Short Cruise Report

Meteor Cruise 55, Curacao to Douala
October 13 to November 17, 2002

Chief Scientist: Douglas Wallace
Forschungsbereich Marine Biogeochemie
Institut für Meereskunde an der Universität Kiel

Summary

METEOR 55 was a single-leg expedition which comprised a trans-Atlantic section from west to east along 11ºN together with a short, mid-ocean North-South transect to the equator (Figure 1).

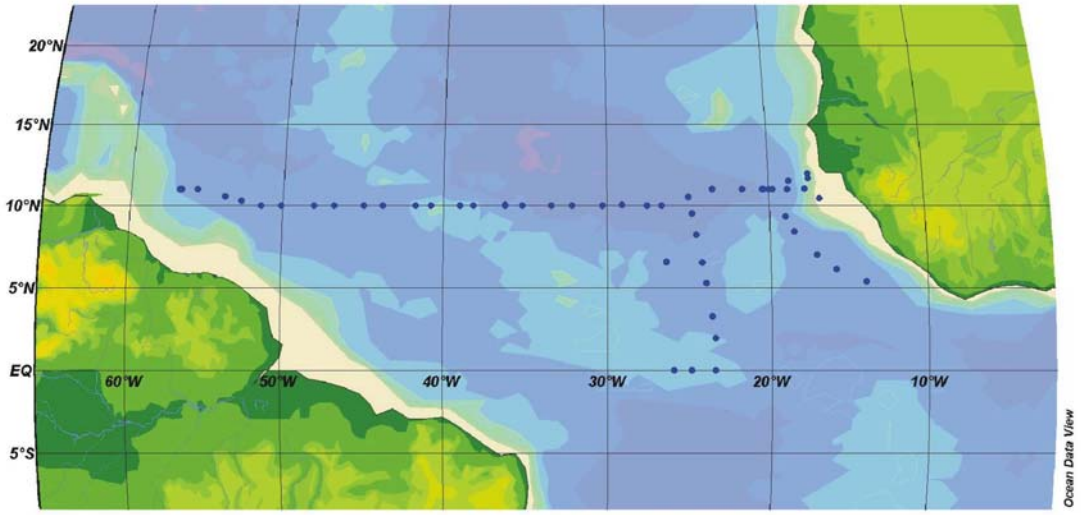

Figure 0. Station locations during the Meteor 55 cruise

The leg covered a wide range of biogeochemical conditions, including both oligotrophic and high productivity regions, regions with low subsurface oxygen concentrations, and regions subject to significant influence from atmospheric dust input. The cruise was designed to initiate longer-term research into atmosphere-ocean biogeochemical interactions within tropical regions. As such it is a forerunner to a national German SOLAS (Surface Ocean Lower Atmosphere Study) research program.

Sampling activities included underway measurements of air, atmospheric particles, rain, and surface seawater, together with mainly shallow (<500 m) CTD casts and biological sampling. Measurements of a wide variety of trace gases, trace metals, nitrogen species and biological parameters were made in both the upper ocean and atmosphere. Experiments were conducted on board to examine the response of

phytoplankton to inputs of various nutrients and biological and environmental factors related to trace gas production. The work on the cruise was conducted jointly by atmospheric chemists and physicists together with chemical and biological oceanographers. During the cruise, a long-term sediment trap of the University of Bremen was recovered at the equator.

Figure 0: Interior of the Geo Labor

The overall objective of the cruise was to examine ways in which surface ocean biology and chemistry affect the atmosphere and, how atmospheric chemistry, in particular the deposition of particles, affects surface ocean biology and chemistry. In particular, the west-to-east transit was designed to sample a wide range of continental aerosol inputs. The north-south transect was included to allow sampling of atmospheric

conditions at the Inter-Tropical Convergence Zone (including rainfall and wet deposition) and Southern Hemisphere air masses. Along this transect, the following research activities took place:

