

Baltic Sea Research Institute Warnemünde



Final Cruise Report

r/v " Prof. Albrecht Penck "

Cruise- No. 40 / 04 / 13

Herbert Siegel
Chief Scientist

Institut für Ostseeforschung Warnemünde
an der Universität Rostock
Seestraße 15
D-18119 Rostock- Warnemünde
GERMANY

 +49-381-5197-0
 +49-381-5197 44

1. **Cruise No.:** 40 / 04 / 13
2. **Dates of the cruise:** from 25 May 2004 to 07 June 2004
3. **Particulars of the research vessel:**
Name: Prof. Albrecht Penck
Nationality: Germany
Operating Authority: Baltic Sea Research Institute (BSRI) Warnemünde
4. **Geographical area in which ship has operated:**
Western Baltic Sea, Kattegatt, Skagerrak, North Sea
5. **Dates and names of ports of call**
Bergen 01 June 04, Oslo 04 June 04
6. **Purpose of the cruise:** Investigation of coccolithophore bloom
7. **Crew:**
Name of master: O. Albrecht
Number of crew: 11
8. **Research staff:**
Chief scientist: Dr. Herbert Siegel

Scientists: Dr. Thomas Blanz
Dr. Thomas Ohde
Dr. Jan Reißmann
Jo Hökedal
Andre Staalström

Engineers:

Technicians: Monika Gerth
Carmen Braun
9. **Co-operating institutions:**
Norwegian Institute for Water Research
10. **Scientific equipment**
CDT, rosette sampler, Rumorlot, radiometer, photometer

1. Introduction

The aim of the cruise on F.S. Albrecht Penck was the investigation of the Coccolithophore bloom in May/June 2004 in the Skagerrak and Kattegat area. The area of investigation and the time period were selected in accordance to the spatio-temporal development of the coccolithophore bloom in that area followed by satellite imagery for several years. The investigations were focussed on the following aspects.

- Determination of optically active water constituents and their absorption and scattering properties and investigation of their influence on the spectral reflectance at the sea surface (ocean colour)
- Determination of the horizontal extend of the bloom
- Composition of Alkenones in the water column and surface sediments in dependence on temperature and salinity
- Validation of MERIS-data (ENVISAT-MERIS)

2. Methods and area of investigation

Satellite data of the visible channels derived from the Advanced Very High Resolution Radiometer (AVHRR) of the National Oceanic and Atmospheric Administration (NOAA) weather satellites were provided by the German Federal Maritime and Hydrographic Agency Hamburg (BSH) and quasi-realtime transferred to the rv Prof. A. Penck to adjust the station plan to the distribution of the bloom. Satellite data of the ocean colour sensors SeaWiFS and MODIS provided by NASA and of MERIS provided by ESA were implemented to investigate the spatio-temporal development of the coccolithophore bloom in detail.

Inherent and apparent optical properties of the water were measured using in-situ and laboratory instruments. Radiation measurements were performed using the free-fall Satlantic-SPMR-profiler (Satlantic Profiling Multichannel Radiometer) including the surface reference (SMSR, Satlantic Multichannel Surface Reference) and the TRIOS System to study the water color in terms of water leaving reflectance.

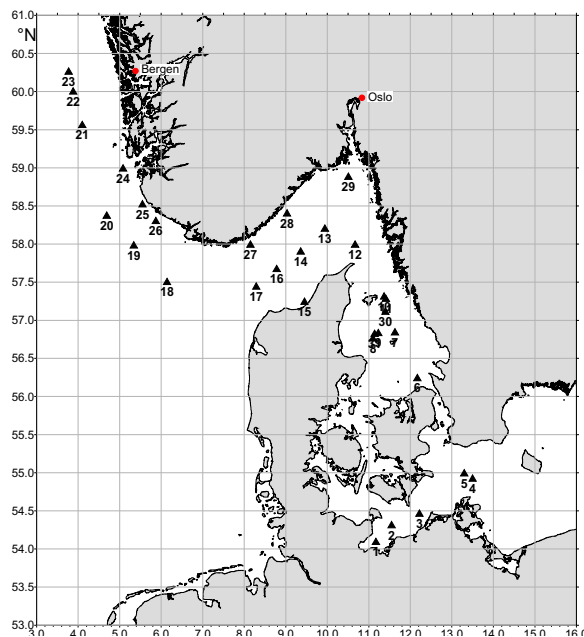


Fig. 1: Area of investigation and location of the stations

Laboratory measurements of the absorption of yellow substances and particulate matter were carried out using a spectral photometer LAMBDA 2 (PERKIN ELMER) in the spectral range between 300 and 750 nm with a spectral resolution of 1 nm. For the determination of the absorption of yellow substances the water samples were filtered through Whatman GFF filters (Højerslev 1980). The filters were used to estimate the absorption of particulate material $a_p(\lambda)$ using the filter pad method. From $a_p(\lambda)$ the absorption of chlorophyllous particle $a_{Ch}(\lambda)$ and detritus $a_d(\lambda)$ as well as the specific absorption of phytoplankton were calculated according to Bricaud and Stramski (1990) as described by Gerth and Siegel (1998).

