (LDPE) bottles. At a total of 208 locations surface seawater samples were collected for trace metal analysis and other parameters including nanomolar level nutrients, CDOM and for incubation experiments.

Full depth seawater samples between 10 and 6000 m were obtained at 51 different sites using the GEOMAR trace metal clean CTD rosette (TM-CTD) equipped with 24 trace metal clean Go-Flo bottles. The TM-CTD water sampling rosette was attached to a conducting plastic coated Kevlar wire and was operated over the A-frame at the aft of the ship via a new trace metal clean winch system. The TM-CTD was equipped with the same standard Seabird temperature/conductivity/pressure/oxygen/turbidity sensor package as the second stainless steel CTD rosette, which was used for sampling of less contaminant prone metals at the same stations. After recovery, the 12 L Go-Flo bottles were immediately carried to the trace metal clean sampling container where unfiltered seawater samples for total dissolvable trace metal analysis were transferred into acid cleaned 125 ml LDPE sample bottles. Another set of unfiltered samples for Pb isotopes (MPI Mainz), nutrient, salinity, and oxygen analyses were collected in acid cleaned LDPE, high density polyethylene bottles and glass bottles, respectively.

Filtered seawater samples for ligand (GEOMAR (iron) and University of Otago (copper)), dissolved trace metal (GEOMAR and Jacobs University Bremen), trace metal isotope (GEOMAR (iron) and MPI Mainz (cadmium)), and shipboard aluminum/iron analysis were obtained by applying a slight N_2 overpressure (~ 0.2 bar) to the Go-Flo bottles and filtration of the seawater through 0.8/0.2 μm Acropak 500 cartridge filters (Pall). These samples were collected in acid cleaned 125, 250, 1000, 4000 mL LDPE bottles, respectively. In order to collect the soluble trace metal fraction, 125 mL of the 0.2 μm filtered seawater were additionally filtered through acid washed 0.02 μm filters (Millipore). The filtrate was dispensed into acid cleaned 60 mL LDPE bottles. Samples for metal complexing ligands were immediately transferred to a -20°C freezer and shipped frozen to GEOMAR, Kiel. All trace metal seawater samples from the GEOMAR group were acidified to $\text{pH} < 2$ by ultra-pure grade hydrochloric acid (HCl, UpA Romil). Suspended particles in seawater samples were collected onto acid washed 0.2 μm polyethersulfone (PES, Millipore) membranes. The membrane was placed in acid washed

Swinnex filter holders that were attached directly to the 0.2 bar pressurized Go-Flo bottles. After a minimum of 4 litres of seawater was filtered the PES membranes were rinsed with 50 mL deionized Milli-Q water, placed in cleaned Petri-dishes and stored in a -20°C freezer. Filtration and acidification of the seawater samples were conducted in a laminar flow bench. The samples were stored in the dark and shipped to GEOMAR, Kiel for further analysis. Particle loaded PES filters were shipped frozen to GEOMAR, Kiel. The trace metal content of soluble, dissolved, and total dissolvable seawater samples will be analyzed by the group of E. Achterberg by inline pre-concentration and isotope dilution inductively coupled plasma mass spectrometry (ID-ICP-MS, Element II XR, ThermoFisher), following Milne et al. (2010). Analyzed elements of the different size fractions will include iron, zinc, cobalt, cadmium, copper, nickel, lead, and manganese.

5.3. Dissolved aluminium distribution

(J.-L. Menzel Barraqueta)

The concentrations of aluminum are only at the nanomolar level, despite that it is the third most abundant element in the Earth's crust. This observation is attributed to the high particle reactivity of aluminium. Dissolved aluminium in surface waters has been used as a tracer for atmospheric dust deposition (Measures et al., 2005) whereas at depth it has been shown to trace major water masses and their mixing (Middag et al., 2011).

Samples were collected from the TM-CTD rosette for dissolved and total dissolvable aluminum on all stations and were filtered, treated and collected as described in section 5.1. Additionally, at one open ocean and one shelf station samples for soluble aluminum were taken. These samples were filtered through acid cleaned (10% diluted UpA HCl, Romil) 0.03 µm polyethersulfonate filters and were acidified to a pH of 1.9 to also be stored in 30 ml LDPE bottles. Samples were analysed on board on a SHIMADZU RF-10A XL fluorometer following the preparation and preconcentration method of Brown and Bruland (2008) after buffering online with a 2M Ammonium acetate buffer (Romil, UpA) to a pH of 5.2. All samples were analysed in duplicate.

Preliminary results (Fig. 5.5) show a distinctive distribution of dissolved aluminum in the profiles of different areas. Higher values were generally found along the shelf likely due to partial dissolution of the direct dust inputs, whereas lowest concentrations were found in the gyre.

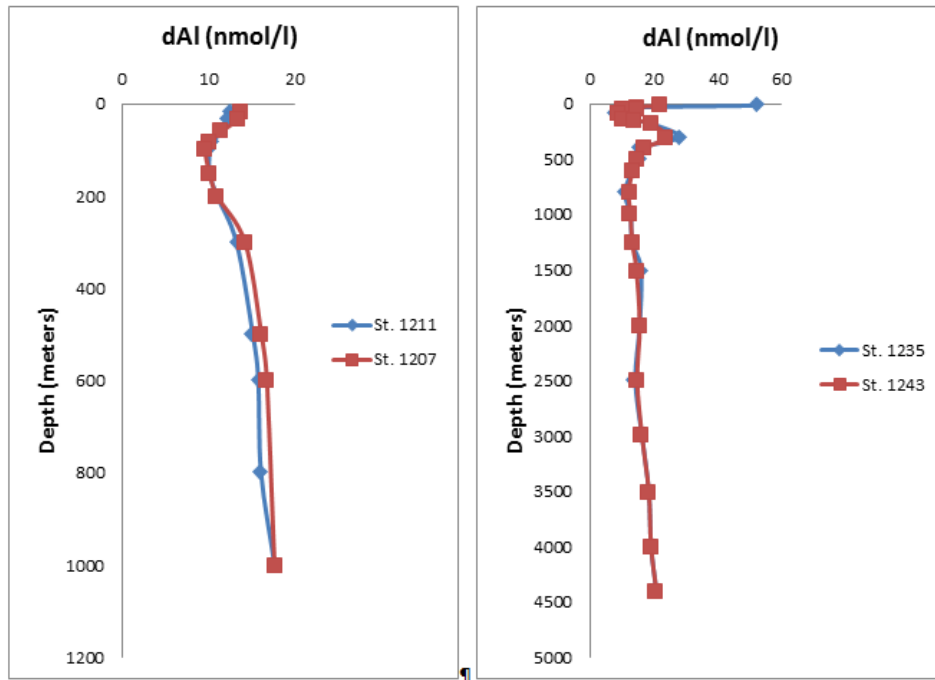


Figure 5.6: Examples of preliminary dissolved aluminium concentrations (nmol/l) on the Angolan shelf (stations 1207 and 1211) and along the open ocean E-W section (stations 1235 and 1243).

5.4. Dissolved Fe speciation and hydrogen peroxide concentrations

(M. Hopwood)

The transient species Fe(II) and hydrogen peroxide (H_2O_2) are both challenging to measure in the marine environment. Fe(II) is a key component in the natural biogeochemical cycle of Fe because of its high bioavailability compared to the Fe(III) species, and hydrogen peroxide is normally present in seawater as a byproduct of photosynthesis. These two species interact with each other as, after oxygen, peroxide is the dominant oxidizing reagent for Fe(II) in the water column.

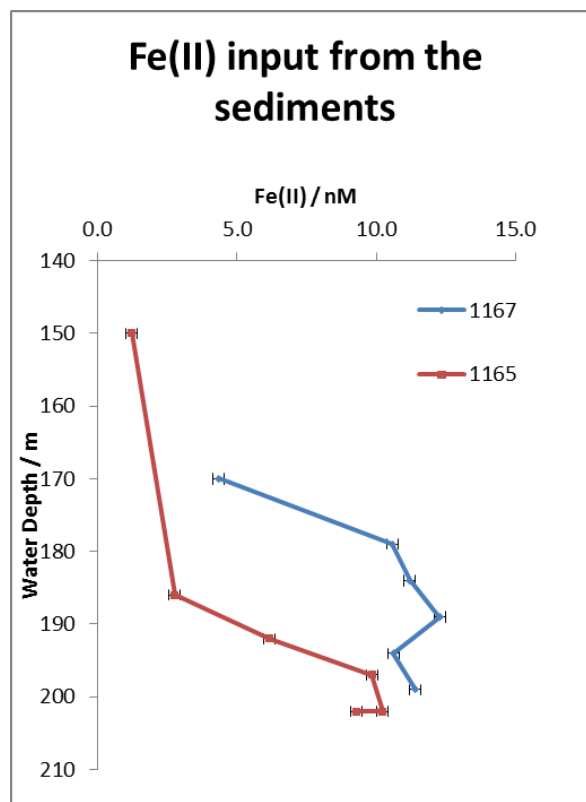
Recent work has suggested that measurable (1-5 nM) concentrations of H_2O_2 can be found in the deep ocean at depths of >1000 m. This is surprising given that the dominant sources of H_2O_2 are thought to be photochemical. Recent work at GEOMAR has, however, identified several ions (such as Fe(II), Fe(III) and V(IV)) as elements interfering with the analysis of H_2O_2 . One of the objectives of cruise M121 will be to determine whether H_2O_2 can really be found in the deep ocean or whether this observation is merely a false positive result associated with problems of the luminol based method used to measure H_2O_2 concentrations in seawater. The availability of ICMPS data on Fe and V speciation will allow these interferences to be properly assessed after the M121 cruise.

The focus of our Fe(II) analysis will be investigating the role of Fe(II) in Fe transport from the shelf to the open ocean. Vertical profiles of Fe(II), also determined using a luminol based flow injection method, will be combined with total, dissolved and colloidal Fe data to assess how the oxygen minimum zone affects the vertical flux of the essential nutrient Fe from sediments into the water column. Fe(II) data will also need calibrating with known interferences (Fe(III) and V(IV)) and thus will be subject of future land-based analyses.

Onboard the vessel a flow injection system was used to determine Fe(II) and H₂O₂ at every station whereby Luminol chemoluminescence was the basis of both analyses. Water samples for H₂O₂ and Fe(II) analyses were collected under a nitrogen atmosphere from Go-FLO bottles mounted on the trace metal clean rosette. Samples were then analyzed as quickly as possible (normally within 1 hour of the bottles arriving on deck) to minimize effects of gas exchange on Fe(II) oxidation.

The uncalibrated data collected in the upwelling regions along the shelf during M121 suggest massive release of Fe(II) into the water column (Figure 5.7), which appears to be correlated with elevated radium concentrations. At several shallow stations along the M121 shelf transect Ra and Fe(II) analyzers had to be recalibrated twice to account for extremely high “off-the-scale” readings.

