Meteor 55 1st Weekly Report (12.10.2002-20.10.2002)

Meteor Cruise 55 departed Willemstad, Curacao on Saturday October 13 at 18.15. Just a week prior to departure, the decision was made to shift the end-port for the cruise from Abidjan in the Ivory Coast to Doula, Cameroon. This was required due to continued civil unrest in the Ivory Coast. Arrangements for Doula were still being made as we left.

Most of the scientific staff arrived in Curacao two days prior to departure after a gruelling 20-hour journey. They were greeted by a few tanned, relaxed colleagues who had wisely travelled earlier. Late that evening Meteor was viewed sailing through the narrow entrance to Willemstad harbour. On October 12, we arrived at dockside to find that all our containers had been delivered and those to be carried on board were already stowed. There followed the usual frenzy of moving boxes, unpacking, and setting up.

The set-up of the laboratories for this cruise has been unusually complex. A large amount of sophisticated analytical equipment is deployed on board, including 7 gas chromatographs within the Universal and Geo Labs alone. Most of these systems are supplied with surface water that is pumped continuously from the Meteor's 'Moon Pool', as well as by centrally-distributed supplies of high-purity nitrogen, ultra-clean air and hydrogen from gas generators. Due to excellent organisation of the shipment and lab assignments by Hermann Bange, and superb cooperation from the crew, the set-up went extremely fast despite the complexity. This allowed us to meet the planned departure time which had been brought forward by 12 hours due to the long transit to Douala ahead.

Meteor 55 is the first German SOLAS (Surface Ocean Lower Atmosphere Study) expedition, and one of the very first SOLAS expeditions worldwide. SOLAS is a brand-new, international global-change research program that is focussed on atmosphere-ocean exchanges. Internationally, only the Canadians have been quicker than Germany to get SOLAS into the water (and air). Briefly put, SOLAS aims to investigate the role of the atmosphere for surface ocean chemistry and biology, and the role of surface ocean biology and chemistry in controlling atmospheric chemistry and climate. For Meteor 55 we have assembled a team of ocean chemists, biologists and atmospheric chemists to work together on a range of issues related to atmosphere-ocean chemical interactions. It is hard within the context of this first report to do justice to the breadth of programs that we are conducting on this cruise. I will leave a detailed discussion of individual scientific programs and their findings to later weekly reports. In this report I would rather convey an impression of the themes underlying the cruise and the general atmosphere that is developing on board.

On the ocean side, the cruise includes a full biological program looking at biomass, productivity and nitrogen fixation along the cruise track. The ocean chemists are measuring a range of dissolved gases ranging from oxygen and CO_2 through the long-lived radiatively-active trace gases N_2O and CH_4, to a wide range of shorter-lived, naturally produced trace gases including halocarbon compounds, dimethyl sulphide, and the alkyl nitrates. The atmospheric chemists are measuring a range of trace oxygenated organic compounds such as acetone, methanol and acetonitrile not only in the atmosphere but also, almost for the first time, in the ocean. Intercalibrations between the ocean and atmosphere measurements, and between the different groups, are being conducted on board. Joint experiments and sampling programs are being undertaken. I have been particularly pleased to see intense communication between 'atmosphere people' and 'ocean people' at mealtimes and coffee breaks. The atmospheric chemists are looking down microscopes and marvelling at plankton diversity. The oceanographers are being exposed to continuous measurements of ozone, methanol and BrO and learning about the structure of the atmosphere.

An important theme for the cruise concerns the role of the atmosphere in suppling key nutrients required for phytoplankton growth. An atmospheric chemistry program examining dry and wet deposition of iron and nitrogen species is therefore closely tied to an ambitious program of biological experimentation. In the experiments, nitrogen, phosphate, iron and even Sahara dust, are being added to water samples collected from along the cruise track in order to study the growth response of phytoplankton to these different nutrient additions.

Based on what I have seen so far, I am sure that the atmosphere and ocean groups will develop long-term collaborations and joint projects based on results and ideas that arise from this cruise. If this happens, then one of the overall aims of the Meteor 55 cruise will have been fulfilled.

Some specific details:
Sampling: We are doing 2 stations per day: a morning station with 2 CTD casts, a trace-metal hydrocast and net tows and an afternoon CTD cast. We made our first station on October 16 about 240 miles due east of Trinidad and Tobago. A very large portion of our measurements however are made on air and pumped surface seawater during steaming.

A notable feature of the cruise so far has been the support we have received from the Deutsche Wetterdienst (DWD). The scientific staff have been provided with meteorological satellite images, analyses of ITCZ position, and all-important rainfall forecasts for our dry and wet deposition measurement program. A coordinated and expanded program of radiosonde launches has been worked out. Cooperation with the DWD will be important for future SOLAS research, and this is a small but promising first step.

At present all our analytical and sampling systems are operational. Experiments are also underway. Here are a few early highlights: our first clear evidence for deposition of dust was measured on 15-16 October with visible red streaks seen on the filters after a 40 hour collection. Dust continued to show up on the filters for a few days until apparently interrupted by a northward excursion of the Intertropical Convergence Zone. High frequency continuous measurements of atmospheric methanol are alsoshowing interesting structure associated with our postion relative to the ITCZ. A new dissolved oxygen sensor that we are field testing along the cruise track has shown excellent stability and extremely high resolution. A diurnal signal in surface water oxygen saturation of a couple of percent is clearly discernible in the data.