The water constituents taken into account were chlorophyll and phaeopigment (Lorenzen and Jeffrey 1980), suspended matter and, in some cases, phytoplankton pigment composition using High Pressure Liquid Chromatography (HPLC).

Scanning electronic microscopy (SEM) and Energetic Disperse X-Ray analysis (EDX) and species counting by light microscopy will be implemented to analyze the particles at selected stations.

General information was retrieved from transparency and ocean color determination using Secchi disc and Forel scale.

For special geochemical analysis of alkenones, Corg, CaCO₃ and SPM continuous sampling at 25 surface transects of surface waters using the intake system of the F.S. Albrecht Penck. At these transects volumes between 75 and 270 L were filtered. Furthermore, sampling was performed at 20 CTD stations where water between 0.25 and 0.5 L was filtered from three depths. After filtration all filters were deep-frozen. Surface sediment was collected using boxcorer. For this study only the surface layer (0-1 cm) of the cores was used and stored in aluminium boxes at -20°C until analysis.

Two Norwegian scientists of the Norwegian Institute for Water Research and University of Oslo participated in the cruise for the leg between the harbours of Bergen and Oslo from 1 to 4 June 2004. They performed optical measurements of spectral reflectance above water (TRIOS system) and of absorption, beam attenuation and backscattering using profiling instruments like AC-9, C-metre and BB-4. Samples were taken to measure absorption of yellow substance and particulate material and to determine suspended matter and nutrients as well as phytoplankton composition and pigments.

The investigations were performed from 25 May until 7 June on surface transects with through-flow measuring system as well as at 30 stations in affected areas in Kattegat, Skagerrak and North Sea in front of the Norwegian coast. Due to the notification the investigations were performed in Danish and Norwegian waters. The station map is presented in Fig. 1.

3. Results

The main objective of the cruise was the investigation of the coccolithophore bloom in the transition area between the Baltic and the North Sea. Before the cruise the development of the bloom was followed by quasi real time satellite data transfer from the receiving station in BSH Hamburg to the IOW.

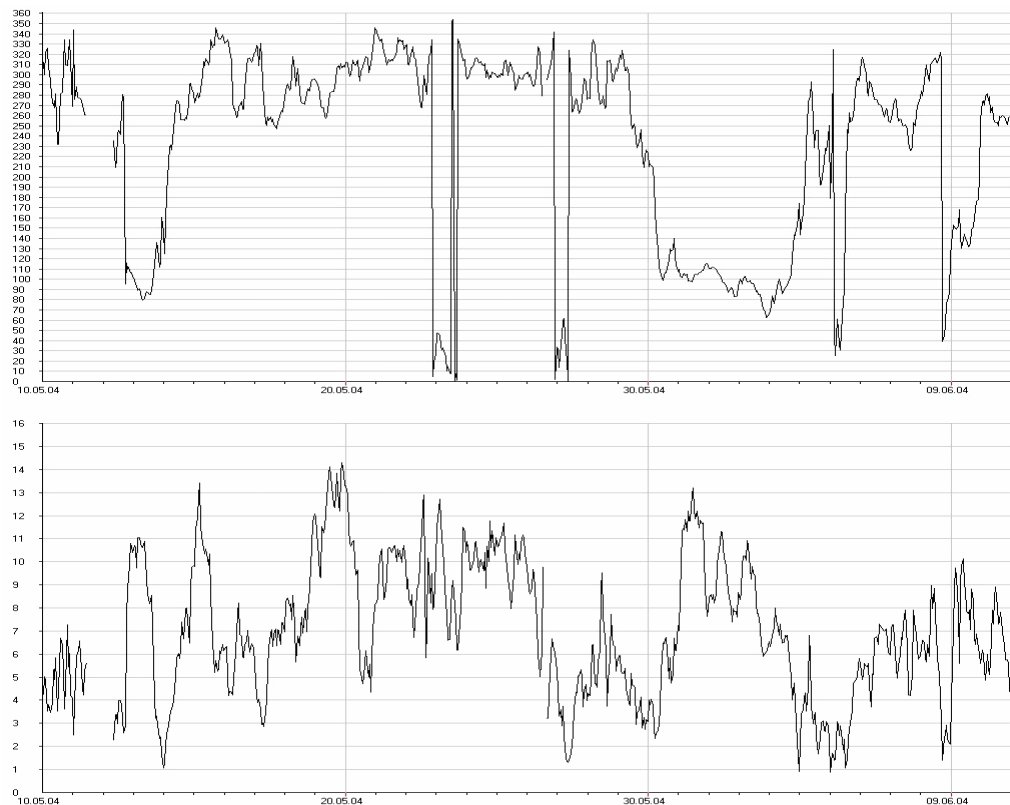


Fig. 2: Wind measurements at the permanent MARNET station Darß Sill, upper panel wind direction, lower panel wind speed