- Characterization of trace gas distributions and identification of production-degradation pathways within tropical surface waters. (N_2O, sulfur-containing gases, naturally produced halocarbons and alkyl nitrates, oxygenated organics, CO_2)
- Determination of the distribution patterns of phytoplankton biomass and species as potential producers of trace gases.
- Characterization of trace gases (including, but not limited to, those in list above) and reactive species (e.g. BrO) distributions in the troposphere. This included an important intercalibration of atmospheric and oceanic measurements, which is necessary for the computation of air-sea fluxes.
- Chemical characterization of atmospheric aerosols and dust particles for their trace metal and nitrogen content. Assessment of the chemical behaviour of such aerosols following deposition to ocean waters.
- Measurement of trace metals (e.g. Fe) and their speciation in surface water and shallow vertical profiles in relation to atmospheric and sub-surface inputs, phytoplankton composition, remineralization, etc..
- Investigation of the surface water nitrogen cycle with an emphasis on nitrogen fixation.
- Assessment of vertical profiles of Fe and nitrogenous nutrients together with estimation of their supply to the euphotic zone via vertical mixing.
- Bioassays and molecular biological studies to determine nutrient and/or trace metal limitation (e.g. N, P, Si, Fe, other metals). Physiological studies of photosynthetic organisms along strong gradients of nutrient limitation.

Cruise Narrative

Week 1 (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. The set-up of the laboratories for this cruise were 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 were supplied with surface water 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.

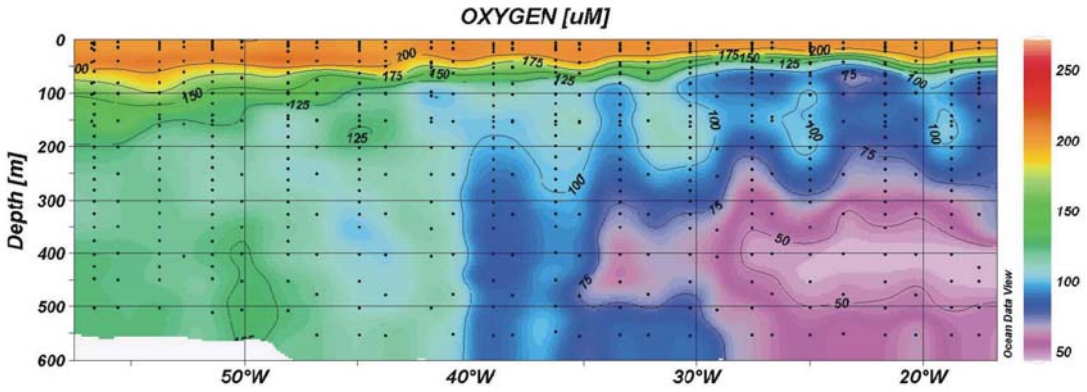

Figure 2: Section of Dissolved Oxygen (uM) from Meteor 55

On a routine basis we occupied 2 stations per day: a morning station with at least 2 CTD casts, a trace-metal hydrocast and net tows and at least one 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 was made on air and pumped surface seawater during steaming.

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. Most of the remainder of the cruise track continued along 10°N instead of 11°N as originally planned.

Week 2 (21.10.2002-27.10.2002)