Based on daily Seawifs images of ocean colour, we altered course to intersect a large region of very high surface chlorophyll that was clearly visible from space at about 10°N, 52°W. The feature reflected Amazon-derived material that had been swept more than 400 miles offshore. Samplingof this plume revealed coastal assemblages of plankton but also, surprisingly for us, many tufts of nitrogen-fixing Trichodesmium were seen. Surface salinity and pCO_2 dropped rapidly to <29 and <290 ppm respectively. Later we sailed through a major surface slick of blooming Trichodesmium. These were growing well above a chlorophyll maximum that was composed of diatoms. This was clearly what Seawifs had detected and without the Seawifs imagery we would have missed this completely. Several experiments were initiated with water collected from within this feature. The remainder of the cruise track may well continue along 10°N instead of 11°N as originally planned. We are receiving several other observational and model products on board, including maps of integrated dust deposition. These products are being examined to guide our cruise track with respect to regions of dust deposition.

In summary, it has been an exciting and busy week full of both expected and unexpected findings that bode well for the remainer of the cruise. Equipment became operational rapidly which means that we are all having fun measuring, experimenting and enjoying our work. The cruise has a very international flavour, and we have scientists on board with origins in 7 nations. Many have not sailed with Meteor before. All the scientific staff are impressed by the capabilities of the crew and officers of Meteor. Not only the professionalism but also the cooperation and friendliness of the crew have been exemplary. The crew of Meteor are a national, even international, treasure.

Doug Wallace
Fahrtleiter, Meteor 55

Meteor 55: 2nd Weekly Report (21.10.2002-27.10.2002)

By the end of the 2nd week we have settled into some sort of routine. The initial excitement of sampling the Amazon plume waters, with theit surprisingly low pCO_2 and a bloom of nitrogen-fixers, has receded in our minds as we concentrate on the more regular section work that is the core of our cruise.

We continue to have two stations per day. The early station, which starts at 05.00, is the more extensive with a minimum of 2 separate CTD casts. On many days, we have added 1 or 2 additional CTD casts in order to collect large volumes of water for on-board experiments. At tbis station we also conduct two casts with Go-Flo sampling bottles specially suited for contamination-free sampling of trace metals. Sampling at this station extends to a maximum depth of 600m with a major emphasis on the waters at, and overlying, the chlorophyll maximum. The afternoon station is usually less extensive, with a single CTD cast as well as measurement of light and fluorescence profiles. The afternoon sampling is also usually to 600m but this has, on occasion, been replaced by a full-depth CTD cast.

In order to satisfy the needs of all groups, several of whom require several liters of water from each depth, we developed a carefully controlled sampling protocol. The high diversity of samples being collected from the CTD casts also threatened to become a nightmare of record-keeping and data management. We have adopted a sample identification system that was initially developed by the Bedford Institute of Oceanography in Canada. This system assigns, to each separate water sample, an identification number that is consecutive throughout the entire cruise. This identification number uniquely identifies the station, cast, depth and sample bottle from which the water sample was collected. The identification numbers are pre-printed onto special sheets of sticky labels that are proven to stick securely to all sample containers, wet or dry. Each sub-sample drawn from a water-sampling bottle (e.g. a nutrient sample) is then labelled with one of these stickers that displays the unique identification number for the sample. Despite some initial skepticism, the advantages of this system for a cruise of this nature are now appreciated by all sampling groups. We wholeheartedly recommend it!

As well as the water column sampling, the underway sampling of surface water and air has also continued at fast pace. Collection of these samples is coordinated on the basis of common sampling times during the day. Underway samples are also collected for a set of on-board nutrient enrichment experiments.

We have suffered few equipment failures. We had one short-lived scare with the CTD which turned out to be software-related, and we had a potentially major problem with our multi-channel fluorometer whose pressure-housing leaked slightly on one deployment. Heroic efforts from the Meteor's excellent electronics team allowed a damaged circuit-board to be repaired, and it is now fully operational again. Otherwise problems have been limited to the usual intense, almost personal, battles of chemists with recalcitrant, sensitive gas chromatographs or the struggles of biologists to carry, manipulate and filter vast quantities of water on a moving vessel. In other words: absolutely nothing out-of-the-ordinary.

Progress

During the 2nd week we have steamed steadily east along 10°N. Altogether, for the period covered by this report we travelled almost 1000 miles to the east. On the evening of the 26th we turned south for a transit to the equator along 26°W. The equator transit is designed to allow air sampling along the steepest gradient of the ITCZ, and we will also recover a sediment trap mooring belonging to the University of

Bremen at 0 N, 23W. Seawifs images have been showing a clear biomass signal that is associated with equatorial upwelling so we will conduct a limited amount of station work at the equator. On the Saturday evening, just as we started to head south, the staff and crew enjoyed a barbecue on deck accompanied by tropical sunset, warm weather and calm seas. A very welcome break from the constant filtration, experiments, analyses and fighting with complex instrumentation of the previous two weeks.