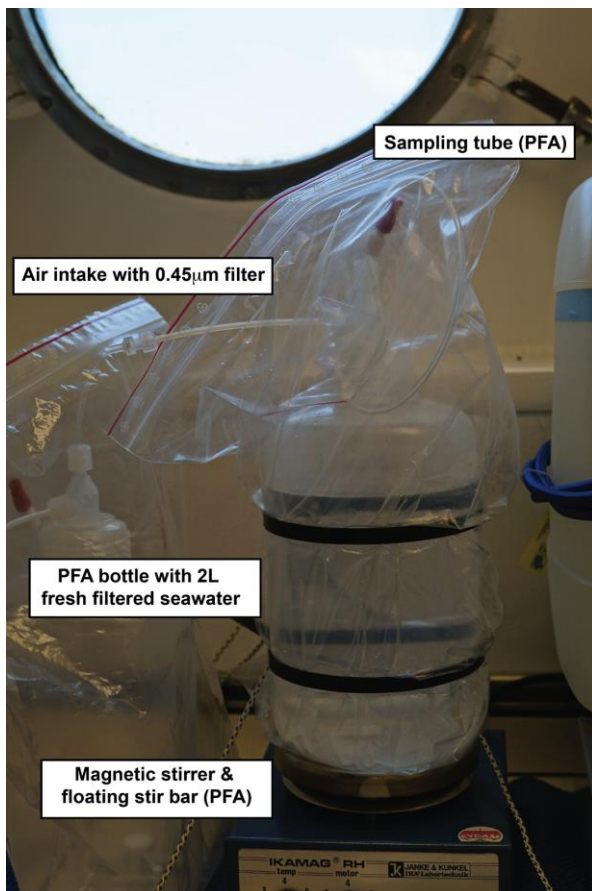
Figure 5.6: Examples for uncalibrated Fe(II) concentration data of two shelf stations with intermediate Fe(II) concentrations.



5.5. Dust leaching experiments (E. Hathorne)

The partial dissolution of mineral dust and volcanic ash deposited in seawater is thought to be an important source of trace metals such as Fe and the Rare Earth Elements (REEs) to surface waters. Although the deposition flux of dust or ash can be measured directly, the fraction that is readily dissolved in seawater is poorly constrained and appears to vary widely. Previous experiments to determine the solubility of various trace metals from dust have been conducted in the laboratory under conditions not entirely representative of the natural situation. For example many Fe solubility experiments were conducted with de-ionised water at relatively high particle concentrations and struggled to mimic the natural processing of dust in the atmosphere via acidic leaches (e.g. Schroth et al., 2009). Cruise M121 afforded the opportunity to take the dissolution experiments to sea and to use freshly collected seawater and natural dust and ash samples to mimic the natural dissolution processes as closely as possible. Experiments were also conducted under natural sunlight conditions on deck to examine the effect of UV radiation on the dissolution process and water from the Congo River plume was used for an experiment to investigate the role of terrestrial organics on dust dissolution in shelf seas.

During M121 twenty dissolution experiments were conducted using four different 10L batches of 0.2 μm filtered surface seawater. We tried to use seawater with the lowest initial trace metal content from the open ocean waters of the South Atlantic gyre. For each experiment 2L of the mixed 10L batch were transferred into a PFA bottle containing a floating magnetic stir bar and a PFA sampling tube and air vent installed in the lid (Figure 5.8). After a short temperature equilibration time the pre-weighed (in the GEOMAR clean laboratory) dust or ash samples (around 4 mg of material resulting in a water/rock ratio of 500,000) were added to the experiment vessel, which was shaken well and was then returned to the magnetic stirrer to ensure the particles to remain in suspension. A control experiment to which no dust or ash was added was also performed. Samples were taken via the PFA sampling tube with an acid cleaned syringe



and then filtered through acid cleaned 0.22 μm PES Express membrane filters in acid cleaned Swinnex filter holders into acid cleaned PE tubes or bottles. Samples were generally acidified within 48 hours of collection with self-distilled HCl (for REEs) or UPA grade HCl (for other trace metals). Samples were taken every 10 mins for the first hour of the experiment, then hourly for the first 6 hours, and then roughly every 3 to 6 hours until the end of the experiment which lasted between 18 and 48 hours. Some samples were taken for shipboard analysis of Fe^{2+} and peroxide concentrations (see section 5.4). The preliminary peroxide results exhibited significantly higher values in the outside experiments on deck during the afternoon hours of peak insolation highlighting that some natural photochemical processes cannot be adequately simulated in the laboratory. In total some 300 samples from the dissolution experiments were returned to GEOMAR for REE analysis and 90 samples for other trace metals.

Figure 5.8: Setup for dust leaching experiments performed.

5.6. High Field Strength Elements

(G. Merschel, R. Zitoun)

Trace metals play an important role for the biogeochemical cycles in the world's oceans but the distribution, sources and sinks of many of them are not yet well understood. During the M121 cruise, 560 samples (filtered through a 0.2 μm filter) were taken at 38 stations under trace metal clean conditions in order to investigate the distribution of the dissolved trace metals Ti, W, Nb, Hf, Zr, V, and Mo and their controlling factors. Potential sources of these elements include riverine and dust inputs and mobilization from shelf sediments. During this cruise, samples were taken at locations close to land on the nearshore S-N section, which are influenced by one or

more of the three potential input sources. In contrast, the samples collected along the open ocean offshore sections allow a comparison of the distribution of these metals with the different major deep water masses that were clearly identifiable by their oxygen and nutrient characteristics determined on board. In addition, aliquots of selected samples at selected stations (355 samples at 26 stations) were also passed through a 0.015 μ m filter to remove the colloidal fraction. This will allow the investigation of the importance of the colloidal pool on the distribution of these elements given that some of these elements are highly particle reactive. The metal concentrations of the samples (915 in total) will be analyzed with the online pre-concentration system SeaFAST coupled to an ICP-MS at Jacobs University Bremen.

In addition, 150 samples were taken at 18 stations to determine the redox speciation of V, Mo, Cr and Mn. Most samples were taken close to the shore to investigate the availability of these micronutrients in waters with high bioproductivity. Given that the speciation of an element also controls its bioavailability, the coastal profiles with a pronounced oxygen minimum zone were of particular interest. V(IV) and V(V) separation was performed under nitrogen atmosphere on board by solid phase extraction, while Mo (V) and Mo (VI) will be separated by solid phase extraction at the Geochemistry Laboratory at Jacobs University Bremen. The concentrations of both element separates will be analyzed by ICP-MS. The redox speciation of Cr (Cr (total); Cr (VI) and Cr (reactive)) will be determined by adsorptive cathodic stripping voltammetry, while Mn (III) and Mn (IV) abundances will be analyzed by a spectrophotometric method, both at Jacobs University Bremen. Unless the samples were processed on board immediately after collection, they were kept frozen until analysis to guarantee their integrity.

In order to predict the nutritive or toxic effect of the mobile and bioactive metal copper in a marine ecosystem its aqueous speciation needs to be determined given that only the free metal ions of a given metal are biologically available. However, organic complexation of metals with natural ligands can markedly influence the availability of metals to biota, which reduces its deleterious effects. 170 water samples for the analysis of copper speciation and corresponding organic ligands were taken during M121 at 20 stations with a focus on the Congo River input and the E-W as well as W-E transects perpendicular to the coastline. These samples will help to develop a better understanding of copper toxicity, complexation, as well as biogeochemical cycling in the open ocean. The samples were frozen for subsequent determination of bioligands, as well as the prevailing copper speciation via the commonly used AdSV voltammetric technique at the University of Otago (New Zealand).

5.7. Radiogenic Isotopes (Nd, Hf) and Rare Earth Elements

(P. Rahlf, M. Frank)

Radiogenic Nd and Hf isotopes are a set of tracers that provide information about water mass mixing and erosional input into seawater. The isotopic signatures in continental rocks vary as a function of type and age of the rocks, which release these signatures during weathering and transfer them to seawater via riverine and dust inputs, but also via exchange with shelf sediments (e.g. Frank 2002). The residence times of both metals are on the order of the global mixing time of the ocean which means that water masses in the Atlantic basin are labeled with distinct isotopic signatures that only change by mixing with other water masses in the absence of external inputs and at a distance from the coast (e.g. Rickli et al., 2009).

During cruise M121, one of the main goals was the determination of the Nd and Hf isotope compositions, as well as of the Rare Earth Element (REE) distributions within the main intermediate and deep water masses (NADW, AAIW, AABW) in order to investigate if the mixing documented by temperature and salinity corresponds to the mixing relationships and gradients given by the Nd and Hf isotope compositions and concentrations along the cruise track, which is crucial for their application as paleo circulation proxies. These radiogenic isotope signatures of the waters are set by inputs from land and thus the second main goal was a detailed sampling of these inputs including the Congo and Orange Rivers, dust inputs as well as exchange with the continental shelf. For this purpose samples from near the bottom and on the shelf along were taken along the entire nearshore S-N section. The Nd and Hf isotope data will be combined with Ra isotope measurements in the surface waters and along the sections along the upper continental slope, which provide detailed information about the inputs from land (see section 5.10.).

For the radiogenic Nd and Hf isotope measurements a total of 208 samples were taken covering the entire cruise track. 20l of seawater from two Niskin bottles of the stainless steel standard rosette collected in 20l cubitainers and were filtered through 0.45µm Nucleopore filters within a few hours after collection. A 2l aliquot of each sample was separated for analyses of REEs and stable Ba isotopes. Concentrated distilled HCl and Fe₃Cl solution were added to the samples and were allowed to equilibrate. After 24 hours, NH₃ was added to increase the pH-value again to values near 8, which resulted in the co-precipitation of the REEs and Hf with the iron hydroxide. After 48 hours the excess water was decanted and the iron hydroxide precipitates were filled into 2l-bottles for transport to the laboratory at GEOMAR for further ion-chromatographic cleaning and measurement via MC-ICPMS.

5.8. Stable Cd Isotopes and radiogenic Pb Isotopes

(S. Galer)

High-precision Cd isotope data on seawater samples collected during M121 will be obtained to further develop the use of Cd isotopes as proxy for water mass mixing and nutrient utilization. No Cd isotope data are yet available for the southeastern Atlantic and the samples from Meteor cruise M121 offer a unique opportunity to investigate the effects of water mass mixing vs. biological uptake on the distribution of dissolved Cd isotopes. Seawater volumes varying between 10 L for surface waters, 4 L for intermediate depth and 1 L for deep waters were sampled using the trace metal clean rosette (surface samples were taken with the towed fish), and were directly filtered through 0.2µm Acropak filter capsules (1 litre and surface water samples) and PES filters (4 litre samples) and acidified to a pH of 1, using ultra-clean HCl. Samples at seven vertical profiles were collected, each consisting of 10 depths, and will be analysed for their stable Cd isotope compositions by Thermal-Ionization Mass Spectrometry in the laboratories of the Max-Planck Institute for Chemistry in Mainz (Germany).