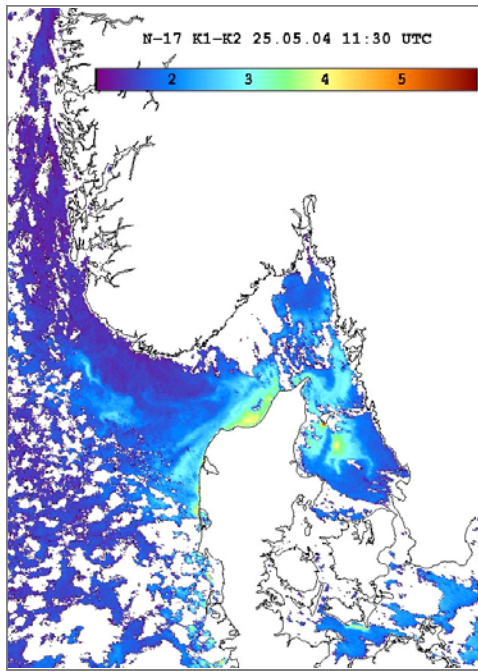
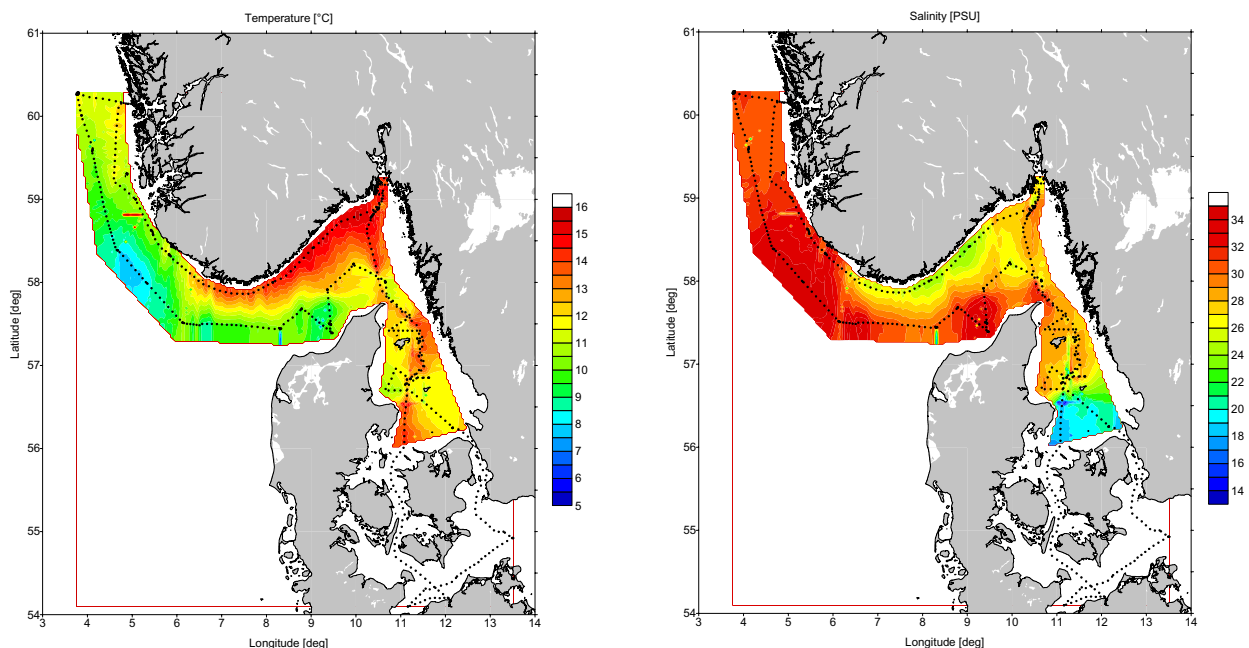


Fig. 3: NOAA-AVHRR image from 25 May showing the coccolithophore bloom in the Kattegat and Skagerrak area