Results

Here follow brief highlight reports from a few of the groups on board. Other groups and themes will be covered in next week's report.

- Dissolved oxygen and nutrients have been measured at all stations and all depths. Chlorophyll has been measured at most stations in the upper 150m. The section to-date shows nitrate and phosphate to be below detection limit in surface waters throughout the section, however the depth of the nutricline has risen steadily towards the east. Nitrate to phosphate ratios show a distinct maximum, exceeding the Redfield ratio, immediately below the chlorophyll maximum. The chlorophyll maximum was deep and weak throughout most of the eastern part of the section, but has became shallower and stonger towards the east. At the easternmost stations occupied immediately prior to our southward turn, we started to encounter the shallow oxygen minimum with concentrations as low as 40 uM. This will become more pronounced when we resume our section and sail further eastwards following our brief equatorial excursion.

- Dust and rain sampling. Dust and rain samples are being collected along the cruise track to investigate how much nitrogen, phosphorus and iron are deposited into the ocean from the atmosphere. Model predictions of dust transport that we have been receiving on board show that we have been sailing directly along the axis of the main transport route for Saharan desert dust across the Atlantic. We are particularly interested in how much iron is carried by this dust. Dust has shown up on our filters on almost very day of the cruise so far. We were fortunate to intercept and sample one particularly spectacular dust transport event that we had previously seen (in Seawifs satellite imagery) leaving the West African coast on October 23rd. The large amount of dust in the air was easily noticed: visibility dropped significantly and the sunset had an unusual pale yellow colour. Rainfall collection success has far exceeded our expectations. Useful amounts of rainfall have been collected on 3 of the past 7 days and it is looking like the M55 cruise will contribute an extensive data set for the chemical characterization of tropical marine rainfall.

- Canister sampling. A significant component of the air chemistry program is the regular collection of cartridge and canister samples for subsequent analysis in the laboratory. The Meteor 55 cruise has attracted the interest and participation of a number of groups due to interest in the region we are studying and the ancillary and related programs that are being conducted on board. Canisters and cartridges are being collected every 6-12 hours for the following groups: the National Center for Atmospheric Research in Boulder (Elliot Atlas), the NOAA Climate Monitoring and Diagnostics Laboratory in Boulder (Jim Butler), the Max Planck Institut für Chemie in Mainz (Jonathan Williams), the Institut für Meereskunde in Kiel (Birgit Quack), and the University of East Anglia (Adele Chuck and Peter Liss). The samples will be analysed for a wide range of halogenated trace gases and other trace organics. The collection strategy allows for high resolution sampling but also, very importantly, for direct intercomparison of data.

- Protein Transfer Mass Spectrometry (PTRMS). A PTRMS system suitable for measuring a range of organic compounds in seawater has been set up in the Geo Labor. This instrument is brand-new and is now making the very first measurements of their kind on seawater samples. At present the instrument is used to investigate the distribution of acetonitrile, isoprene and acetone in surface waters and in depth profiles. A separate system is installed in the Luftchemie Labor and is making measurements of the same species at 2 minute frequency in boundary layer air. The goal is to investigate source-sink behaviour for these compounds along the cruise track. Initial results suggest that no regions with significant oceanic emissions or oceanic production of these compounds were crossed last week. This was confirmed by very low gas-phase concentrations. The first profile measurements show evidence for within-ocean destruction of these species: acetone, acetonitrile and isoprene were all below detection limit in a sample collected at 200m.

- Nutrient Addition Bioassays: in addition to characterization of biomass and productivity along the cruise track, an intensive program of biological experimentation is being conducted. These experiments are designed to determine which nutrients limit primary production. The growth and physiological response of phytoplankton is monitored during incubations following addition of different combinations of N, P and Fe. The large number of possible combinations of these nutrients together with the need to avoid contamination of the incubation bottles, means that these experiments are extremely difficult and time-consuming. So far, 2 separate experiments have been completed. Each experiment has involved about 10 separate nutrient treatments requiring almost 120 separate incubations. Preliminary results of the first experiment show a significant response after the addition of Saharan dust that contained Fe and P. The second experiment, made further to the east where surface water iron levels were high, showed the strongest response to combined additions of N and P. These experiments are conducted every 3-4 days. The next one is scheduled for our southward transit to the equator.

Stay tuned for more reports next week on other groups' activities, notably the results of the various trace gas investigations that are being conducted on board.

Doug Wallace
Fahrtleiter, Meteor 55

Note: Short photoessays from the Meteor 55 cruise should be viewable on www.meeresforschungonline.de at regular intervals.

Meteor 55: 3rd Weekly Report (28.10.2002-3.11.2002)

It continues to be hard to report succintly on Meteor 55 due to the diversity of measurement programs going on. The third week of the cruise passed quickly and several exciting results are starting to emerge. The intense cross-discipline discussion continues at coffee breaks and at the lunch table. Presently plans are being hatched, during informal discussions, for a set of mega-experiments to be conducted during the long final transit to Cameroon. It looks like this 'grand-finale' may end up involving almost all of the biological and chemical groups on board.

