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Challenger 55/89 24/6/89 - 7/7/89

CRUISE REPORT

1 Introduction

This was the twelfth in a series of fifteen monthly surveys of a fixed track pattern in the North Sea. The central goal of these cruises is to determine as fully as possible the seasonal cycle of all the major oceanographic variables in the North Sea. This information will form a unique baseline data set on seasonal changes in an archetypal shelf sea which will be used as a basis for initialising and testing models of vertical exchange, horizontal transport and the seasonal cycle of production and nutrient regeneration. These models represent essential intermediate goals in the long term development of skillful models describing the fate of pollutants which are released into the North Sea.

The track for the survey (fig. 1) is designed to provide full coverage of the three characteristic summer regimes south of 56°N: mixed, stratified and frontal and to adequately sample the water properties in the vicinity of each of the major freshwater inputs. Six moorings, 2 deployed in each of the regimes, provide continuous measures of physical parameters and, in some cases, chlorophyll fluorescence. An important function of each of the cruises is to recover, service and re-deploy these moorings on a monthly cycle.

In the event this largely pre-determined routine cruise was given some particular element of interest and excitement because of exceptional weather conditions which permitted the reception of a sequence of satellite images showing the development of a coccolithophore bloom within the survey area. On the basis of the information two deviations were made from the track to facilitate direct sampling of the bloom.

2 Summary narrative

The Cruise started on June 24th at the end of a period of sustained anticyclonic weather. The one day turn-round in Great Yarmouth went smoothly and the vessel departed on schedule at 12.30 BST following the usual route initially northwards inside the Scroby Bank and then eastward to the first station at AA.

Most members of the scientific party were already experienced in the routine of the survey and, after the first few stations, settled into a regular and efficient working pattern. We recovered, serviced and re-deployed the first mooring E in just one hour and then proceeded to a long period of CTD survey covering all the stations in the southern Bight with CTD and, in many cases, a net haul for zooplankton.

The weather during this period (24/6 - 26/6) was excellent and we took the opportunity to check calibration procedures and data quality standards. Several problems were identified and overcome. Most serious perhaps was an offset in the salinity readings (0.6 psa) which prompted us to open and clean the salinity cell. There was significant contamination with barnacles, big enough to identify, growing on the toroidal sensor. Cleaning restored the offset to a level (0.15) which is more consistent with earlier calibrations but values from previous cruises will need to be checked.

The salinity trace also exhibits some spiking the origin of which is not known though it has been attributed to bubble formation. The consistent amplitude of the spiking is, however, suggestive of digital noise. The trouble recurred occasionally throughout the cruise but contamination is not so severe as to prevent the recovery of an adequate data record. Nontheless the problem will need further investigation.

Leaks in the flow through system were diagnosed as the cause of discrepancies between the two transmittance sensors. After rectifying these problems, a regular pattern, of cleaning and calibrating both transmittance sensors on a daily basis, was established.

The second mooring F was located, recovered with all in order and re-deployed (0918 Z 25/6) without difficulty. We then proceeded north-west to the mooring D position where we recovered the first of the ADCP units on the morning of 27/6 (0827Z) and re-laid it, and the adjacent thermistor-chain mooring, completing by 1000Z.

A problem with the nitrate determinations emerged at this stage. It seems that the ammonium chloride, used in the analysis, has been contaminated with nitrate and this has introduced some uncertainty into the auto-analyser determinations from the early stations.

On the 28th as we moved into the German Bight, the weather was deteriorating with winds up to force 6. The programme continued, however, without interruption though the motion was lively on some of the north-going legs. Winds reached 35 knots at times and the CTD crew were fully stretched handling the large frame at stations BS and BT.

By the 29th, however, the wind diminished though a strong swell from the north-west continued for some time. We reached the turning point, station CF, at 0030 on 30/6 proceeding to mooring B where both rigs (thermistor chain and 4 CM U mooring) were successfully recovered and re-deployed (113-01430/30).