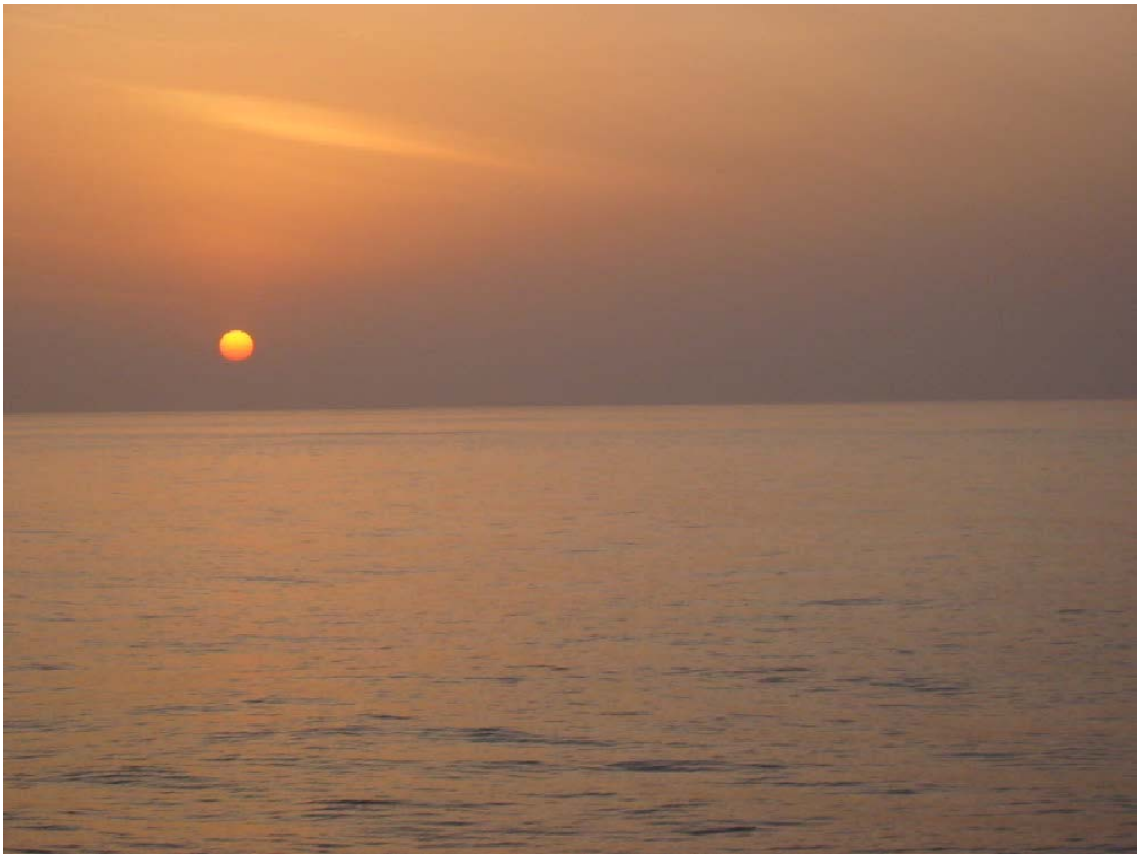

Figure 3: Dusty sunset over the tropical Atlantic

We continued to occupy two stations per day. The early station, which started at 05.00, was the more extensive with a minimum of 2 separate CTD casts. On most days, we

added 1 or 2 additional CTD casts in order to collect large volumes of water for on-board experiments. At tbis station we also usually conducted two casts with Go-Flo sampling bottles specially suited for contamination-free sampling of trace metals. Sampling at this station extended to a maximum depth of 600m with a major emphasis on the waters at, and overlying, the chlorophyll maximum. The afternoon station was usually less extensive, with a single CTD cast as well as measurement of light and fluorescence profiles. The afternoon sampling was also usually to 600m but this was, on occasion, replaced by a full-depth CTD cast.

During the 2nd week we steamed steadily east along 10°N. On the evening of the 26th we turned south for a transit to the equator along 26°W. The equator transit was designed to allow air sampling along the steepest gradient of the ITCZ. 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.

3rd week (28.10.2002-3.11.2002)

The 3rd week started with the transit towards the equator along 26° 30'W. 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 the 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.

4th Week (4.11.2002-10.11.2002)

The fourth week was full of incident. Especially memorable was an unexpected meeting with Polarstern on the high seas (see below). 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.

An unusual high-seas meeting of the two major German research vessels, Polarstern and Meteor, took place on Friday 8th November at 1300 UTC. We had learned, mid-way through our cruise, that Polarstern was steaming southwards from Vigo to Cape Town. 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 the waters of Guinea Bissau 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.

Gerhard Kattner of the Alfred-Wegener Institut in Bremerhaven, was chief scientist on board Polarstern and we learned that their science program had some similarities with ours, ranging 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.

Following our morning station on Friday the 8th we sailed back to the agreed upon meeting 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.

Figure 4: Polarstern viewed from Meteor

Figure 5: Meteor and Polarstern in the tropical Atlantic

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. We took the opportunity to transfer frozen samples to Polarstern for safer, cheaper shipment back from Cape Town. The occasion was also used by the atmospheric chemists from Polarstern and Meteor to compare their respective programs. Notably, Polarstern and Meteor were both equipped with Multiaxial Differential Optical Absorption Spectroscopy systems from the University of Heidelberg.

The meeting was a welcome interlude to our science program. During the 4th 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 sampled an 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.

5th week (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.

After station 51 our work reverted to underway sampling and air analyses along a transit from the last station to Douala of 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. 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.