The week started with a transit towards the equator along 26° 30'W. This transit had been planned to allow the atmospheric chemists to sample across the Intertropical Convergence Zone (ITCZ), and this worked out perfectly. The crossing of the ITCZ was seen very clearly in the atmospheric pCO_2 data (the strong seasonality of northern hemisphere pCO_2 causes northern hemisphere air to have a slightly lower pCO_2 than southern hemisphere air at this time of year). The gradient between the hemispheres was also exceptionally well resolved in several trace gases, with acetone and methanol being higher in the northern hemisphere air and dimethyl sulphide being higher south of the ITCZ. At the time and location of our transit, the gradients were quite sharp, being concentrated into a band between 7°N and 5°N.

The southward transit also allowed us to sample higher surface biomass, visible in Seawifs imagery, lying within 1 degree north and south of the equator. We arrived at the equator early on the morning of 29 October, just in time for the morning productivity station. In total 4 stations were occupied at the equator between 26°W and 23.5°W. At these stations we found significantly deeper mixed layers (up to 80m deep) and, associated with this, higher near-surface bromoform levels and lower methyl iodide concentrations. On the morning of 30 October we arrived at the location of a University of Bremen long-term sediment trap mooring. It took less than 2 hours to release the mooring and get it on deck, which is testimony to the efficiency and great skill of the Meteor's deck crew.

Following the brief stay at the equator we returned northwards along 24°W in order to resume our main west-east transect. Much of this time we lay under a dense swath of cloud and we were able to sample occasionally intense tropical rainstorms. The remainder of the section work will be conducted next week. We have planned an ambitious series of stations along a transit into the coastal waters of Guinea Bissau. One goal is to examine trace-gas production in the productive waters off the west coast of Africa and to see whether we can detect an influence of coastal upwelling, or upwelling associated with the Guinea Dome, on surface water gas saturations, air-sea fluxes and atmospheric concentrations.

In addition to measurements and experiments we have been busy taking lots of photos. Some of these have been compiled into photo-essays designed to give younger schoolchilden an impression of who we are and what we are doing. These should be accessible at: www.meeresforschungonline.de

And now, as promised last week, here are reports from the various trace gas measurement groups on board:

- Brominated Halocarbons. The ocean is a source for a wide variety of naturally occurring volatile halogenated compounds. Of particular significance is the sea-to-air flux of bromoform ($CHBr_3$) which significant for ozone destruction reactions. The strong atmospheric convection typical of tropical regions provides a mechanism for rapid transport of short-lived gases from the ocean surface to the upper troposphere and lower stratosphere. We are therefore characterizing the sea-to-air flux of bromoform and related compounds along the Meteor 55 cruise track. Preliminary results, from mass spectrometry based measurements, show peak levels of bromoform close to the sub-surface chlorophyll maximum and a strong gradient towards the surface. Below the chlorophyll max, levels decrease with depth and concentrations of other compounds that are degradation products of bromoform, increase. We are therefore also investigating whether this bromoform degradation pathway has potential for use as a circulation tracer over timescales of many decades to hundreds of years.

- Alkyl nitrates: Another family of trace gases being measured on board are the light alkyl nitrates. Methyl and ethyl nitrate have recently been found to be emitted from the ocean in certain regions - a result that was surprising as these gases had been assumed to be present in the atmosphere mainly as a result of anthropogenic activities. The alkyl nitrates influence the ability of the atmosphere to cleanse itself of pollutants and other chemical species. The discovery of an oceanic source for these species has therefore opened up many questions. Vertical profiles of these compounds are being measured in order to shed light on the (unknown) processes responsible for production of these gases. In addition, surface underway samples and air samples are being collected and analysed to calculate the fluxes of these compounds in and out of the ocean.

- Methyl Iodide. Methyl iodide (CH_3I) is responsible for carrying a large flux of iodine from the ocean to the atmosphere, where the CH_3I is rapidly broken down. The iodine subsequently participates in a range of potentially important atmospheric processes. A regular program of measurements for CH_3I in surface water and air has been conducted along the cruise track. Separate measurements of depth profiles are being made in conjunction with the alkyl nitrate determinations. The CH_3I has been strongly supersaturated throughout the cruise, and some clear spatial variations have been observed, particularly close to the equator. In the past week, a series of incubation experiments has been initiated to investigate factors responsible for the high supersaturation of CH_3I in surface seawater. In particular we want to determine whether there is any direct biogenic formation of this compound, or whether photochemical processes are primarily responsible. Initial results from the very first of these experiments this week look promising, and if repeatable, may shed considerable light on the formation of this gas.

- DMS and DMSP. A set of simulated in situ experiments are being conducted on board to estimate the production and turnover of dissolved and cellular dimethylsulphoniopropionate (DMSP) and its response to enrichments of dissolved organic and inorganic nutrients. DMSP is generated in large amounts by phytoplankton and, as the precursor of dimethyl sulphide (DMS), it is the major biogenic source for the volatile reactive sulphur emitted from the ocean. Incubation experiments have been conducted on deck in large-volume containers. We have also conducted a set of experiments to determine the variability of the bacterial degradation of dissolved DMSP in response to selective nutrient enrichments. In the first results available, we detected a strong response of DMSP degradation to enrichment with dissolved organic nutrients but relatively low response to enrichment with dissolved inorganic nutrients in both the equatorial upwelling as well as in oligotrophic waters.