On the basis of the visible channels of the NOAA-weather satellites the bloom was observed from approximately 10 May 2004. It started to develop in the central Skagerrak as known from other years (Siegel et al. 2000). The meteorological situation was characterized by long lasting north-westerly winds starting from 14 May until 29 May measured at the permanent MARNET station at the Darß Sill. The wind direction and speed are presented in Fig. 2. This led to high concentrations at the Danish Skagerrak coast and in the northern Kattegat area after the 20 May 2004. On 25 May the starting day of the cruise the concentration increased particularly in the Kattegat and along the Danish coast as seen in the image from 25 May in Fig 3. In order to find the optimal stations, at the night 26/27.5.04 a survey with the through-flow system was performed. Thereupon on the subsequent day 5 stations in the Kattegat were worked on. The investigations were continued in the Skagerrak westward at a central transect. Due to the satellite information the transect was interrupted to execute a station 15 in the bloom maximum near the Danish coast (Fig.1). The transect was continued in the North Sea parallel to the Norwegian coast with the same distance up

to the latitude of approx. 60° N into the clear water area. On 1 June two Norwegian colleagues were followed and they depart on 4 June in Oslo. On a transect along the coast from Bergen to Oslo the optical investigations were resumed supplemental by the devices of the Norwegians, whereby only the last station before Oslo on 3 June was located in the bloom area. On the way from Oslo to Rostock two stations in the Kattegat in the alga bloom and outside were performed. The temperature and salinity surface distribution of the entire cruise shows that the highest concentrations of coccolithophore correspond to waters of higher salinity and lower temperature particularly in the Skagerrak and partly in the Kattegat (Fig. 4).



Skagerrak-Kattegat area in May/June 2004

Fig. 4: Temperature and salinity distribution in the

Normally, the Coccolithophore bloom occurs with its maximum in the central Skagerrak around the transect performed. Due to the strong wind period from 19-26 May the maximum of the bloom was located in front of the Danish Skagerrak coast and in the Kattegat. There, the bloom was stable for a few days. The bloom changed the water colour as usual to milky turquoise and the transparency was reduced to 2.8 m at station 8 in the Kattegat and 2m at station 15 in the Skagerrak at the Danish coast. The maximum transparency of 18 m was measured in the North Sea at the northern most station. The Scanning Electronic Micrographs showed the high



Fig. 5: Extent of coccolithophore bloom on 1 June 2004 on the basis of MODIS

concentration of Coccolithophores and a mono species bloom of *Emiliana huxleyi*. The presence of the marker pigment 19 Hexanoyloxyfucoxanthin and the absorption spectra determined for selected stations underline these results. The high scattering by the calcite scales changes the water colour milky turquoise. That reflects also the measured spectral reflectance at the sea surface. The chl_a+phaeo concentration varies between 0.5 and 1 mgm⁻³ in the surface layer of the open North Sea stations and maximum values of 8 mgm⁻³ at the entrance of the Skagerrak. The suspended matter concentration ranged in the surface layer between 1.5 mgdm⁻³ and 15 mgdm⁻³ at station 11 in the Kattegat. The inorganic portion is partly higher than 80%. The yellow substance absorption at 440 nm was strongly related to the salinity and varied between 0.1 m⁻¹ at the North Sea stations with salinities of about 34 PSU and 0.3 m⁻¹ along the Norwegian Skagerrak coast

at station 27 and 28 with 24 PSU.

The maximum extent of the coccolithophore bloom was observed in a MODIS scene on 1 June 2004 and covered nearly the entire Skagerrak and the northern part of the Kattegat (Fig.5). For MERIS validation 10 overpasses were available and 9 usable for match-up data analysis.

The alkenone method is used since 20 years for reconstructing past sea surface temperatures (SST). This method is based on the fact that certain haptophyte algae, especially the coccolithophores *Emiliana huxleyi*, synthesize long chain (C₃₇-C₃₉) unsaturated ketones (alkenones) in different proportions depending on the growth temperature of the algae. Growth conditions of this species are influenced by high incident solar radiation, stabile stratification, and iron content. Field sampling and culture experiments with various species of haptophytes confirmed a relationship between water temperature and unsaturation ratios of long chain alkenones. The highest alkenone concentrations were found in the Skagerrak with concentrations up to 8.600 ngL⁻¹. The alkenone concentration drops down to 3.000 ngL⁻¹ from the Skagerrak into the Kattegat, whereas in the southern part of North Sea the alkenone concentrations decreased to 500 ngL⁻¹. In northern direction the alkenone concentration drops down to 200 ngL⁻¹ and at the northern position alkenones were not detected.

The optical profiling measurements showed a vertical extent of the coccolithophores lower than 15 to 20 m. The dominating species was *Emiliana huxleyi*.

Summary

The coccolithophore bloom in the Skagerrak and Kattegat area was investigated in spring 2004 for the first time by a group of IOW using a combination of satellite remote sensing and different in situ methods. The results shall help to improve the interpretation of satellite data in that region.