With the improved weather, we made good speed and allowed ourselves the luxury of a deviation from the standard track after station CM to a position 55° 50'N, 4°E where an area of strong reflectance was apparent on the latest AVHRR image (26/6). Unfortunately we arrived in the area at night so we were not able to photograph the bloom or make reflectance measurements.
A strong change in optical attenuance (x3 relative to background) and the "milky" appearance of the sea surface in the ship's lights confirmed the presence of enhanced scattering. A large number of samples were taken and the presence of coccolithophores, mostly in a moribund state confirmed by microscopic examination. We mapped the area of the bloom maximum as fully as time would allow before re-joining the track at station CO.

A new satellite image received the next morning (1/7) showed the bloom distributed much as before and there was a close correlation with our surface mapping results.

The A mooring (ADCP + thermistor chain) was successfully serviced in 90 minutes late on the afternoon of 1/7 and we proceeded to complete the long northern boundary section by the early hours of 2/7. A full day of CTD stations (CY - DL) then brought us to mooring C at first light on 3/7. The weather, by now, was excellent and we had no difficulty in servicing this last mooring (ADCP + thermistor chain) thus completing our success in recovering and re-laying the whole array.

With the warm calm weather, it was agreed to put the boat over during a CTD station at EE, to clear some fishing net from the propeller and allow three hardy individuals to swim (surface temperature was 14.5°C). The occasion also allowed some scope for photography of the ship and over-the-side operations.

Later in the day (3/7) a number of dolphins were sighted (at least 8 in one group) but the species was not reliably determined.

The reception of further high quality satellite images prompted us to make another deviation from the planned track to observe a second centre of the suspected coccolithophore bloom. This time we reached the area of peak concentration during daylight and were, thus, able to measure the large reflectance anomaly associated with the bloom. The biologists were able to confirm the pre-dominance of coccolithophores in the bloom though, again, most of the individuals were dead. Mapping with surface sensors continued until the early hours of 4/7 and three extra CTD stations were worked in the bloom area.

At sunset several members of the scientific party observed the "green flash" a phenomenon usually only reported in the tropics.

The survey continued without further incident on the 4, 5, 6 July in near perfect weather. All stations on the track were worked including a repeat of the first station AA which we completed at 0700 Z on the morning of the 6th before proceeding to Great Yarmouth in time for the midday tide.

3 CTD Station Summary

A total of 126 stations (fig. 2) were worked using the CTD/Rosette system providing profiles of temperature, salinity, D.O. chlorophyll fluorescence, optical beam transmittance and 2 pi irradiance upwelling and downwelling (during daylight hours). Water samples were obtained for the determination of suspended particulates, chlorophyll a, nutrients, biogenic gases, primary production and phytoplankton species composition. Net casts for zooplankton were also made at 78 stations.

Station positions were close to the official survey stations with only two significant exceptions, both during the bloom mapping exercises. Station CN was moved to 55° 50'N; 4°E to coincide with the bloom centre observed on 30/6. Similarly station EC was moved to 55°N; 2°E and supplemented by stations EC2 - EC4 in the bloom area.

CTD calibration was performed on almost every station. The temperature sensor agreed consistently with the two reference thermomemters to within $\pm$ 2m°C over the full period of the cruise. The salinity sensor correction was provisionally determined as $\pm$ 0.06 $\pm$ 0.005 and again was consistent throughout the cruise.

Provisional plots of the T/S data show the characteristic features of the summer regime in the North Sea. Fig. 3 shows a summary of the T/S field in the form of contours of the stratification parameter $\phi(Jm^{-3})$. Strong stratification in the northern North Sea due to surface heating contracts with the well-mixed areas to the south and on the Dogger Bank where $\phi \simeq 0$.

4 Moorings summary

All six moorings were recovered, serviced and re-deployed without loss. Most of the recovered instruments contained good data; the exceptions were (i) ADCP data from mooring C is restricted to about half the deployment

time, (ii) the thermistor chain at mooring C had an open-circuit so that all thermistors were disconnected, (iii) three individual thermistors on the B mooring had failed.