- N_2O. Nitrous oxide (N_2O) is an atmospheric trace gas which, directly (as a greenhouse gas) and indirectly (as precursor for radicals involved in stratospheric ozone depletion), influences climate. Preliminary measurements in the atmosphere and surface ocean reveal surface concentrations that are close to equilibrium value indicating that oligotrophic tropical Atlantic is a weak source of N_2O for the atmosphere. We have also measured a number of vertical profiles which show that N_2O is supersaturated throughout the sub-surface water column including a considerable accumulation below the euphotic zone with maximum values at about 400m. As we have progressed from west to east we have seen increasing maximum N_2O concentrations which are inversely correlated with the dissolved oxygen concentration in the oxygen minimum zone.

- CO_2. Measurements of the CO_2 partial pressure of surface seawater and air are being made continuously during the M55 cruise. So far, most measurements have documented conditions typical for tropical oceans with surface waters being close to equilibrium with the atmosphere. Strong deviations from equilibrium have also been measured however. Significant undersaturation was found within a large region affected by the Amazon river plume. The undersaturation likely documented the biogeochemical aftermath of an earlier phase of high productivity. The observed pattern gave rise to a sizable sink for atmospheric CO_2. Significant supersaturation was observed at the equator representing the effects of equatorial upwelling. Due to the sluggish exchange of CO_2 between ocean and atmosphere, measurements of the CO_2 partial pressure likely provide a long-term surface 'memory' of prior upwelling.

Next week we will have reports from the biology and trace metal programs as well as more atmospheric chemistry programs.

Doug Wallace
Fahrtleiter, Meteor 55

Meteor 55: 4th Weekly Report (4.11.2002-10.11.2002)

The fourth week of the cruise has been full of incident. Remaining uppermost in our minds is our unexpected meeting with Polarstern on the high seas. More about that later. The week also saw us collect our 2000th water sample, complete our section across the tropical Atlantic including sampling over the continental shelf of Guinea Bissau, and we also conducted our final 'routine' CTD station. We initiated a series of 'mega-experiments', or on-deck incubations, involving most of the groups on board. These experiments will continue during the transit to Douala. The experiments are already stimulating a lot of discussion concerning follow-up research on future expeditions. More about those ideas in my final report perhaps. Underway and air sampling will continue until we leave the waters of the Ivory Coast.

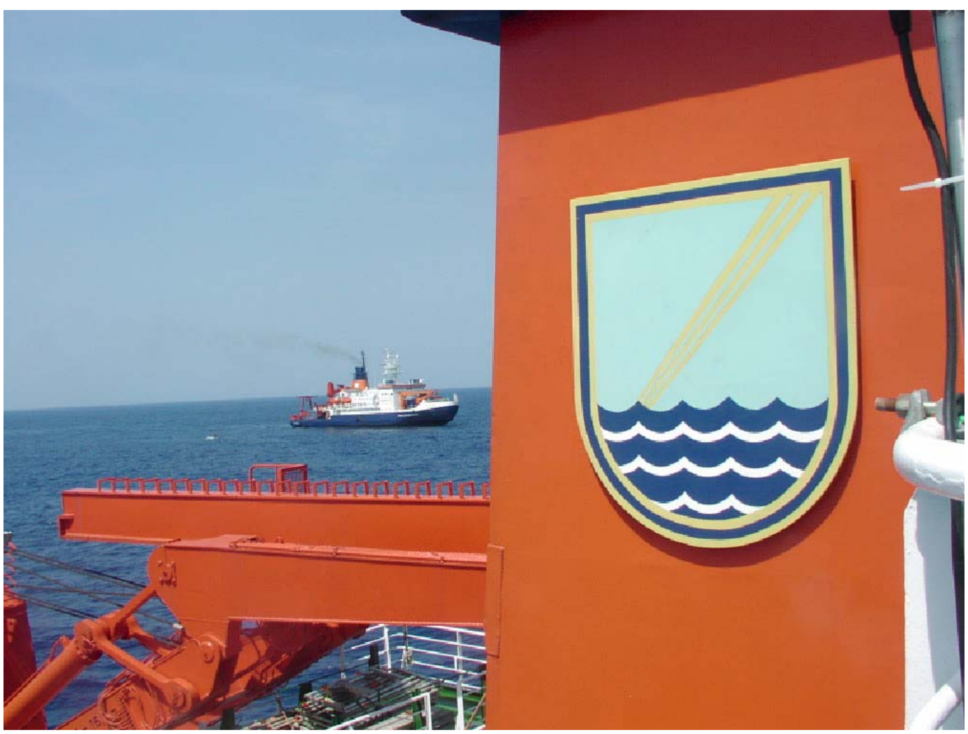
Our memories of the past week are dominated by the high-seas meeting of Polarstern and Meteor which took place on Friday 8th November at 1300 UTC. Thanks to networking between the DWD weather technicians on board Polarstern and Meteor, we had learned, mid-way through our cruise, that Polarstern was steaming southwards from Vigo to Cape Town. Clearly our cruise tracks were going to cross, but the chance of an intersection seemed exceedingly remote. Polarstern was on a rapid transit to Cape Town and had a very tight schedule. Our temporal constraint was based on our permission to do station work in the EEZ of Guinea Bissau for a maximum of 72 hours. We had to make sure that we used every minute of this allowed time in order to complete our transect to the African coast. If Polarstern entered our area before or during those 3 days, then no meeting would be possible. As it was, Polarstern gave us an ETA at 11°N 20°W of Friday 8th November, 1300 UTC. We were scheduled to finish our last station in Guinea Bissau waters at 11°N, 19°W late on Thursday night. Our plan had been to do more stations in the region along 11°N. It was clear that our paths were going to intersect.