At these seven stations a total of four 1 litre samples each were taken from water depths below 1500 m with the trace metal clean rosette and were also immediately filtered to determine the least anthropogenically influenced radiogenic Pb isotope compositions of deep waters using a ²⁰²Pb-²⁰⁵Pb double spike. The double spike will allow simultaneous determination of Pb concentration by isotope dilution and instrumental mass fractionation correction. Chemical

separations and isotope measurements by Thermal-Ionization Mass Spectrometry will be performed at the Max-Planck Institute (Mainz). The objective of investigations of the distribution of Pb and its isotopes is to study the impact of anthropogenic inputs (mainly gasoline Pb) on ocean biogeochemistry by documenting the distribution and the various natural sources of Pb to the ocean and to assess deep ocean ventilation rates.

5.9. Particulate Trace Metals, Aerosols and Rain

(E. Achterberg)

Sampling of suspended and sinking particles was carried out using *in situ* pumps. In addition, at a range of stations Mn cartridges for Ra isotope analyses were deployed with the pumps. All particulate samples and long-lived Ra isotopes will be analysed in land-based laboratories. The short-lived Ra isotopes were counted at sea (see 5.10). A total of 5 *in situ* pumps (Challenger Oceanics Ltd) were applied for *in situ* high volume filtration. The pumps were kindly provided by the NERC Research Equipment facility of the National Oceanographic Centre, Southampton, United Kingdom. The pumps were fitted with a 53 µm Nylon filter and a 1 µm polycarbonate (Nucleopore) filter. The nylon filters were rinsed with deionised water and the polycarbonate filters were acid cleaned with ultrapure HCL (1 M) prior to use.

At stations on the longitudinal east to west and west to east transects, Mn cartridges were deployed in the pumps, in addition to the filters. At a number of dedicated stations, the *in situ* pumps were deployed without filters but only with Mn cartridges for radium isotope sampling. The pumps worked very reliably, following an overhaul of the electronic components by the NERC technicians.

A total of 36 deployments of the 5 pumps were undertaken. At a number of occasions one of the pumps did not pump, which was likely the result of insufficient priming of the pumps with deionised water prior to deployment. The applied pumping time ranged from 1 to 1.5 hours, depending on the expected particle loading in the water. The total volume filtered by the pumps ranged from 150 to 1600 litres. The filters were stored frozen and shipped to Kiel at -20°C. The Mn cartridges were handled at sea by Lucia Vieira. All particulate samples and long-lived Ra isotopes on collected by the Mn cartridges will be analysed in the land-based laboratories. The short-lived Ra isotopes were counted at sea (see 5.10).

The 5 pumps were deployed spaced out in the water column on the plastic coated Meteor line to a maximum depth of ca. 1250 m at deep oceanic stations, and to maximum depths close to the seafloor on the shelf. At 3 deep open ocean stations we the pumps were deployed attached to the steel cable of the CTD. These deployments were aimed at sampling for Ra isotopes near the seafloor in order establish Ra supply released from the sediments. Indeed, at two of the deep deployments significantly elevated counts of short-lived ^{223}Ra and ^{224}Ra were observed near the seafloor documenting the release of Ra from the deep-sea sediments, which will form the basis for dedicated sampling efforts during future expeditions.

We deployed two high volume aerosol collectors (Tisch TE-6070V-BL; University of Birmingham Dr Z Shi), which sampled the PM10 dry aerosol fraction during the cruise. The flowrate of the aerosol collectors was between ca. 1-1.7 m³ min⁻¹. The collectors were placed on the monkey island of the vessel, and away from areas where personnel were smoking. The collectors were switched off during periods of unfavourable winds, when stack contamination was a possibility.

We employed on one of the collectors a Whatmann 41 filter (acid-cleaned, 203mm x 254 mm) for trace elements and isotope sampling. The other collector had a quartz filter (QMA, Whatmann, pre-combusted; 203 mm X 254 mm) for organic matter and mineral collection. Filters were changed every 24-48 h, and stored frozen (-20°C). A total of 17 filters each were collected during the cruise. The sampling protocol followed the GEOTRACES recommendations.

To complement aerosol sample collection during the cruise, a rain water collector was set up on the uppermost deck. Clean plastic funnels were opened only at the start of rain events to collect trace metal clean rain water samples and then water was immediately processed in the laboratory and distributed to interested partners for chemical analysis. 8 samples were collected in total, with volumes ranging from 10 mL to 1.5 L per event. The rain samples were filtered on the vessel, and stored for analysis at GEOMAR in Kiel.

5.10. Radioactive Isotopes (Ra)

(L. Vieira)

The four radium isotopes (^{226}Ra , $T_{1/2}=1600$ y; ^{228}Ra , $T_{1/2}= 5.75$ y; ^{223}Ra , $T_{1/2}=11.4$ d; ^{224}Ra , $T_{1/2}= 3.66$ d) have been widely used as geochemical tracers and applied in studies of the age of water masses and ocean circulation. Long-lived ^{226}Ra and ^{228}Ra are mainly supplied to the ocean by diffusive inputs from deep-sea and continental shelf sediments, respectively, and are able to provide information on both horizontal and vertical mixing in the ocean. Short-lived ^{223}Ra and ^{224}Ra are used to investigate the fluxes of submarine groundwater discharge (SGD) into coastal seas, the horizontal mixing between the coast and offshore waters, to trace river plumes, and to determine the ages of continental shelf waters since their last contact with the coast. In the frame of M121 the four radium isotopes are applied to constrain the influence of the Congo River and its contribution to the distribution of TEIs in surface and deep waters of the Angola Basin and to evaluate the sources of TEIs such as Fe in the study region.

Along the cruise track water sampling was carried out using the standard rosette for full water column sampling of ^{226}Ra isotopes. At selected stations (see below) our sampling was complemented by deployments of in-situ Challenger Oceanics pumps in order to obtain water column profiles of dissolved $^{228}\text{Ra}/^{226}\text{Ra}$ and $^{224}\text{Ra}/^{223}\text{Ra}$. The pumps were equipped with Mn-cartridges which adsorb the dissolved Ra. All radium isotopes were also sampled from surface waters by pumping ~ 250 L of seawater into 100 L barrels on the working deck during stations, from where the water was slowly pumped over a Mn-fiber column. Short-lived radium isotopes ^{224}Ra and ^{223}Ra were measured on-board using four delayed coincidence counters (RaDeCC, (Moore and Arnold, 1996)). The long lived ^{226}Ra will be determined in the land-based laboratories using an Element 2 HR-ICPMS. For the determination of $^{228}\text{Ra}/^{226}\text{Ra}$ the Mn-cartridges and Mn-fibers will be ashed and acid-leached followed by a SrSO_4 precipitation and the measurements will also be performed by HR-ICPMS. The discrete ^{226}Ra measurements will be combined with $^{228}\text{Ra}/^{226}\text{Ra}$ from Mn-cartridges and Mn-fibers to calculate seawater ^{228}Ra concentrations.

The preliminary distribution of the short-lived ^{224}Ra in the surface water samples (the final concentrations (dpm/100L) will be obtained after further measurements) along the coast in the northern part of the study area is shown below (Fig. 5.9). The Congo plume is clearly reflected by highly elevated concentrations of ^{224}Ra , for which pronounced gradients in the $^{224}\text{Ra}/^{223}\text{Ra}$ distribution between the river mouth and the open ocean are expected.

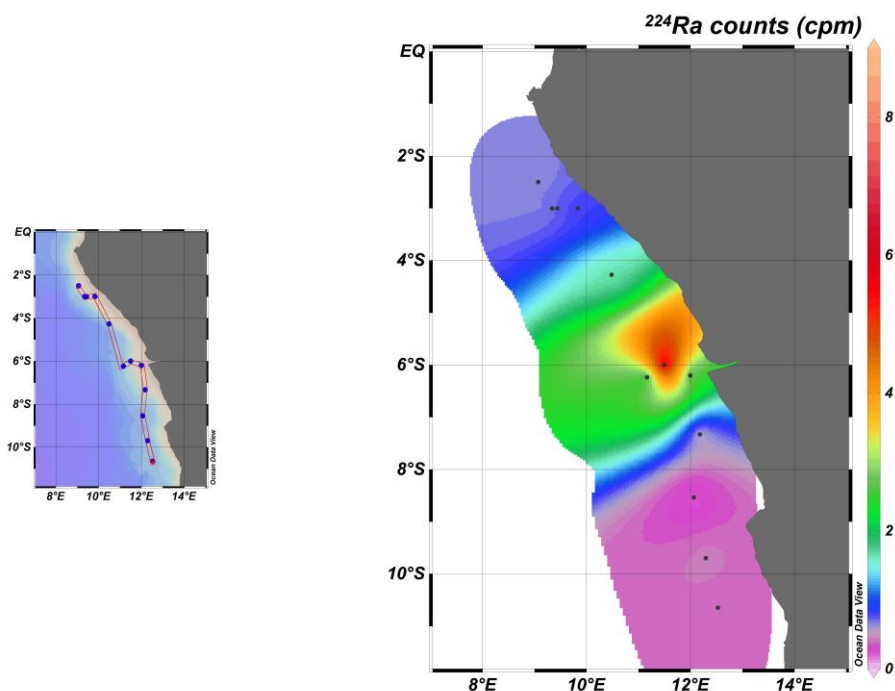


Figure 5.9: Preliminary distribution the short-lived ^{224}Ra concentration (cpm) in surface waters of the northern part of the cruise track including the Congo inflow at 6°S. The plot was produced using the ODV software (Schlitzer, 2012).

5.11. Radioactive Isotopes (^{231}Pa , ^{230}Th)

(F. Deng, G.M. Henderson)

Naturally occurring radionuclides ^{231}Pa (half-life 32.5 kyr) and ^{230}Th (half-life 75.2 kyr) are produced in seawater through α -decay of dissolved ^{235}U and ^{234}U , respectively. Since uranium in seawater is uniformly distributed spatially and temporally, ^{231}Pa and ^{230}Th are produced in water column at a constant production ratio of 0.093. Once produced, ^{231}Pa and ^{230}Th are removed from the water column through scavenging by sinking particles and subsequent burial in sediments. While ^{230}Th is readily removed to the sediment, less particle-reactive ^{231}Pa can be advected away from its site of formation by ocean circulation. Variations of the strength of ocean circulation and the rate of water mass exchange are therefore reflected by changes in $^{231}\text{Pa}/^{230}\text{Th}$ ratios in the sediment, which have been linked to abrupt climatic changes in the past (e.g. McManus et al., 2004). However, other factors such as particle flux and its composition also play a role in controlling the distribution of ^{231}Pa and ^{230}Th in the water column, which needs to be better understood for the reliable use of sedimentary $^{231}\text{Pa}/^{230}\text{Th}$ ratios as a proxy for the reconstruction of past ocean circulation.

Water-column measurement of ^{231}Pa and ^{230}Th obtained from cruise M121 will allow the test of hypotheses regarding the relative importance of regional variations in circulation, particle composition, and particle flux. The data of the cruise will also allow the quantification of boundary scavenging of ^{231}Pa and ^{230}Th associated with the biologically productive Benguala upwelling system and of bottom scavenging of both radionuclides by resuspended sediments in nepheloid layers.