Because of the generally favourable weather, all recovery and launch operations went smoothly and rigs were re-layed in positions very close to those occupied previously.

5 Shipboard ADCP

This system was set up using configuration file CH4989/SH at the beginning of the cruise and operated continuously. Data was checked regularly and transferred to the ABC computer system every few days. For a short period while we were in deeper water configuration CH4989/DE was used.

Apart from one paper jam in the printer (when the system defaults to a no-print mode) the system performed satisfactorily throughout.

6 Dissolved Oxygen and Primary Production

(Dr. D. A. Purdie, Ms A. Iriarte)

The following measurements were made as part of the routine sampling duties of the Biologist on survey cruises. The Biologist (Purdie) undertook alternate watches with the sedimentologist (Moffat) to process water samples for chlorophyll and suspended sediments and collect preserved water samples for phytoplankton counts.

a) Chlorophyll: Water samples were collected from 117 stations (missing out less than 10) in total. Water was collected in 10 litre Go-Flo bottles attached to the CTD frame and 1 litres filtered for later chlorophyll analysis from surface, middle and bottom depths. Additional depths were sampled for chlorophyll at the close-to-dawn station where water for 14C productivity experiments was collected from 1, 3, 7, 15, 20 and normally 30 meters.

b) Preserved water samples: Surface samples from every other CTD station were preserved for later phytoplankton enumeration. Additional samples were taken from the dawn CTD station and at mooring station A.

c) Primary production measurements: 14C productivity experiments were conducted on each of 10 days during the cruise (25th June to 4th July inclusive). Samples were collected from six depths (1, 3, 7, 15, 20 and 30m) at a station close to dawn and the incubation begun at about 3.30 am (GMT). Three bottles from each depth were incubated at an appropriate light level in the on-deck tube incubator and one incubated in the dark, then all bottles transferred to an opaque cylinder at around dusk (9.00 pm, GMT). The samples were filtered the following morning after setting up the next 14C experiment.

d) The pulsed oxygen electrode system monitoring the non-toxic supply was regularly calibrated with Winkler samples analysed on an automated titrator system. Samples for oxygen analysis were also collected from two CTD profiles per day to allow a retrospective calibration of the CTD oxygen probe.

6.1 Additional Measurements

A second biologist on board (Ms Iriarte, Ph.D. student at SUDO) enabled a series of additional primary productivity measurements to be made with the specific aim of assessing the importance of picophytoplankton productivity in various regions of the North Sea at this time of year. A combination of approaches was used to determine phytoplankton productivity. On most days during the cruise, parallel on-deck incubations were conducted using oxygen flux and 14C uptake measurements. Water samples from one depth, generally 3-10m were incubated at six light levels on-deck in screened incubators. The 14C samples were later filtered at dusk and a replicate sample fractionated through a 3um filter.

A second set of experiments was conducted where oxygen production and 14C uptake was compared using a light-gradient incubator. The water samples for oxygen analysis were prefractionated through a 3um Nuclepore filter whereas the 14C samples were fractionated after completion of the incubation. The use of an epifluorescent microscope on-board enabled a quick look at fractionated water samples during the cruise to assess the state of picophytoplankton populations and determine the efficiency of fractionation.

6.2 Initial Observations and Conclusions

a) Phytoplankton populations observed during CR. 55.
The Phaeocystis bloom which had previously extensively dominated the plankton of central and eastern areas of the Southern Bight during April, May and early June had diminished and was only found at one station in the mouth of the Rhine. A coccolithophore bloom was encountered in two areas in the northern part of the survey and was successfully mapped following AVHRR images received on the ship. The bloom was not particularly active and samples contained few viable cells estimated from epifluorescent microscopy. Another indication of the low activity of the bloom was the oxygen saturation value which was not much greater than 100%. Noctiluca was also found in large numbers in northern Dutch coastal waters and in the German Bight but was not in sufficient numbers to cause discolouration of the surface waters as was observed during Challenger cruise 54.
At a few stratified stations in northern waters, a considerable sub-surface fluorescence peak was observed which contained large populations of picophytoplankton estimated from epifluorescence microscopy.