Meeting Polarstern offered up a solution to a problem that had been worrying us. The last-minute change of port call from Abidjan to Douala had messed up our plans for return shipment of frozen samples. Our agent in Douala gave us a price of thousands of dollars for the very limited quantities of dry ice we needed. Clearly shipping frozen samples from Douala was not going to work. We were facing having to leave the samples on board Meteor until she reached Cape Town after Christmas. The Polarstern's rapid transit to Cape Town opened up an alternative means to get our samples back safely and quickly.

I was pleased to learn that my fellow marine chemist, Gerhard Kattner of the Alfred-Wegener Institut in Bremerhaven, was chief scientist on board Polarstern. I learnt from Gerhard that Polarstern had a mixture of disciplines on board that was very similar to ours. Their science programs ranged from measurements of a range of trace atmospheric species including ozone, through to marine chemistry and marine biological investigations. One key goal of their cruise was to collect data (e.g. with an upward-looking FTIR system) in order to calibrate the new European satellite ENVISAT. Another program is looking at persistent organic pollutants to obtain information about transport and exchange in and between the atmosphere and the ocean. The biological program deals with the distribution of the tropical zooplankton and its biochemical composition with special regards on lipids. These programs were being conducted at the start of Polarstern's 20th Antarctic research campaign. She is due to dock in Cape Town on November 22. We agreed over the radio that this was an excellent opportunity to compare programs and exchange ideas. Also, Polarstern generously agreed to accept our frozen samples for more rapid shipment back to Germany from Cape Town.

Following our morning station on Friday the 8th we sailed back to the agreed upon meeting location, with Polarstern clearly visible on the horizon. Curiously, a drifting orange float, that Neptune had apparently left for us, marked the rendezvous location. Conditions were ideal for the meeting: hot and sunny with calm seas. Polarstern manoevered into position a few hundred meters away from us and then Gerhard Kattner and the senior scientific staff from the Polarstern travelled to Meteor on rubber boats.

Meteor and Polarstern



Polarstern and Meteor funnel logo


POLARSTERN

Kattner and Wallace

After this initial meeting, there was an extensive exchange of scientific staff and crew members between the ships for a period of 3 hours. The rubber boats shuttled back and forth between the two ships while hundreds of photographs were being taken, tours of the ships conducted and souvenirs swapped and purchased. In addition to making final arrangements for the sample shipments, the occasion was used by the atmospheric chemists from Polarstern and Meteor to compare their respective programs. Notably, Polarstern and Meteor are both equipped with Multiaxial Differential Optical Absorption Spectroscopy systems from the University of Heidelberg. The meeting allowed an unusual opportunity for direct inter-comparison of these systems at sea.

After about 3 hours, the last rubber boats returned staff to their respective vessels, the ships horns were sounded, and Meteor and Polarstern sailed apart to resume their respective programs.

Polarstern silhoutte

The meeting was a welcome interlude to our science program. During the past week, we crossed the waters of the Guinea Dome and performed several stations over the continental slope and shelf of Guinea Bissau. We completed two east-west transects over the continental margin, including several deep stations. At Station 43 on November 7th we celebrated the collection of sample number 2000. During this eastern portion of the transect we have been sampling a more intense oxygen minimum at about 400m as well as a shallow oxygen minimum at less than 100m. Both minima are clearly reflected as maxima in N_2O concentrations. Nutrient isolines have shoaled and gradients steepened.

Along the section, the halocarbons such as methyl iodide and bromoform are showing highly consistent profiles: generally they show a sub-surface maximum either above or in the vicinity of the chlorophyll maximum. The processes responsible for producing this trace gas maximum are still unclear and presently the subject of considerable experimental work on board. At this stage it looks as though a definitive experimental definition of the environmental factors controlling the formation of these compounds may elude us. However the profiles and experiments we have conducted so far are the basis for hypotheses that can be tested subsequently in the laboratory.

We have been fortunate that the CTD and rosette, in the capable hands of Jens Schafstall and Hans-Peter Hansen, have worked almost flawlessly since early in the cruise. Not more than a handful of Niskin bottles have failed to close or closed at the wrong depth. We are, therefore, already well along with our data assembly. The CTD oxygen sensor calibration is nearly completed and all the CTD data together with nutrient, oxygen, chlorophyll and primary productivity data have been assembled and plotted as profiles and sections. The quality of the overall data set appears to be very high.