During the cruise a total of 187 of seawater samples (5-10 liters) for determination of dissolved ^{231}Pa and ^{230}Th were collected. Samples of 5 liters were taken from the Niskin bottles of the standard CTD rosette covering the full water column at 12 stations. Surface samples of 10

liters corresponding to these stations were collected using the towed fish. Surface samples, at 15 m (5 liters) and 30 m (10 liters), were also collected at 16 shallow standard CTD stations along the nearshore section near the coast. Seawater was filtered directly from the Niskin bottles through Supor filters (0.8mm, 0.45µm) into acid cleaned sample bottles and stored for further treatments and analysis to be carried out at the University of Oxford. These include addition of ^{233}Pa and ^{229}Th - ^{236}U spikes, chemical separation and purification of Pa and Th by anion exchange chromatography, and measurement by ICP-MS.

5.12. Nitrogen loss and fixation

(L. Bristow, S. Meyer)

The main goal of the work on the nitrogen cycle was to investigate the rates and pathways of microbial nitrogen transformation in the water column as a function of environmental characteristics. A particular focus was the effects of oxygenation and particle association on both aerobic and anaerobic processes, as well as on the rates of nitrogen fixation across the macro- and micronutrient gradients observed in the working area.

Along the near coastal S-N transect between 29°S and 3°S, 9 stations (3 to 4 depths per station, in total 1500 samples) were sampled for microbial nitrogen transformations, with a focus on nitrogen loss (anammox and denitrification) and the processes supplying the substrates for these processes (namely nitrate reduction, ammonia oxidation and nitrite oxidation). Water samples were amended with different combinations of ^{15}N and ^{14}N labeled substrates, which will allow eventual partitioning of these processes after analysis on a GC-IRMS at MPI, Bremen. Experiments were conducted at both in situ (in the approximate range 15 to 100 µmol/kg depending on the depth / station) and zero oxygen conditions in order to investigate the oxygen sensitivity of these processes. In addition, at 5 of these sites and with a focus on the Congo plume, rates were analysed in two size fractions (bulk and < 1.6 µm), to assess which of these processes are particle associated and how/if these interactions vary between the two oxygen concentrations studied. The main objective was to assess the potential importance of particles and their associated microenvironments for microbial diversity and function within low oxygen regions, which is a continuation of recently published work (Ganesh et al, 2015) from the eastern tropical North Pacific oxygen minimum zone.

Along the cruise track of M121, a total of 60 nitrogen fixation experiments were conducted at 18 stations over a depth range of 15 to 400 m, thereby capturing gradients in both oxygen concentration and fluorescence. Alongside these rate determination experiments (and those mentioned above), samples were collected to enable characterization of the microbial community including samples for DNA (105 samples), FISH (fluorescence insitu hybridization; 280 samples) and nanoSIMS (nanometer-scale secondary ion mass spectrometry; 100 samples). In addition, depth profiles were collected at 18 stations for N_2O concentrations, which is a potent greenhouse gas.

5.13. Phytoplankton and Productivity

(T. Browning)

Samples were collected to characterize phytoplankton biomass, community structure and physiological status along the entire cruise track. These measurements will represent one of the largest and most comprehensive sampling efforts for these parameters in the South East Atlantic.

Given that phytoplankton is the primary driver of nutrient and carbon cycling in surface waters, as well as for nutrient and carbon export to deeper waters, these measurements will also be important for interpreting the TEI data collected during the expedition.

Samples were collected at every station at 6 depths throughout the euphotic zone. Sampling depths were selected after consultation of the fluorescence sensor on the CTD. Water was collected in 10L opaque carboys and processed immediately after collection. Generally 1-2 samples were also collected from the ship's non-toxic underway supply or from the towed fish between stations.

Samples were collected for the following analyses:

Chlorophyll-a concentrations: 100 mL samples were filtered onto Macherey-Nagel GFF filter pads and extracted for 12-24 hours in 10 mL 90% acetone in a -20 °C freezer in the dark before measurement on a Turner Designs trilogy fluorometer following Welschmeyer (1994).

Analytical flow cytometry: 1.87 mL of seawater was mixed with 0.125mL 16% paraformaldehyde yielding a final paraformaldehyde concentration of 1%. Mixing was carried out using a vortex, after which samples were left for 10 minutes at room temperature in the dark before transfer to a -80 °C freezer. Samples will later be analysed on a FACSort flow cytometer (Beckton-Dickinson, UK) following the method of e.g. Davey et al. (2008), with the intention of analysing for nanophytoplankton, picophytoplankton, *Synechococcus*, *Prochlorococcus* and total bacterial cell counts.

Fast Repetition Rate fluorometry (FRRf): A FASTOcean fluorometer (Sensor ID: 14-9740-003) with integrated FASTact laboratory system (both Chelsea Technologies LTD., UK) was used to measure in vitro variable fluorescence of phytoplankton samples after a 30 minute dark acclimation period (with temperature maintained by submersion in continuously flowing water from the ships underway system). Fluorescence light curves were also ran following a protocol of progressively increasing light intensities between 20 and 2000 $\mu\text{mol photons m}^{-2} \text{s}^{-1}$ (as described in Browning et al., 2014). Blank filtrates (0.2 μm filtrates) were measured for virtually all samples. All FRRf data will be blank-corrected and fluorescence parameters will be recalculated in the laboratory at GEOMAR.

Spectrally resolved absorption (surface samples only): 0.2-1.5L of seawater was filtered onto an Advantec filter pad and was frozen immediately in the -80°C freezer. Samples will be analysed following the method of Kishino et al. (1985).

Heme b: Samples were taken at all stations apart from station 1210. 1-3.5L were filtered onto glass fiber filters (25mm). Filters were frozen at -80°C for later analysis by high performance liquid chromatography - electrospray ionisation - mass spectrometry following the method of Gledhill et al. (2013).

POC/PON: Samples were taken at all stations apart from station 1210. 0.2-1.5L was filtered onto precombusted GF/F filters (25mm) and frozen at -80°C for later analysis in the laboratory in Kiel.

Incubation experiments

48 hour duration on-deck incubation experiments were carried out in 1L trace-metal-clean polycarbonate bottles. Seawater was collected using the trace-metal-clean towed-fish. Filling times were approximately ~20 minutes for 1L bottle experiments (total volume = 30L). Bottled seawater was spiked with the following combination of nutrients/trace metals:

N, Fe, Co, NFe, NCo, FeCo, NFeCo, NCoFe+ vitamin B12

Final incubation concentrations of Fe and Co were 2 nM and 100 pM vitamin B12, as well as 1 micromolar of NO_3^- and NH_4^+ . Initial conditions were sampled in 1L bottles for all experiments at 3 time points throughout the bottle filling procedure. Triplicate control bottles (1L) with no nutrients added were also sampled alongside all treatment experiments. Bottles were placed in on-deck incubators connected to the ships underway seawater supply system to continuously maintain temperatures at those of the surface waters. Incubators were screened with Blue Lagoon screening (Lee Filters), which maintained irradiance at ~30% of that of the surface. After 48 hours of incubation, the experiments were stopped and measurements made for: Chlorophyll-a concentrations (1 replicate per treatment bottle), FRRf (single acquisitions for each triplicate bottle), analytical flow cytometry, particulate B12 concentrations (pooled treatments), protein analysis (pooled; control and Fe-treated samples only).

5.14. Total Alkalinity (TA) and Dissolved Inorganic Carbon (DIC), $\delta^{13}\text{C}$ of DIC, dissolved organic carbon (DOC), $\delta^{13}\text{C}$ of DOC, dissolved organic phosphorus (DOP) and nitrate isotopes

(E. Achterberg, F. Deng)

TA and DIC: The sampling procedure used for TA and DIC (and its carbon isotope composition) followed Dickson et al. (2007). At every station samples were collected from most depths from the Niskin bottles of the stainless steel rosette in 250 ml Schott Duran borosilicate glass bottles with glass stoppers. Samples for $\delta^{13}\text{C}$ measurements of DOC were collected at the superstations only. All samples were taken directly after the Niskin bottles were opened. A piece of silicone tubing was used for the sampling and care was taken to prevent trapping of air bubbles in the sample. The bottles were immediately poisoned with a saturated solution of mercuric chloride (60 μl) and were then sealed air-tight with a glass stopper. The samples will be analysed at the University of Southampton. Analysis of TA and DIC will be conducted using a Vindta 3C, and $\delta^{13}\text{C}$ will be measured using a Thermo Gasbench attached to a Delta V mass spectrometer. A total of ~750 samples were collected for DIC/TA and ~350 samples were taken for $\delta^{13}\text{C}$ of DIC.

DOC: At every station DOC samples were also collected from most depths from the Niskin bottles and samples for the measurement of $\delta^{13}\text{C}$ of DOC were also collected at the superstations only. Seawater samples taken from the surface down to 300 m depth were filtered using pre-combusted (450 °C, 4 h) GF/F filters to remove particulate carbon and most organisms. Samples were filled into pre-combusted glass ampoules and acidified to $\text{pH} < 2$ with 55 μL of 6 M HCl immediately after collection. DOC samples will be analysed at GEOMAR using the high temperature combustion technique using a Shimadzu TOC-TDN instrument. A total of ~750 samples were collected for DOC and ~350 for $\delta^{13}\text{C}$ of DOC.

DOP: At every station samples for DOP analyses from the uppermost 400 m of the water column were filtered directly from the Niskin bottle using an 0.2 μm filter cartridge (Acropack). The samples were collected in 40 ml low density polyethylene tubes and frozen at -20°C immediately upon collection. Analysis of total dissolved phosphorus (TDP) will be undertaken at GEOMAR using standard autoanalysis techniques following chemical persulphate oxidation

with the use of a microwave. The DOP concentration will then be determined by subtraction of the phosphate from the TDP concentration. A total of ~300 samples were collected.

Nitrogen isotope composition of nitrate: Samples for the analysis of the nitrogen isotope composition of dissolved nitrate were filtered directly from the Niskin bottles using a 0.2 μm filter cartridge (Acropack) from most depths at the superstations and at a range of additional standard stations. The samples were collected in 60 ml low density polyethylene bottles (Nalgene) and frozen at -20°C immediately upon collection. Analysis of the $\delta^{15}\text{N}$ of nitrate isotopes will be undertaken using established protocols at Stanford, U.S., in the laboratory of Prof. Karen Casciotti. A total of ~600 samples were collected.

5.15. Collection of New GEOTRACES Reference Samples (C. Schlosser)

Reference materials are critical to validate and compare measurements of chemical compounds in seawater. In the past years seawater trace metal concentrations have been validated using SAFe and GEOTRACES reference seawaters with dissolved iron concentrations ranging from low picomolar concentrations (surface waters) to low nanomolar concentrations (deep waters). These widely used reference seawaters were collected under trace metal clean conditions by the group of Ken Bruland, University of California, Santa Cruz, USA during three cruises. However, stocks of the seawaters are running low and a new supply is required. In order to validate trace metal concentrations for GEOTRACES sampling campaigns we collected two new reference seawaters under trace metal clean conditions during M121 using the equipment developed by Geoffrey Smith and Ken Bruland.