b) Primary production rates.
Data from oxygen flux measurements determined at sea indicated that there was a very large variation in phytoplankton photosynthesis activity throughout the North sea during the cruise. Considerably greater rates were measured in the southern well mixed waters and in the subsurface chlorophyll maximum in the northern stratified waters. These measurements will be compared to 14C data later. Picophytoplankton photosynthesis (estimated from oxygen flux measurements) was greater than 50% of total production at a few stations in the northern section of the survey. Further conclusions are not possible until the 14C data has been fully analysed.

c) Dissolved oxygen data.
Oxygen concentration was over-saturated at a few bloom stations e.g. Phaeocystis waters up to 115%. Sub-oxic conditions were shown to exist at a few stations throughout the water column, e.g. Humber

estuary and the Wash (90%). The presence of undersaturated water was also seen in stratified areas of the German Bight and Danish coastal waters, below the thermocline (80%). A sub-surface peak in oxygen was often associated with the deep chlorophyll maximum occurring immediately below the thermocline.

7 Nutrient Measurements

(B. Grantham)

Measurements were made of nitrate, nitrite, ammonia, phosphate and silicate by Autoanalyzer at 124 stations. Some problems were encountered with the nitrate line which were eventually traced to contamination of the ammonium chloride buffer. All batches of the chemical on board were equally affected and with no alternative buffer available the nitrate line was run without buffer. The sensitivity was considerably reduced but the calibration remained linear. As an additional check duplicate samples were taken from a number of stations and frozen for later analysis with the correct chemistry. No problems were encountered with any of the other nutrient lines.

Over all the area covered, nutrient levels were generally low with highest values, particularly, of silicate and ammonia being found in the deeper water of stratified areas. Silicate was noticeably higher (up to 6μM) at station C6 off the Danish coast than at any other station.

In the area of the blooms, nutrients were again very low with no apparent anomalies.

8 Suspended Sediments Experiment

(T. J. Moffat)

Continuous surface profiles were obtained along the survey track using two deck-mounted Sea Tech transmissometers. Vertical profiles were obtained at all the CTD stations using a Sea Tech transmissometer mounted horizontally on the CTD frame.

Water samples were taken at 3 depths (the surface, mid-depth and bottom) using the rosette sampler/GoFlo bottles at about 100 CTD station. The water samples were filtered through pre-weighed GF/C filters.

A total of 56 water samples were collected from the non-toxic and CTD stations : 2294-2296 and 2323-2326 for analysis at PML.

A good standard of transmittance data was achieved by cleaning the two deck-mounted tranmissometers on a daily basis. Air calibrations were constant throughout the cruise. A reduction in quality resulted from some rough weather which introduced air bubbles into the nontoxic supply.

The distributions of suspended sediment and attenuation were as anticipated. Regions of high attenuation and concentration were

observed along the English coastline particularly off East Anglia and in the Humber plume, and also off the Rhine and in the German Bight. By contrast the central North Sea and the area between East Anglia and the Rhine were characterised as regions of low attenuation and sediment concentration.

There was very little structure vertically except for higher attenuation levels associated with either water column biological activity or bottom water resuspension events attributable largely to the rough weather.

9 Zooplankton sampling

(M. A. Baars)

On 78 stations in total, CTD-casts were attended by vertical hauls with the NIOZ net 300 μm. At 57 of these stations, a vertical haul with the small net (50 μm) was done as well. At the other 21 zooplankton stations either the sea state was too rough (27-29 June) or plastic sample cups were running short (3-6 July), so here hauls with the small net were cancelled or done at alternating stations only.

