P.O.L.

RRS "CHALLENGER"

CRUISE 56/89

8-22 JULY 1989

NORTH SEA PROJECT

PROCESS STUDY ON FRONTAL CIRCULATION

CRUISE REPORT NO. 7

1989

NATURAL ENVIRONMENT RESEARCH COUNCIL

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ABSTRACT

This report describes RRS "Challenger" cruise no. 56/89, which took place from 8 to 22 July 1989. It was a process study on frontal circulation in the Flamborough Head area, part of the NERC North Sea Project.

The objectives of the cruise were to use the seasoar, CTD, ship-mounted ADCP, moored current meters and thermistor chains and drifting buoys to survey the salinity, temperature and current field in the Flamborough frontal region. A study of wave measurements by ship's radar was also to be done.

All the programme of work was successfully carried out. Of the moored instruments, many of which were recovered during cruise 58/89, only one thermistor chain was lost. Over 140 hours of sea-soar data was obtained. The drifting buoys, however, failed to record their Decca positions satisfactorily.

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Copies of this report are available from:
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CRUISE OBJECTIVES

The broad aim as set out in the cruise plan was to study the circulation in the Flamborough frontal region of the North Sea. This formed a process study as part of the NERC North Sea project (1988-89).

The methods were

1. To survey the frontal region and provide salinity, temperature and current sections by using the ship-mounted acoustic doppler current profiler (ADCP) together with the sea-soar towed vehicle. Some of these sections were to be repeated over a tidal cycle so that tidal currents could be removed from the data and interactions with the tide could be studied. For salinity and temperature, the CTD was to be available as well as the sea-soar, while continuous surface sampling was to run throughout the cruise.
2. To deploy moorings at the sites shown in figure 1. These consisted of a current meter string at FA, a current meter string and thermistor chain at FB, an ADCP and thermistor chain at FC, a current meter string and thermistor chain at DA and an ADCP and thermistor chain at DB. A current meter string for DB was also prepared. Moorings were to be recovered during Challenger cruise 58/89.
3. To deploy and later recover 10 drifting buoys, Argos tracked and Decca position recording, in two groups of 5 spanning the front. 5 of the buoys were to be redeployed for recovery during cruise 58.
4. Photographs of the (standby) radar screen were to be taken for a study of the technique of wave measurement by radar.

As will be seen from the narrative, all the planned programme of work was successfully carried out, except that problems with the drifting buoys meant that a proposed redeployment did not take place. Photography of the radar screen took place at times of significant wave activity and films were developed on board.

NARRATIVE

RRS Challenger left Great Yarmouth on time at 11.00 GMT on 8 July and made for site FA. At 12.11 the Simrad echo sounder pole was deployed and the continuous surface sampling was begun at 13.00. The ship-mounted ADCP was also switched on. At 01.51 on 9 July the first CTD profile (North Sea Project station 2354) was started, at a position 10n.mi. from FA. A second CTD profile was done 5 n.mi. from FA. Bottle samples, taken from 1.7 litre rosette sampler bottles, were used for calibration of salinity. Temperature calibration was done using thermometers T250 and T183. Sampling was then done regularly at

least every third or fourth CTD station, so that 21 calibrations were done for the 50 CTD stations eventually completed. A total of 34 samples were taken for salinity calibration of the surface sampling system.

On reaching FA at 04.00 on 9 July, a CTD was taken showing the water to be slightly stratified. The deployment of the current meter rig at FA, a U-shaped mooring with three Aanderaa RCM's at 10, 20 and 30m above the sea bed and marked by a spar buoy, was begun at 05.04 and finished at 05.18. No surface pellet floats were visible after the deployment (the floats were replaced with a longer line on 19 July). A wire test of acoustics was conducted between 05.55 and 06.38. Further wire tests were carried out at station FB between 07.39 and 08.19. The current meter mooring deployment at FB was begun at 08.52. This mooring was U-shaped, with RCM meters at 10m and 24m and an S4 at 39m above the sea bed. A CTD profile taken at 09.30 to 09.39 showed the FB site to have a stratified water column. At 11.38 the deployment of the pop-up mooring at FB with a thermistor chain between 16 and 41m above the sea bed was begun. This deployment ended at 11.41.

Station FC was reached at 12.56 on 9 July, and a U-shaped mooring marked by a spar buoy with a thermistor chain between 18 and 43m above the sea bed was begun at 13.00 and completed at 13.08. A CTD profile (2358) showed the water here to be stratified. The ADCP instrument POLDOP7 was then deployed between 16.25 and 16.36.