The final week of the cruise will see completion of two additional experiments, processing of samples, assembly and distribution of shipboard data and, of course, packing.

And now, as promised last week, here are reports concerning the biology and trace metal programs:

Phytoplankton biomass and productivity:

Many of the chemical species (or their precursors) emitted from the ocean and measured by the marine and atmospheric chemists are hypothesised to have been produced initially by phytoplankton. Therefore, parallel to the chemical measurements the distribution and activity of the phytoplankton is routinely determined in the upper 150m of the water column. The photosynthetic pigment chlorophyll, common to all phytoplankton groups, is used to map the distribution pattern of the algae. In general surface chlorophyll values were pretty low (< 0,1 µg/l) with small maxima in the Amazon plume and close to the African coast. We clearly see a deep chlorophyll maximum between 60m to 35m which becomes shallower and more pronounced towards the east along the transect. Such a deep chlorophyll maximum is typical for these tropical regions and is caused by lack of nutrients in the surface waters forcing the phytoplankton to resort to the deeper part of the euphotic zone where they can acquire nutrients from within the thermocline. Despite the high chlorophyll concentrations, primary production is very low at this depth and light is the limiting factor for phytoplankton growth. Experiments with water from the deep chlorophyll maximum show that phytoplankton from this low-light environment respond fast when brought up to higher light intensities. In contrast to the surface water, they are not nutrient limited and develop high growth rates at higher light levels. Post-cruise analysis of a range of different pigments, flow cytometry and microscopy will give additional information concerning which phytoplankton groups are present in the chlorophyll maximum and in the other parts of the water column. In first microscopic inspections we observe a wide variety of species that are either autotrphic or heterotrophic, including very colourful copepods, many of them carrying eggs, many dinoflagellates, tintinnids, and radiolarians.

Most pronounced among the autotrophic phytoplankton are occasionally relatively high densities of the nitrogen-fixing cyanobacterium Trichodesmium. They occur in long trichoms consisting of hundreds of cells and the trichoms are again packed in colonies of two different forms. On calm days the colonies float on the surface visible by the naked eye as little yellow- brownish dots. Production by Trichodesmium is a crucial variable because these organisms are amongst the only ones that are independent of nitrogenous nutrients. They are able to take up dinitrogen from the water and convert it into biomass. The biomass is then later degraded in the water column delivering additional nutrients to an otherwise limited environment. This is one of the main reason to study Trichodesmium production during the cruise in more detail.

On average, primary production has been 1 g C m^{-2} d^{-1} and in the Amazon plume and close to the African coast it was 3-4 times higher. Satellite images that we received on board showed higher chlorophyll concentrations along the equator originating from the upwelling region off the African coast. However, our data showed only a modest increase above the average level at the equator. This suggests that the elevated chlorophyll levels observed by the satellite were probably produced "downstream" and haD been advected to our position.

The small phytoplankton (less than 2µm in diameter) are the most active and they dominate primary production. This is also typical for tropical plankton. In order to understand the balance between production of organic matter and its breakdown, we also measure bacterial production and the activity of hydrolytic enzymes (phosphatase). These measurements will give an indication how fast the organic matter produced by the phytoplankton is being recycled.

Trace Metals:

During the M55 cruise the trace metal group from IfM – Kiel has been examining the influence of Saharan dust on the concentration of iron in the near surface waters across the central Atlantic. Iron is a major constituient of Saharan dust, but is poorly soluble in seawater, and so most rapidly sinks from the surface ocean to the sediments below. Iron is a key element for phytoplankton growth as it is required for both photosynthesis and respiration., in many open ocean regions, away from sources of iron supplied directly by rivers or from coastal shelves, iron has been shown to be the key limiting element for phytoplankton growth.

Our results gained so far during M55 point to the strong influence of Saharan dust on the distribution of iron in the central Atlantic with by far the highest concentrations found in the eastern basin closest to the source regions in the Sahara itself. Our work has also focussed on the different forms of iron found in seawater and how they change upon addition of the Fe-rich Saharan dust falling from above. Interpretation of the data will be assisted by comparison with dust deposition estimates derived from an atmospheric transport model. This combination of real-time model predictions of atmospheric dust input, with in-situ observations has, to the best of our knowledge, not been attempted before. During the later stages of the cruise we plan to conduct some dissolution experiments using dust collected along the transect. The results to date suggest that the work in this region should greatly increase our understanding of the processes that affect the distribution and cycling of iron in the ocean.

Next week: wrap-up of the cruise and, hopefully, insight into results from the on-board bioassay experiments and the 'mega-experiments'. Also: the ideas for our next Meteor cruise!

Doug Wallace
Fahrtleiter, Meteor 55

Meteor 55: 5th Weekly Report (11.11.2002-17.11.2002)

The beginning of the 5th week saw us complete our final CTD at station 51 west of Liberia. This was the 110th CTD cast of the cruise. This completed a short series of stations that we had made while steaming south-eastwards from 11°N, 20°W at the beginning of our transit to Douala. This short section allowed us some time to do a couple more deep CTD casts in order to resolve the deep N_2O profiles.