Results on zooplankton during this highly successful survey are only to be described generally, as sorting and counting will be done later at the Texel Institute. Also, the displacement measurements performed during all the preceding surveys, were severely hampered by massive occurrences of either Noctiluca (mainly in the Southern Bight and in the southeast corner of the German Bight), remains of Phaeocystis blooms (along the Dutch coast), or combjellies and jelly fish (the northern leg plus the northwestern part of the study area). After some trials, displacement measurements were therefore abandoned, both for practical reasons and because of the measurement not being representative for zooplankton biomass under these conditions. However, it can be stated that stations with a predominance of "normal" zooplankton were quite rare, often larvae of bottom-inhabiting organisms (molluscs, echinoderms) outnumbered copepods and chaetognaths. The distribution of these larvae as well as of other components in the zooplankton was very patchy, neighbouring stations frequently did not resemble each other in species composition.

Special attention was paid to zooplankton abundance in the southwestern part of the bloom of coccoliths, at about 55°N, 2°E. Four or five hauls in and around the centre of this part of the patch revealed an astonishingly low biomass of zooplankton, especially at stations EC-1 and EC-2. Normally, these shallow (25m) sites at the Doggerbank exhibit a relatively high zooplankton biomass during summer, compared with other offshore areas in the North Sea. That we found the opposite reinforces the conclusion from the low chlorophyll and oxygen content indicated by the probes on the rosette sampler, that the patch consisted at the time of the survey of dying and dead coccoliths, with a very slow mineralization rate of skeletons. This probably kept nutrients and irradiance at such low levels that other algae were not able to succeed the coccolith period sufficiently, and the presumed drop in primary productivity apparently had a very drastic effect on the secondary production.

10 Trace Gases

(S. Turner and J. Stevenson)

Surface water samples were taken from over 100 stations using the CTD rosette and analysed for trace gases. The dissolved trace gases were extracted and concentrated using a purge and cryogenic-trap technique and then analysed using three Gas Chromatographs (2 FPD and 1ECD).

Concentrations of dimethyl sulphide (DMS) and its precursor Dimethylsulphoniopropionate (DMSP) were determined. Stations were also sampled for low molecular weight halocarbon compounds, with approximately 20 of these gases being regularly detected. Those compounds being determined included methyl iodide, bromoform, methylchloroform and carbon tetrachloride. Chlorophyll samples were frozen for laboratory analysis and phytoplankton samples were preserved using Lugol's iodine and formalin.

This was a successful cruise, no major problems were encountered with the analytical apparatus or the sampling equipment.

11 Air/Sea fluxes

(J. Merrett and A. Rendell)

Despite dry weather for much of the period, cruise 55 was not as successful as hoped for in the collection of dry deposition. Wet conditions and adverse weather prevented the collection of dry particulate samples off the Dutch coast and in the German Bight. However, six organic and inorganic particulate high volume samples, each of approximately 14 hours duration and a cascade impactor sample of 90 hours were collected for subsequent analysis at Liverpool.

Other work (for Chris Ottley; Essex) included a total of twelve high volume filters each of approximately 10 hours and a large particulate cascade impactor sample of 80 hours duration.
The wet deposition work was more successful with four good quality rain samples collected, the majority from along the Dutch coast and in the German Bight.

12 Conclusion and Acknowledgement

In almost every respect Challenger 55/89 has been a most successful cruise. The data return in most areas met the full survey specification and even exceeded it in some cases.

A number of deficiencies and malfunctions in the scientific gear have been detailed in the report of proceedings and do not require repetition here except perhaps to emphasise our concern about the failure, yet

again, of the meter block on the hydrographic winch. The non-functioning of this device puts the CTD/rosette system at risk on every cast and a radical overhead (or replacement) should be given the highest priority at RVS.

In general though, we were well pleased with the support for the cruise from RVS, especially the contributions of Phil Taylor and Andrew Cormack, who worked tirelessly to meet our requirements. The Captain and crew also provided excellent support and greatly assisted in the successful completion of programmes in one day less than the planned schedule.