A reference surface seawater was collected using the towed fish deployed in the South Atlantic gyre (SAG), and a reference deep seawater was sampled at 2200 m depth in the core of North Atlantic Deep Water in the Cape Basin (CAB) using the trace metal clean CTD. Surface waters were filtered inline using a set of GE-Osmonics 0.45 μm and 0.2 μm cartridge filters and pumped into one of two trace metal clean 500 L polypropylene (PP) tanks (Table 5.1). Both tanks were set up in a trace metal clean all plastic bubble in the second cargo hall of the RV *Meteor*. The collected seawater was acidified with 1.1 L concentrated HCl (UpA grade, Romil) and mixed by pumping the seawater from one tank into the other and back again using a Teflon bellows pump. After measurement of the pH (to be below 1.6), the seawater was pumped in a circulatory system and filled into 0.5 L acid cleaned LDPE bottles (SAG 1 to 547). Deep waters from 2200 m depth were collected during two TM-CTD deployments and transferred from the sampling van into a 500 l PP tank using the same tubing as used for the towed fish collection and was treated similarly to the surface reference waters. From the CAB reference water, 657 bottles were filled (CAB 1 to 657). SAG and CAB reference water bottles were stored in 10 L plastic buckets and shipped to the GEOMAR, Kiel. Before shipping the reference material to our international colleagues, the trace metal content of both new reference waters will be analyzed at GEOMAR by inline pre-concentration and isotope dilution inductively coupled plasma mass spectrometry (ID-ICP-MS, Element XR, Thermo), following the method described by Milne et al. (2010).

Table 5.1: Locations, time, and sampling depth of the two new reference seawaters collected.

Event #	TM-CTD #	Date	Time (UTC)	Depth (m)	Latitude	Longitude
Fish (SAG)	/	16.12.2015	13:15-15:39	3	-29.406	1.400
1308 (CAB)	40	19.12.2015	14:06	2200	-28.998	12.030
1309 (CAB)	41	19.12.2015	17:54	2200	-28.998	12.030

The complete TM-CTD casts #1308 and #1309 were combined for the CAB reference seawater.

6 Ship's Meteorological Station

(A. Raeke)

On the 22nd November, 09:15 local time, RV Meteor left the harbor of Walvis Bay (Namibia) for expedition M121. Before the cruise started, the air pressure gradient had intensified to the west of the cruise area. This was due to the south Atlantic tropical high and a heat low over Namibia. The southerly swell along the planned route increased to 4 to 5m. On the 21th November, still in the harbor, heavy deposition of desert dust on the vessel occurred. At the beginning of the cruise a near shore low was causing light to moderate winds from variable directions. The high then weakened so that the wind decreased to the west of the cruise area. During the northward continuation of the cruise on the swell decreased to 2m until the 24th. The air temperature was near 15°C as a consequence of the prevailing cold Benguela current at a temperature near 16°C. The wind shifted to southerly directions reaching strengths of 4 to 5 Bft.

From the 25th November onwards a high was located over the southeastern Atlantic while weak low pressure troughs prevailed over Namibia. This resulted in southerly trade winds of 3 to 4 Bft. The sea reached a height of 1 to 1.5m. These weather conditions allowed the recovery of three gliders deployed on the previous expedition. Having left the influence of the Benguela Current air and water temperatures close to the Angolan coast reached 27°C. In the following days good working conditions persisted along the northern edge of the pressure ridge of the subtropical high. The swell was only 0.5 to 1m with southwesterly to southerly winds at force 3 to 4 Bft. On the 29th November the Intertropical Convergence Zone was encountered and first rain showers occurred close to the mouth of the Congo River. The southerly to south-westerly winds reached 3 Bft and were accompanied by wave height of 1m. Until the 1st of December further showers were common along the southern edge of the low pressure trough.

From the 1st to the 5th December, after the cruise track had turned west along 3°S, southerly to southeasterly winds at strength 4 to 5 Bft were experienced due to a low pressure gradient. The sea showed a height of 1 to 1.5m and small local rain showers were weak.

On the following southerly cruise track along the zero meridian the tropical low pressure trough lost its influence on the cruise track of RV Meteor and a continuous southeast trade wind at 3 to 4 Bft was experienced. The sea reached a height of 1.5 to 2m, at times accompanied by a cross swell from southeast to south. The trade wind inversion below 1000 m gave way to develop a pronounced stratus cloud layer and a few rain showers occurred. From the 13th December the clouds showed some clearance in the center of the subtropical high near 20 degree latitude. The wind blew lightly to moderately from variable directions. The swell was 1.5m with generally only slight contributions from wind generated waves. On the 16th December the cruise track turned east along 29°S. The favorable weather conditions prevailed until the 19th when a cold front with local showers crossed the cruise track. The southeasterly wind increased to 5 to 6 Bft. Storm activity south of the subtropical high enhanced the southerly swell. In the night of the

21st the pressure over Namibia dropped resulting in a higher pressure gradient. The wind increased to 6 Bft and with the southeasterly wind resulted in a cross sea. On the morning of the 22nd the swell reached its peak of 3m and a sea of 4 m, which resulted in the trace metal clean CTD not being deployable. On the 23rd the sea decreased 2 to 2.5m and the wind decreased to 5 Bft. After the last glider was successfully recovered on the 24th a low pressure system close to Walvis Bay increased the pressure gradient and the wind increased to 6 to 7 Bft with a sea near 3m. When RV Meteor reached the center of the low close to Walvis Bay the wind and sea decreased allowing RV Meteor to go to port in Walvis Bay in calm weather on 26th December.

7 Station List M121

Station	Gear	Date	Station Start				Station End		
			Time	Pos. Long.	Pos. Lat.	Depth	Time	Pos. Long.	Pos. Lat.
METEOR						(m)			
M121_1155	Fish	2015/11/22	09:26:00	014° 19.78' E	22° 44.89' S	75.4			
M121_1156	CTD/SS	2015/11/22	18:36:00	013° 10.99' E	21° 58.45' S	194.2	18:59:59	013° 10.99' E	21° 58.45' S
M121_1157	GoFlo	2015/11/22	19:22:00	013° 10.99' E	21° 58.45' S	191.7	19:55:59	013° 10.99' E	21° 58.45' S
M121_1158	GoFlo	2015/11/22	19:59:00	013° 11.00' E	21° 58.45' S	192.6	20:17:59	013° 10.99' E	21° 58.45' S
M121_1159	CTD/SS	2015/11/23	03:00:00	012° 53.49' E	20° 52.17' S	199.9	03:17:59	012° 53.49' E	20° 52.17' S
M121_1160	GoFlo	2015/11/23	03:27:00	012° 53.49' E	20° 52.17' S	200.4	03:55:59	012° 53.49' E	20° 52.17' S
M121_1161	GoFlo	2015/11/23	03:58:00	012° 53.49' E	20° 52.17' S	200.6	04:16:59	012° 53.49' E	20° 52.17' S
M121_1162	CTD/SS	2015/11/23	04:28:00	012° 53.49' E	20° 52.17' S	197.9	04:44:59	012° 53.49' E	20° 52.17' S
M121_1163	CTD/SS	2015/11/23	11:34:00	012° 17.32' E	19° 45.88' S	201.5	11:55:59	012° 17.31' E	19° 45.88' S
M121_1164	CTD/TM	2015/11/23	12:16:00	012° 17.31' E	19° 45.88' S	202.4	12:42:59	012° 17.29' E	19° 45.87' S
M121_1165	CTD/SS	2015/11/23	13:13:00	012° 17.28' E	19° 45.87' S	201.6	13:31:59	012° 17.28' E	19° 45.87' S
M121_1166	CTD/SS	2015/11/23	20:07:00	011° 46.86' E	18° 39.63' S	204.3	20:30:59	011° 46.86' E	18° 39.63' S
M121_1167	CTD/TM	2015/11/23	20:43:00	011° 46.84' E	18° 39.62' S	203.7	21:02:59	011° 46.80' E	18° 39.60' S
M121_1168	CTD/SS	2015/11/24	03:30:00	011° 26.37' E	17° 33.41' S	211.6	03:48:59	011° 26.38' E	17° 33.41' S
M121_1169	CTD/TM	2015/11/24	04:00:00	011° 26.37' E	17° 33.44' S	210.6	04:20:59	011° 26.28' E	17° 33.80' S
M121_1170	CTD/SS	2015/11/24	05:05:00	011° 26.28' E	17° 33.81' S	209.8	05:20:59	011° 26.35' E	17° 33.94' S
M121_1174	CTD/SS	2015/11/25	08:16:00	010° 50.93' E	15° 47.65' S	3659.1	10:08:59	010° 50.92' E	15° 47.65' S
M121_1175	CTD/TM	2015/11/25	10:25:00	010° 50.84' E	15° 47.49' S	3064.4	13:42:59	010° 50.89' E	15° 47.10' S
M121_1176	CTD/SS	2015/11/25	14:04:00	010° 50.88' E	15° 47.12' S	3068.1	14:45:59	010° 50.79' E	15° 47.08' S
M121_1177	CTD/SS	2015/11/25	23:40:00	010° 54.36' E	14° 05.98' S	3473.7	01:39:59	010° 54.58' E	14° 05.98' S
M121_1178	SAPS	2015/11/26	02:00:00	010° 54.59' E	14° 05.98' S	3475.9	03:47:59	010° 54.63' E	14° 05.99' S
M121_1179	CTD/SS	2015/11/26	03:56:00	010° 54.63' E	14° 05.99' S	3473.5	04:14:59	010° 54.64' E	14° 06.00' S
M121_1180	GoFlo	2015/11/26	04:26:00	010° 54.64' E	14° 06.00' S	3470.4	05:30:59	010° 54.75' E	14° 06.13' S
M121_1181	GoFlo	2015/11/26	05:33:00	010° 54.75' E	14° 06.16' S	3470.1	06:00:59	010° 54.81' E	14° 06.36' S
M121_1182	CTD/TM	2015/11/26	08:17:00	011° 05.31' E	13° 49.96' S	3391.2	11:49:59	011° 05.86' E	13° 49.24' S
M121_1183	CTD/SS	2015/11/26	19:51:00	012° 00.95' E	12° 29.97' S	2367.7	21:31:59	012° 00.96' E	12° 29.97' S
M121_1184	CTD/TM	2015/11/26	21:39:00	012° 00.95' E	12° 29.96' S	2372.4	23:21:59	012° 00.92' E	12° 29.96' S
M121_1185	CTD/SS	2015/11/26	23:37:00	012° 00.92' E	12° 29.96' S	2372.6	23:53:59	012° 00.92' E	12° 29.96' S
M121_1186	CTD/SS	2015/11/27	00:20:00	012° 00.92' E	12° 29.96' S	2363.1	00:49:59	012° 00.92' E	12° 29.96' S
M121_1188	CTD/SS	2015/11/27	16:05:00	012° 31.58' E	10° 38.82' S	1592.5	17:07:59	012° 31.57' E	10° 38.82' S
M121_1189	CTD/TM	2015/11/27	17:15:00	012° 31.57' E	10° 38.82' S	1596.4	18:20:59	012° 31.41' E	10° 38.87' S
M121_1190	CTD/SS	2015/11/27	18:40:00	012° 31.40' E	10° 38.89' S	1602.8	18:58:59	012° 31.40' E	10° 38.89' S
M121_1191	SAPS	2015/11/27	19:14:00	012° 31.40' E	10° 38.89' S	1602.7	23:39:59	012° 31.54' E	10° 38.92' S
M121_1192	CTD/SS	2015/11/28	04:59:00	012° 17.63' E	09° 41.75' S	1612.0	06:04:59	012° 17.63' E	09° 41.76' S