At Station 51 water was collected to initiate a second 'mega-experiment' in which most groups on board once again participated. In these experiments, 48 hour incubation experiments are conducted on-deck using 12-liter bottles. In the first experiment, the incubation bottles had been deliberately manipulated in various ways in order to stimulate either phytoplankton or bacterial growth. The treatments in the 2nd experiment were more limited, involving the addition of 'all' nutrients or the addition of dissolved organic carbon (to stimulate bacterial growth), and there were replicate treatments. The 12-liter bottles were maintained on deck under near-surface light conditions and sampled for a wide variety of parameters after 24 and 48 hours. A preliminary look at the data from the experiments suggests no obvious trends for the volatile halocarbons and N_2O over the course of the incubations. Experiments of this nature are likely to be a focus for future SOLAS research however, because a causal and mechanistic understanding of oceanic trace gas production is required. Through conducting these experiments on board towards the end of the cruise, and discussing the experimental design and results together, we have started developing ideas how such experiments should be conducted.

After station 51 our work reverted to underway sampling and air analyses. The transit from the last station to Douala was approximately 1400 nautical miles! The halocarbon and alkyl nitrate groups took the opportunity of this long transit to intercompare standards. Other groups spent time working up their data and, of course, writing their sections of the cruise report. An important late evening activity was working on the Meteor guest book. (The Chief Scientist kept a deliberately hands-off policy on this and expects, as a result, to find some embarrassing pictures in the final product). We held a science results discussion at which the various groups highlighted their initial findings, and outlined their short-term plans for working up samples and analyzing results. In the course of this discussion, additional useful collaborative analyses between groups were identified. It is clear that all groups that were on board have collected excellent data sets and that there are many exciting and new findings to write about. Given the risk associated with taking so many complex analytical systems to sea, several for the first time, it was gratifying to see that all groups had a highly successful cruise.

Some highlights that appeared:

- The west-east transit showed strong gradients in dissolved and particulate iron in the water column. A unique aspect of this cruise is our ability to relate these water-column measurements to dust characteristics measured simultaneously along the transit as well as to models of dust deposition provided by the atmospheric chemistry groups.

- We collected sufficient data for alkyl nitrates and halocarbons to identify very clear patterns in the vertical profiles. Many gases show profiles characterized with a maximum near, but not necessarily at, the chlorophyll maximum. Detailed analysis of these profiles together with biomass and biological rate measurements is already providing insight into likely production pathways. In the case of CH_3I, on-board experiments have revealed, for the first time, the factors that control its production.

- In the case of N_2O, the along-transit gradients of sub-surface dissolved oxygen are mirrored in N2O concentrations. Detailed analysis of these gradients and of the steep N2O gradients that exist through the thermocline should provide useful information on N2O formation rates and fluxes.

- The nutrient bioassay experiments conducted throughout the cruise have provided insight into the nutrients that limit primary production along the transect. These experiments were also used to experimentally investigate the influence of limitation by different nutrients on nitrogen fixation. Initial results show a major limiting role for inorganic nitrogen throughout the cruise, with a secondary role for iron and/or dust in certain parts of the section. Findings concerning the influence of nutrient and dust additions on nitrogen fixation await analysis of samples in the laboratory.

The transit allowed us to have boxes packed and ready upon arrival in Douala. However container packing had to be done in Douala. Our planned arrival at the pilot station at 08.00 on the 17th was delayed until 16.00 due to lack of berths in the harbour. Finally we docked at about 18.00 and completed formalities fairly smoothly. At the time of writing we are still waiting to pack the remaining containers that are being delivered this morning (the 18th). Given that the science party are scheduled to depart this evening for home at 2300, its going to be a very busy and tiring day.

Synopsis: the Meteor 55 cruise was the first German SOLAS (Surface Ocean Lower Atmosphere Study) cruise and one of the very first SOLAS cruises worldwide. I think that we were very successful in bringing marine chemists, atmospheric chemists and biologists together to work together on common themes. The enthusiasm for this interdisciplinary work was shared by all on board, and, by the end of the cruise all could see the benefits. The days of atmospheric chemists measuring oceanic trace gas distributions in the absence of related oceanographic or biological information are, hopefully, over. Similarly, a host of new scientific questions involving the atmosphere have been identified by the marine scientists, and their understanding of and interest in the dynamics of the atmosphere has been increased greatly. The marine chemists have also been exposed to state-of-the-art atmospheric trace gas measurement systems.

All of this, as with all Meteor cruises, was only possible because of the excellent performance of the ship and her officers and crew. The science support has been exceptional throughout. The experience and creativity of the officers and crew is what stands out: they are flexible, and able to quickly and accurately analyze special needs and situations that develop. This is as true of the seamen on deck as it is of the technical staff and officers. Things run smoothly and well. Problems get solved. People are helpful and genuinely concerned that the science gets done efficiently, excellently and safely. All of the scientists on board Meteor 55 are grateful for the support they received and we wish the officers and crew all the very best for the future. We sincerely hope that the excellence that characterizes Meteor at the present time can be maintained into the future.

Doug Wallace
Fahrtleiter, Meteor 55