July 28th 1989

J. H. Simpson
Principal Scientist

CHALLENGER 55

24 June - 7 July 1989

Participants

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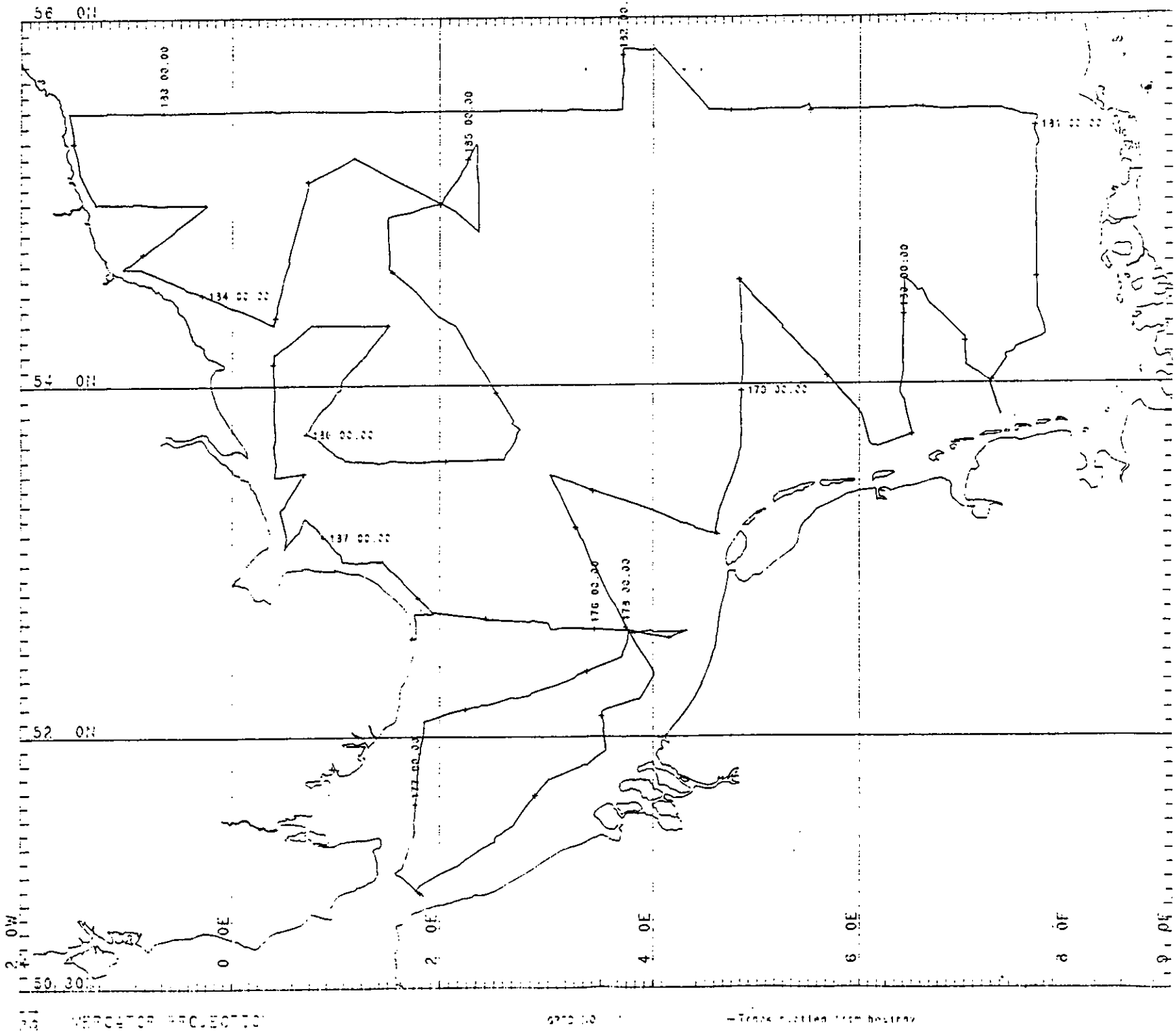