Station	Gear	Date	Station Start				Station End		
			Time	Pos. Long.	Pos. Lat.	Depth	Time	Pos. Long.	Pos. Lat.
METEOR						(m)			
M121_1193	CTD/TM	2015/11/28	06:11:00	012° 17.62' E	09° 41.76' S	1611.5	07:11:59	012° 17.50' E	09° 41.77' S
M121_1194	CTD/SS	2015/11/28	07:25:00	012° 17.41' E	09° 41.80' S	1622.0	07:39:59	012° 17.41' E	09° 41.81' S
M121_1195	CTD/TM	2015/11/28	07:47:00	012° 17.40' E	09° 41.80' S	1617.4	07:54:59	012° 17.31' E	09° 41.85' S
M121_1196	CTD/SS	2015/11/28	14:02:00	012° 03.77' E	08° 32.21' S	2028.5	15:15:59	012° 03.77' E	08° 32.21' S
M121_1197	CTD/TM	2015/11/28	15:20:00	012° 03.78' E	08° 32.21' S	2030.0	16:44:59	012° 03.74' E	08° 32.34' S
M121_1198	CTD/SS	2015/11/28	16:51:00	012° 03.74' E	08° 32.34' S	2026.2	17:05:59	012° 03.74' E	08° 32.34' S
M121_1199	SAPS	2015/11/28	17:12:00	012° 03.74' E	08° 32.34' S	2025.1	21:01:59	012° 03.77' E	08° 32.37' S
M121_1200	CTD/SS	2015/11/29	04:03:00	012° 10.81' E	07° 19.48' S	287.5	04:22:59	012° 10.81' E	07° 19.48' S
M121_1201	CTD/TM	2015/11/29	04:27:00	012° 10.81' E	07° 19.48' S	288.6	04:42:59	012° 10.81' E	07° 19.42' S
M121_1202	CTD/SS	2015/11/29	10:32:00	011° 59.68' E	06° 11.93' S	57.4	10:44:59	011° 59.68' E	06° 11.93' S
M121_1203	CTD/TM	2015/11/29	10:53:00	011° 59.68' E	06° 11.93' S	56.8	11:03:59	011° 59.70' E	06° 11.93' S
M121_1204	CTD/TM	2015/11/29	11:10:00	011° 59.71' E	06° 11.94' S	57.8	11:17:59	011° 59.73' E	06° 11.94' S
M121_1205	SAPS	2015/11/29	11:29:00	011° 59.73' E	06° 11.94' S	56.5	13:09:59	011° 59.74' E	06° 11.94' S
M121_1206	CTD/SS	2015/11/29	17:27:00	011° 09.82' E	06° 13.97' S	1004.1	18:17:59	011° 09.78' E	06° 14.00' S
M121_1207	CTD/TM	2015/11/29	18:24:00	011° 09.77' E	06° 14.00' S	1005.2	19:08:59	011° 09.69' E	06° 14.08' S
M121_1208	CTD/SS	2015/11/29	19:23:00	011° 09.69' E	06° 14.08' S	1008.6	19:53:59	011° 09.69' E	06° 14.08' S
M121_1209	SAPS	2015/11/29	20:06:00	011° 09.69' E	06° 14.08' S	1008.1	23:23:59	011° 09.69' E	06° 14.08' S
M121_1210	CTD/SS	2015/11/30	02:01:00	011° 29.48' E	06° 00.01' S	356.4	02:26:59	011° 29.48' E	06° 00.00' S
M121_1211	CTD/TM	2015/11/30	02:34:00	011° 29.46' E	05° 59.99' S	364.5	02:52:59	011° 29.40' E	05° 59.93' S
M121_1212	CTD/SS	2015/11/30	03:17:00	011° 29.39' E	05° 59.93' S	378.3	03:39:59	011° 29.39' E	05° 59.93' S
M121_1213	SAPS	2015/11/30	03:51:00	011° 29.40' E	05° 59.93' S	381.3	05:54:59	011° 29.40' E	05° 59.93' S
M121_1155	Fish						15:30:00	011° 29.40' E	05° 30.74' S
M121_1155	Fish	2015/11/30	23:05:00	010° 28.92' E	04° 16.31' S	895.4			
M121_1214	CTD/SS	2015/11/30	23:07:00	010° 28.92' E	04° 16.31' S	895.4	23:46:59	010° 28.92' E	04° 16.31' S
M121_1215	CTD/TM	2015/11/30	23:51:00	010° 28.91' E	04° 16.31' S	895.8	00:25:59	010° 28.84' E	04° 16.34' S
M121_1216	CTD/SS	2015/12/01	00:44:00	010° 28.83' E	04° 16.33' S	904.5	01:06:59	010° 28.83' E	04° 16.33' S
M121_1217	SAPS	2015/12/01	01:14:00	010° 28.83' E	04° 16.33' S	901.9	04:17:59	010° 28.83' E	04° 16.33' S
M121_1218	CTD/SS	2015/12/01	11:16:00	009° 49.71' E	03° 00.08' S	52.2	11:31:59	009° 49.71' E	03° 00.08' S
M121_1219	CTD/TM	2015/12/01	11:42:00	009° 49.65' E	03° 00.02' S	52.5	11:51:59	009° 49.63' E	02° 59.93' S
M121_1220	CTD/TM	2015/12/01	11:56:00	009° 49.62' E	02° 59.89' S	52.9	12:01:59	009° 49.61' E	02° 59.84' S
M121_1221	SAPS	2015/12/01	12:12:00	009° 49.57' E	02° 59.80' S	52.2	13:56:59	009° 49.69' E	02° 59.91' S
M121_1222	CTD/SS	2015/12/01	16:55:00	009° 25.97' E	03° 00.06' S	179.4	17:15:59	009° 25.97' E	03° 00.06' S
M121_1223	CTD/TM	2015/12/01	17:20:00	009° 25.97' E	03° 00.06' S	179.9	17:35:59	009° 25.93' E	03° 00.01' S
M121_1224	CTD/SS	2015/12/01	18:10:00	009° 25.93' E	03° 00.01' S	178.9	18:29:59	009° 25.93' E	03° 00.01' S

Station	Gear	Date	Station Start				Station End		
			Time	Pos. Long.	Pos. Lat.	Depth	Time	Pos. Long.	Pos. Lat.
METEOR						(m)			
M121_1225	SAPS	2015/12/01	18:36:00	009° 25.93' E	03° 00.01' S	178.7	20:58:59	009° 25.93' E	03° 00.01' S
M121_1226	CTD/SS	2015/12/01	21:53:00	009° 20.04' E	03° 00.14' S	533.3	22:24:59	009° 20.04' E	03° 00.14' S
M121_1227	CTD/TM	2015/12/01	22:28:00	009° 20.03' E	03° 00.14' S	507.1	22:54:59	009° 20.00' E	03° 00.16' S
M121_1228	CTD/SS	2015/12/01	23:07:00	009° 20.00' E	03° 00.16' S	512.7	23:46:59	009° 20.00' E	03° 00.16' S
M121_1229	SAPS	2015/12/02	00:52:00	009° 20.00' E	03° 00.16' S	512.8	02:57:59	009° 20.00' E	03° 00.16' S
M121_1230	CTD/SS	2015/12/02	06:00:00	009° 03.99' E	02° 59.93' S	1027.0	06:42:59	009° 03.99' E	02° 59.93' S
M121_1231	CTD/TM	2015/12/02	06:47:00	009° 03.99' E	02° 59.93' S	1029.3	07:26:59	009° 03.93' E	02° 59.97' S
M121_1232	CTD/SS	2015/12/02	07:39:00	009° 03.93' E	02° 59.98' S	1032.7	07:54:59	009° 03.93' E	02° 59.97' S
M121_1233	SAPS	2015/12/02	08:24:00	009° 03.92' E	02° 59.97' S	1032.1	11:44:59	009° 03.92' E	02° 59.97' S
M121_1234	CTD/SS	2015/12/02	22:48:00	006° 46.56' E	03° 00.05' S	4188.6	01:36:59	006° 46.57' E	03° 00.04' S
M121_1235	CTD/TM	2015/12/03	02:05:00	006° 46.57' E	03° 00.04' S	4180.9	04:45:59	006° 46.54' E	03° 00.05' S
M121_1236	CTD/SS	2015/12/03	04:51:00	006° 46.54' E	03° 00.05' S	4170.1	05:15:59	006° 46.54' E	03° 00.05' S
M121_1237	SAPS	2015/12/03	05:23:00	006° 46.54' E	03° 00.05' S	4172.8	09:09:59	006° 46.54' E	03° 00.05' S
M121_1238	CTD/SS	2015/12/03	20:31:00	004° 24.95' E	03° 00.16' S	4503.0	23:10:59	004° 24.95' E	03° 00.16' S
M121_1239	CTD/TM	2015/12/03	23:14:00	004° 24.95' E	03° 00.16' S	4505.6	01:57:59	004° 24.94' E	03° 00.19' S
M121_1240	CTD/SS	2015/12/04	02:09:00	004° 24.94' E	03° 00.19' S	4520.6	02:37:59	004° 24.94' E	03° 00.19' S
M121_1241	SAPS	2015/12/04	02:43:00	004° 24.94' E	03° 00.19' S	4500.8	06:00:59	004° 24.94' E	03° 00.19' S
M121_1242	CTD/SS	2015/12/04	06:10:00	004° 24.94' E	03° 00.19' S	4512.0	06:27:59	004° 24.93' E	03° 00.23' S
M121_1243	CTD/SS	2015/12/04	17:23:00	002° 12.83' E	03° 00.04' S	4503.8	20:09:59	002° 12.82' E	03° 00.04' S
M121_1244	CTD/TM	2015/12/04	20:15:00	002° 12.81' E	03° 00.04' S	4507.6	23:07:59	002° 12.76' E	03° 00.05' S
M121_1245	CTD/SS	2015/12/04	23:19:00	002° 12.76' E	03° 00.05' S	4504.4	23:33:59	002° 12.76' E	03° 00.05' S
M121_1246	SAPS	2015/12/04	23:39:00	002° 12.76' E	03° 00.05' S	4504.5	02:56:59	002° 12.76' E	03° 00.05' S
M121_1247	CTD/SS	2015/12/05	14:05:00	000° 00.31' W	02° 59.91' S	4474.3	19:17:59	000° 00.43' W	02° 59.93' S
M121_1248	CTD/SS	2015/12/05	19:57:00	000° 00.43' W	02° 59.93' S	4476.9	22:13:59	000° 00.43' W	02° 59.94' S
M121_1249	CTD/TM	2015/12/05	22:22:00	000° 00.43' W	02° 59.94' S	4698.4	01:38:59	000° 00.45' W	02° 59.94' S
M121_1250	CTD/SS	2015/12/06	01:50:00	000° 00.45' W	02° 59.95' S	4481.3	02:16:59	000° 00.45' W	02° 59.95' S
M121_1251	SAPS	2015/12/06	03:04:00	000° 00.49' W	02° 59.97' S	4480.1	06:17:59	000° 00.47' W	02° 59.95' S
M121_1252	CTD/SS	2015/12/06	19:46:00	000° 00.01' E	05° 29.96' S	4223.5	20:04:59	000° 00.01' E	05° 29.96' S
M121_1253	CTD/TM	2015/12/06	20:11:00	000° 00.01' E	05° 29.96' S	4217.7	22:44:59	000° 00.01' E	05° 29.98' S
M121_1254	CTD/SS	2015/12/06	22:56:00	000° 00.01' E	05° 29.99' S	4217.1	01:29:59	000° 00.01' E	05° 29.99' S
M121_1255	CTD/SS	2015/12/07	10:26:00	000° 00.00' W	07° 12.00' S	4914.4	13:08:59	000° 00.01' W	07° 12.00' S
M121_1256	CTD/TM	2015/12/07	13:14:00	000° 00.01' W	07° 12.00' S	4916.0	16:38:59	000° 00.05' E	07° 12.84' S
M121_1257	CTD/SS	2015/12/07	16:44:00	000° 00.05' E	07° 12.84' S	4918.8	17:20:59	000° 00.05' E	07° 12.86' S
M121_1258	SAPS	2015/12/07	17:26:00	000° 00.05' E	07° 12.86' S	4921.8	20:51:59	000° 00.17' E	07° 12.86' S
M121_1259	CTD/SS	2015/12/08	06:04:00	000° 00.09' E	08° 54.02' S	5256.9	08:58:59	000° 00.10' E	08° 54.03' S