Fig. 1

Challenger 55/89

Cruise Track

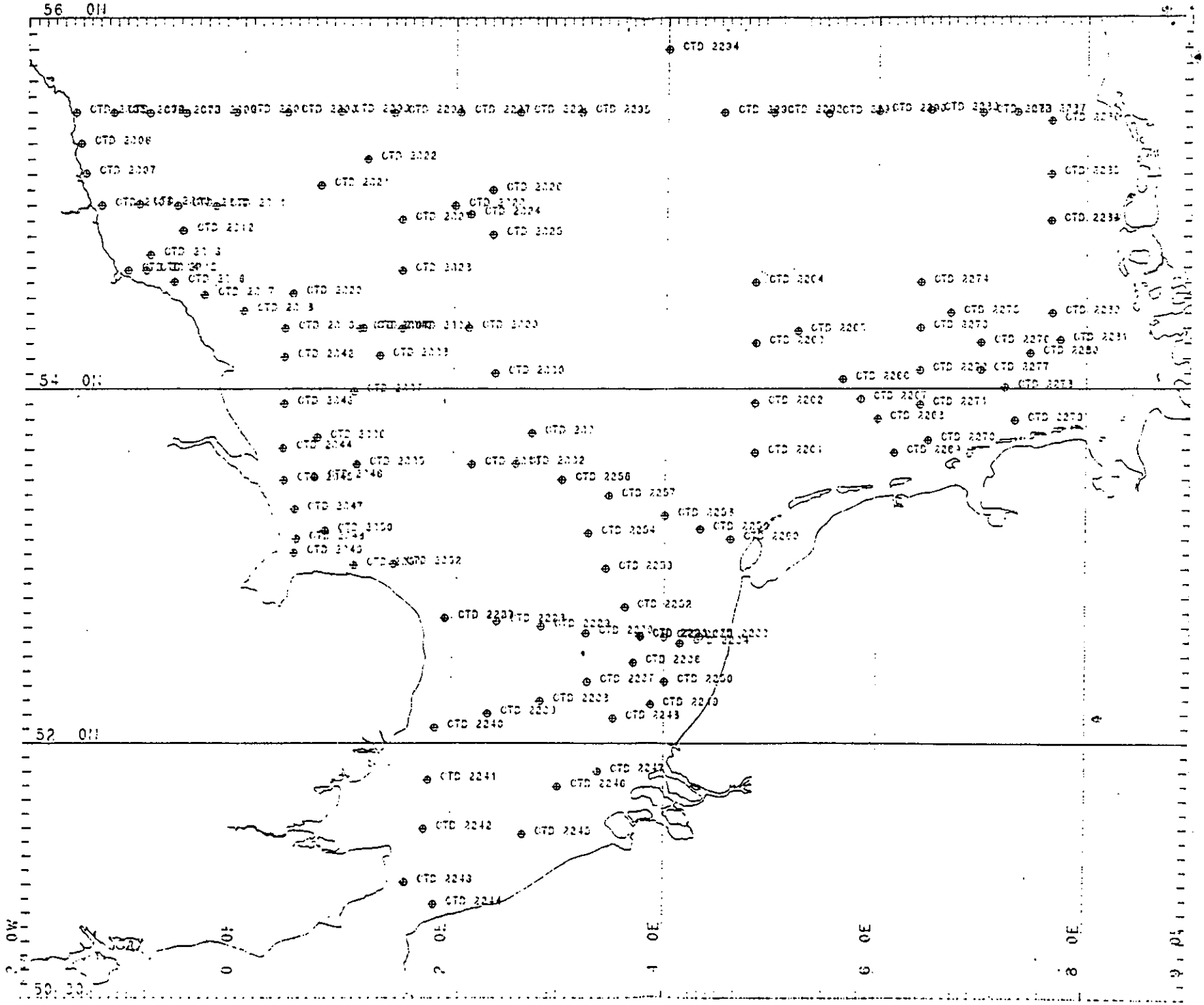

Fig. 2

Challenger 55/89

CTD stations