Station	Gear	Date	Station Start				Station End		
			Time	Pos. Long.	Pos. Lat.	Depth	Time	Pos. Long.	Pos. Lat.
METEOR						(m)			
M121_1260	CTD/TM	2015/12/08	09:08:00	000° 00.09' E	08° 54.02' S	5255.8	12:39:59	000° 00.05' E	08° 54.14' S
M121_1261	CTD/SS	2015/12/08	12:51:00	000° 00.05' E	08° 54.14' S	5277.6	13:02:59	000° 00.05' E	08° 54.14' S
M121_1262	CTD/SS	2015/12/09	10:58:00	000° 00.01' W	13° 00.93' S	5435.1	14:05:59	000° 00.01' W	13° 00.93' S
M121_1263	CTD/TM	2015/12/09	14:10:00	000° 00.01' W	13° 00.92' S	5435.4	17:28:59	000° 00.09' E	13° 01.30' S
M121_1264	CTD/SS	2015/12/09	17:37:00	000° 00.09' E	13° 01.31' S	5428.4	18:13:59	000° 00.09' E	13° 01.31' S
M121_1265	SAPS	2015/12/09	18:20:00	000° 00.09' E	13° 01.32' S	5930.7	21:57:59	000° 00.09' E	13° 01.32' S
M121_1266	CTD/SS	2015/12/09	22:07:00	000° 00.09' E	13° 01.32' S	5430.1	22:38:59	000° 00.09' E	13° 01.32' S
M121_1267	CTD/SS	2015/12/10	09:26:00	000° 00.04' E	15° 04.22' S	5779.4	12:39:59	000° 00.04' E	15° 04.22' S
M121_1268	CTD/TM	2015/12/10	12:44:00	000° 00.04' E	15° 04.22' S	5812.8	16:31:59	000° 00.03' E	15° 04.22' S
M121_1269	CTD/SS	2015/12/10	16:36:00	000° 00.02' E	15° 04.22' S	5829.1	16:46:59	000° 00.02' E	15° 04.22' S
M121_1270	CTD/SS	2015/12/11	06:05:00	000° 00.03' W	17° 30.93' S	5749.2	09:04:59	000° 00.02' W	17° 30.93' S
M121_1271	CTD/TM	2015/12/11	09:09:00	000° 00.03' W	17° 30.93' S	5362.5	12:37:59	000° 00.10' W	17° 30.97' S
M121_1272	CTD/SS	2015/12/11	12:46:00	000° 00.11' W	17° 30.98' S	5380.5	13:22:59	000° 00.11' W	17° 30.98' S
M121_1273	SAPS	2015/12/11	13:28:00	000° 00.11' W	17° 30.98' S	5380.6	16:48:59	000° 00.11' W	17° 30.97' S
M121_1274	CTD/SS	2015/12/12	05:49:00	000° 00.01' W	19° 54.93' S	6223.6	09:00:59	000° 00.01' W	19° 54.93' S
M121_1275	CTD/TM	2015/12/12	09:06:00	000° 00.02' W	19° 54.95' S	5177.8	12:03:59	000° 00.04' W	19° 54.98' S
M121_1276	CTD/SS	2015/12/12	12:12:00	000° 00.04' W	19° 54.98' S	5162.9	12:34:59	000° 00.04' W	19° 54.98' S
M121_1277	CTD/SS	2015/12/13	01:30:00	000° 00.01' E	22° 17.58' S	5103.0	04:33:59	000° 00.01' E	22° 17.58' S
M121_1278	CTD/TM	2015/12/13	04:40:00	000° 00.00' W	22° 17.58' S	5099.2	07:34:59	000° 00.02' E	22° 17.64' S
M121_1279	CTD/SS	2015/12/13	07:45:00	000° 00.02' E	22° 17.65' S	5106.0	08:22:59	000° 00.02' E	22° 17.65' S
M121_1280	SAPS	2015/12/13	08:34:00	000° 00.02' E	22° 17.65' S	5107.0	12:08:59	000° 00.02' E	22° 17.65' S
M121_1281	CTD/SS	2015/12/14	01:08:00	000° 00.02' W	24° 42.87' S	5385.0	04:22:59	000° 00.00' W	24° 42.94' S
M121_1282	CTD/TM	2015/12/14	04:26:00	000° 00.00' W	24° 42.95' S	5293.1	07:37:59	000° 00.04' W	24° 43.00' S
M121_1283	CTD/SS	2015/12/14	07:47:00	000° 00.05' W	24° 43.02' S	5292.3	08:02:59	000° 00.05' W	24° 43.02' S
M121_1284	CTD/SS	2015/12/14	20:30:00	000° 00.03' W	27° 05.53' S	4967.7	00:51:59	000° 00.05' W	27° 05.46' S
M121_1285	CTD/TM	2015/12/15	00:56:00	000° 00.05' W	27° 05.46' S	4968.3	03:52:59	000° 00.02' W	27° 05.50' S
M121_1286	CTD/SS	2015/12/15	04:00:00	000° 00.00' W	27° 05.50' S	4968.7	04:21:59	000° 00.00' W	27° 05.51' S
M121_1287	SAPS	2015/12/15	04:31:00	000° 00.01' W	27° 05.52' S	4969.8	07:56:59	000° 00.04' E	27° 05.52' S
M121_1288	CTD/SS	2015/12/15	20:22:00	000° 00.02' E	29° 34.72' S	4715.7	22:58:59	000° 00.01' E	29° 34.72' S
M121_1289	CTD/TM	2015/12/15	23:04:00	000° 00.02' E	29° 34.71' S	4779.3	01:31:59	000° 00.05' E	29° 34.69' S
M121_1290	CTD/SS	2015/12/16	01:40:00	000° 00.05' E	29° 34.69' S	4681.9	02:15:59	000° 00.05' E	29° 34.68' S
M121_1291	SAPS	2015/12/16	02:23:00	000° 00.05' E	29° 34.68' S	4792.5	06:00:59	000° 00.04' E	29° 34.69' S
M121_1292	CTD/SS	2015/12/16	21:11:00	002° 44.45' E	29° 22.57' S	4718.8	01:43:59	002° 44.45' E	29° 22.58' S
M121_1293	CTD/TM	2015/12/17	01:52:00	002° 44.38' E	29° 22.60' S	3691.2	03:54:59	002° 44.64' E	29° 22.75' S

Station	Gear	Date	Station Start				Station End		
			Time	Pos. Long.	Pos. Lat.	Depth	Time	Pos. Long.	Pos. Lat.
METEOR						(m)			
M121_1294	CTD/SS	2015/12/17	04:01:00	002° 44.65' E	29° 22.76' S	4847.3	04:21:59	002° 44.69' E	29° 22.84' S
M121_1295	CTD/SS	2015/12/17	16:50:00	005° 32.07' E	29° 13.75' S	5020.6	22:18:59	005° 32.15' E	29° 13.76' S
M121_1296	CTD/TM	2015/12/17	22:23:00	005° 32.16' E	29° 13.77' S	5039.8	01:14:59	005° 32.20' E	29° 13.77' S
M121_1297	CTD/SS	2015/12/18	01:26:00	005° 32.20' E	29° 13.77' S	5017.2	02:01:59	005° 32.20' E	29° 13.77' S
M121_1298	SAPS	2015/12/18	02:12:00	005° 32.20' E	29° 13.77' S	5033.4	05:46:59	005° 32.20' E	29° 13.77' S
M121_1299	CTD/SS	2015/12/18	17:11:00	008° 03.21' E	29° 07.61' S	5076.4	20:17:59	008° 03.31' E	29° 07.65' S
M121_1300	CTD/TM	2015/12/18	20:24:00	008° 03.33' E	29° 07.65' S	5057.4	23:19:59	008° 03.01' E	29° 08.39' S
M121_1301	CTD/SS	2015/12/18	23:28:00	008° 03.01' E	29° 08.39' S	5073.9	23:40:59	008° 03.01' E	29° 08.39' S
M121_1302	SAPS	2015/12/18	23:54:00	008° 03.01' E	29° 08.39' S	5072.5	03:09:59	008° 02.74' E	29° 08.94' S
M121_1303	CTD/SS	2015/12/19	16:30:00	010° 42.41' E	29° 01.89' S	4763.8	22:14:59	010° 42.41' E	29° 01.89' S
M121_1304	CTD/TM	2015/12/19	22:20:00	010° 42.40' E	29° 01.89' S	4760.7	01:00:59	010° 42.30' E	29° 01.90' S
M121_1305	CTD/SS	2015/12/20	01:11:00	010° 42.28' E	29° 01.90' S	4765.2	01:31:59	010° 42.28' E	29° 01.90' S
M121_1306	SAPS	2015/12/20	01:47:00	010° 42.28' E	29° 01.90' S	4766.1	05:23:59	010° 42.28' E	29° 01.90' S
M121_1307	CTD/SS	2015/12/20	05:30:00	010° 42.28' E	29° 01.90' S	4767.1	06:11:59	010° 42.28' E	29° 01.90' S
M121_1308	CTD/TM	2015/12/20	13:11:00	012° 01.86' E	28° 58.69' S	4029.2	14:51:59	012° 01.79' E	28° 59.83' S
M121_1309	CTD/TM	2015/12/20	16:50:00	012° 01.78' E	28° 59.90' S	0.0	18:40:59	012° 01.54' E	29° 01.03' S
M121_1310	CTD/SS	2015/12/21	01:07:00	013° 10.66' E	28° 55.53' S	2626.9	02:46:59	013° 10.66' E	28° 55.53' S
M121_1311	SAPS	2015/12/21	02:53:00	013° 10.66' E	28° 55.53' S	2625.1	06:04:59	013° 10.57' E	28° 55.14' S
M121_1312	CTD/SS	2015/12/21	06:11:00	013° 10.57' E	28° 55.15' S	2629.0	06:24:59	013° 10.49' E	28° 55.19' S
M121_1313	CTD/TM	2015/12/21	06:31:00	013° 10.48' E	28° 55.23' S	2630.4	08:13:59	013° 10.31' E	28° 56.00' S
M121_1314	CTD/SS	2015/12/21	14:34:00	014° 22.80' E	28° 50.35' S	466.2	14:59:59	014° 22.82' E	28° 50.36' S
M121_1315	CTD/TM	2015/12/21	15:01:00	014° 22.82' E	28° 50.36' S	465.8	15:25:59	014° 22.87' E	28° 50.57' S
M121_1316	SAPS	2015/12/21	15:38:00	014° 22.86' E	28° 50.58' S	465.2	18:26:59	014° 23.29' E	28° 50.60' S
M121_1317	CTD/SS	2015/12/22	00:36:00	015° 33.50' E	28° 44.96' S	187.8	00:51:59	015° 33.50' E	28° 44.96' S
M121_1318	GoFlo	2015/12/22	01:00:00	015° 33.50' E	28° 44.96' S	187.1	01:32:59	015° 33.50' E	28° 44.96' S
M121_1319	GoFlo	2015/12/22	01:38:00	015° 33.50' E	28° 44.96' S	517.3	01:52:59	015° 33.50' E	28° 44.96' S
M121_1320	CTD/SS	2015/12/22	02:02:00	015° 33.50' E	28° 44.96' S	187.7	02:16:59	015° 33.50' E	28° 44.96' S
M121_1321	SAPS	2015/12/22	02:19:00	015° 33.50' E	28° 44.96' S	188.2	04:19:59	015° 32.87' E	28° 45.12' S
M121_1322	CTD/SS	2015/12/22	08:37:00	016° 16.06' E	28° 40.56' S	67.4	08:49:59	016° 16.06' E	28° 40.56' S
M121_1323	CTD/TM	2015/12/22	08:55:00	016° 16.06' E	28° 40.56' S	68.8	09:04:59	016° 15.99' E	28° 40.53' S
M121_1324	SAPS	2015/12/22	09:31:00	016° 15.96' E	28° 40.52' S	71.7	11:10:59	016° 15.96' E	28° 40.52' S
M121_1325	CTD/SS	2015/12/22	19:39:00	014° 50.93' E	27° 51.85' S	236.9	19:59:59	014° 50.93' E	27° 51.85' S
M121_1326	GoFlo	2015/12/22	20:09:00	014° 50.93' E	27° 51.85' S	236.1	21:06:59	014° 50.67' E	27° 51.80' S
M121_1327	GoFlo	2015/12/22	21:11:00	014° 50.63' E	27° 51.80' S	251.8	21:23:59	014° 50.50' E	27° 51.76' S
M121_1328	SAPS	2015/12/22	21:30:00	014° 50.41' E	27° 51.74' S	263.2	23:42:59	014° 49.94' E	27° 51.64' S

Station	Gear	Date	Station Start				Station End		
			Time	Pos. Long.	Pos. Lat.	Depth	Time	Pos. Long.	Pos. Lat.
METEOR						(m)			
M121_1329	CTD/SS	2015/12/23	06:04:00	014° 44.57' E	26° 40.65' S	190.1	06:21:59	014° 44.57' E	26° 40.65' S
M121_1330	CTD/TM	2015/12/23	06:26:00	014° 44.57' E	26° 40.65' S	189.8	06:40:59	014° 44.52' E	26° 40.65' S
M121_1331	SAPS	2015/12/23	07:15:00	014° 44.50' E	26° 40.65' S	191.0	09:40:59	014° 44.50' E	26° 40.65' S
M121_1332	CTD/SS	2015/12/23	09:49:00	014° 44.50' E	26° 40.65' S	191.3	10:02:59	014° 44.50' E	26° 40.65' S
M121_1333	CTD/TM	2015/12/23	13:25:00	014° 41.22' E	26° 04.48' S	159.2	13:37:59	014° 41.25' E	26° 04.48' S
M121_1334	CTD/SS	2015/12/23	16:53:00	014° 27.35' E	25° 31.70' S	154.7	17:05:59	014° 27.37' E	25° 31.72' S
M121_1335	CTD/TM	2015/12/23	17:00:00	014° 27.36' E	25° 31.71' S	154.0	17:22:59	014° 27.37' E	25° 31.76' S
M121_1336	SAPS	2015/12/23	17:36:00	014° 27.37' E	25° 31.76' S	154.6	19:56:59	014° 27.37' E	25° 31.76' S
M121_1337	CTD/SS	2015/12/23	20:03:00	014° 27.37' E	25° 31.76' S	155.1	20:25:59	014° 27.37' E	25° 31.76' S
M121_1338	CTD/SS	2015/12/24	02:30:00	014° 12.00' E	24° 23.18' S	137.9	02:43:59	014° 11.99' E	24° 23.17' S
M121_1339	CTD/TM	2015/12/24	02:48:00	014° 12.01' E	24° 23.19' S	136.0	02:58:59	014° 12.00' E	24° 23.22' S
M121_1341	CTD/SS	2015/12/24	11:01:00	013° 55.33' E	22° 56.28' S	139.5	11:13:59	013° 55.33' E	22° 56.28' S
M121_1342	CTD/TM	2015/12/24	11:19:00	013° 55.33' E	22° 56.28' S	140.5	11:30:59	013° 55.37' E	22° 56.28' S
M121_1343	SAPS	2015/12/24	11:49:00	013° 55.37' E	22° 56.28' S	139.9	13:58:59	013° 55.37' E	22° 56.28' S
M121_1344	CTD/SS	2015/12/24	20:03:00	013° 10.80' E	21° 58.37' S	195.0	20:20:59	013° 10.80' E	21° 58.38' S
M121_1155	Fish						20:08:00	013° 10.80' E	21° 58.38' S
M121_1345	CTD/TM	2015/12/24	20:26:00	013° 10.80' E	21° 58.38' S	195.9	20:39:59	013° 10.73' E	21° 58.37' S

Gear acronyms in the Station list:

CTD/NISK	CTD-SS stainless steel water sampler with Niskin bottles
CTD/TM	Trace metal clean CTD water sampler with GO-FLO bottles
GoFlo	single GO-FLO bottles on Meteor line
FISH	Towed Fish surface water sampler
SAPS	In-situ pumping system

8 Data and Sample Storage and Availability

A cruise summary report (CSR) was compiled and submitted to DOD (Deutsches Ozeanographisches Datenzentrum), BSH, Hamburg, immediately after the cruise. Parts of the cruise were performed in waters under jurisdiction of Namibia, Angola, Gabon, and Equatorial Guinea. As requested, the CTD data and this cruise report have been transferred to the respective authorities.

All hydrographic data acquired during the cruise have been stored at the GEOTRACES data base at BODC, Liverpool, U.K., and will also be made available at the PANGAEA data base, AWI, Bremerhaven. All trace metal and isotope data to be acquired will also be fed into these data bases and will be made publicly available within 3 years after production. All water and particulate samples are stored at the respective laboratories, where the measurements will be carried out. The Kiel Data Management Team (KDMT) provides an information and data

archival system where metadata of the onboard DSHIP-System are collected and are publicly available. This Ocean Science Information System (OSIS-Kiel) is accessible for all project participants and can be used to share and edit field information (<https://portal.geomar.de/metadata/leg/show/333357>). Table 8.1 lists the target data bases, tentative availability times and responsible scientists.

Hydrography - CTD and ADCP data are held at GEOMAR Helmholtz Centre for Ocean Research Kiel and will be made publicly available at the end of 2018 (responsible: Prof. M. Frank).

Dissolved trace metals - samples and data are held at GEOMAR, Kiel (responsible: Prof. E. Achterberg).

Particulate trace metals - samples and data are held at GEOMAR, Kiel (responsible: Prof. E. Achterberg).

Radiogenic isotopes (Hf/Nd) - samples and data are held at GEOMAR, Kiel (responsible: Prof. M. Frank).

Stable Cd isotopes and radiogenic Pb isotopes - samples and data are held at the Max Planck Institute for Chemistry, Mainz (responsible: Dr. W. Abouchami, Dr. S. Galer).

Stable Fe isotopes - samples and data are held at GEOMAR, Kiel (responsible: Prof. E. Achterberg).

Radium isotopes - samples and data are held at the Institut für Geowissenschaften, Christian Albrechts Universität Kiel (responsible Dr. J. Scholten).

Radionuclides (²³⁰Th/²³¹Pa) - samples and data are held at the Department of Earth Sciences, University of Oxford, U.K. (responsible Prof. G.M. Henderson).

High Field Strength Elements – samples and data are held at the Jacobs University Bremen (responsible Prof. A. Koschinsky).

Phytoplankton/productivity – samples and data are held at GEOMAR, Kiel (responsible Dr. T. Browning).

Nitrogen loss and fixation - samples and data are held at the MPI for Marine Microbiology Bremen (responsible Dr. Laura Bristow).

Nutrients, stable nutrient isotopes ($\delta^{15}\text{NO}_3^-$, $\delta^{13}\text{C}_{\text{DIC}}$), carbon cycle - samples and data are held at GEOMAR, Kiel (responsible Prof. E. Achterberg).

Table 8.1: Data storage and tentative availability

Type	database	free access	contact
Hydrography	BODC/PANGAEA	Dec. 2019	mfrank@geomar.de
Nutrients	BODC/PANGAEA	Dec. 2019	eachterberg@geomar.de
Dissolved trace metals	BODC/PANGAEA	Dec. 2019	eachterberg@geomar.de
Particulate trace metals	BODC/PANGAEA	Dec. 2019	eachterberg@geomar.de
High field strength elements	BODC/PANGAEA	Dec. 2019	a.koschinsky@jacobs-university.de
Radiogenic Nd/Hf isotopes	BODC/PANGAEA	Dec. 2019	mfrank@geomar.de
Stable Cd-isotopes and radiogenic Pb isotopes	BODC/PANGAEA	Dec. 2019	Steve.galer@mpic.de
Stable Fe isotopes	BODC/PANGAEA	Dec. 2019	eachterberg@geomar.de
Radium isotopes	BODC/PANGAEA	Dec. 2019	js@gpi.uni-kiel.de

$^{231}\text{Pa}/^{230}\text{Th}$	BODC/PANGAEA	Dec. 2019	Gideon.Henderson@earth.ox.ac.uk
Nitrogen loss and fixation	BODC/PANGAEA	Dec. 2019	lbristow@biology.sdu.dk
Phytoplankton/productivity	BODC/PANGAEA	Dec. 2019	tbrowning@geomar.de
Nutrient isotopes and carbon cycle	BODC/PANGAEA	Dec. 2019	eachterberg@geomar.de

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