Following these deployments a CTD survey (numbers 2359-2372) was conducted overnight on a grid near the Flamborough Head area. The results showed a complex frontal structure with possible eddy activity. CTD station 2372 was completed at 06.52 on 10 July. Five drifting buoys with 5x6m window-blind drogues at 15m below the surface were then deployed in a pattern, the corners and centre of a square of side 5 n.mi. near Flamborough Head (see Table 3 and Figure 5). The first was launched at 08.01 and the fifth at 10.32. At 09.20 the surface sampling fluorimeter had been switched off and was transferred to the seasoar. Then a course was set for mooring position DA, near the Dogger Bank, and a CTD was done every 10 n.mi. These CTDs were numbered 2373-2376, completed at 16.38. Only a few hours after deployment it was learnt that one of the Argos buoys (no. 3949, at the most southerly corner of the square, and the second to be deployed) had been recovered by a fishing boat and taken to Bridlington. The Argos positions received on subsequent days confirmed this. CTD's 2377 to 2388 were in a grid pattern spanning the front west of the Dogger Bank, and were begun at 18.53 on 10 July and completed at 04.07 on 11 July.

The deployment of the U-shaped current meter rig at DA began at 05.26 on 11 July. This had Aanderaa RCMs at 9.5 and 20.5m from the bed and an S4 at 31m from the bed, with a spar buoy as marker. Deployment was completed at 05.36. CTD no. 2389, showing stratification, was taken at DA, and then the pop-up mooring at DA, with a thermistor chain between 8 and 33m from the bed, was deployed between 06.16 and 06.19.

A course was then set for mooring site DB, where deployment of a U-shaped current meter rig was begun at 08.15 on 11 July. This was marked by a toroid and had RCMs at 10.5 and 25.5m and an S4 at 41m from the sea bed. Deployment was completed at 08.24. CTD station 2390 was then carried out. It showed stratification, stronger than at DA. The pop-up thermistor chain mooring at DB, with the chain between 18 and 43m from the bed, was then deployed between 09.13 and 09.16. Deployment of ADCP instrument POLDOP9 at DB began at 11.48 and ended at 11.57.

Five Argos buoys were then deployed, at corners and centre of a square as before, just to the north of the DA and DB moorings (see Table 3 and Figure 6). The first was launched at 12.49 and the fifth at 14.58 on 11 July. The sea-sõar was then prepared for a test run in water of depth greater than 60m. An attempt to send by fax a sketch of a satellite picture of the front failed because of a fault on the telecom section of the satcom. It appeared that fax communication to Challenger would not be possible. The sea-soar test run took place from 18.46 to 22.40 along a line from the buoy deployment sites towards Flamborough Head, always keeping in water greater than 60m depth to avoid the danger of hitting the bottom. This run was successful and gave enough confidence in the system's operation to allow later use in shallower water. The results showed the expected stratified water in this region.

From 23.40 on 11 July to 03.42 on 12 July a line of CTD stations (2391 to 2396) was done in an easterly direction towards the Dogger Bank. The sea-soar was redeployed at 07.20 on 12 July and tidal cycle sections of the front parallel to the line DA-DB were begun. Initially, sections lasting one hour were performed. The sea-soar was recovered at 23.00 on 12 July but the sections continued overnight for ADCP current measurements. Telexes giving the Argos positions of the drifting buoys were received each evening: for all the positions of the ten buoys these cost around £200 each day.

To prevent a drift in positions of the sections end points were fixed at 54° 53.5'N 01° 06.3'E and 54° 52.25'N 01° 18.5'E and the sea-soar redeployed at 08.38 on 13 July. The sea-soar was recovered at 11.18, so that the sections had

covered over two tidal cycles. The sections showed that the front on the western slope of the Dogger Bank was mainly a bottom front, and in the rough seas of 13 July the thermocline had sharpened. There was evident movement of the front over the tidal cycle.

A southerly course on 01° 10'E was then set crossing the "Hills" region of rapidly changing bathymetry, with CTD stations every 5 n.mi. Station 2397 began at 12.03 on 13 July and station 2403 was completed at 17.13. When the bathymetry had become smoother the sea-soar was redeployed (at 18.20) and the southerly course continued. The tidal mixing front was crossed well before the end of the run at 53° 45'N, reached at 22.30. Then a zig-zag course was taken with the sea-soar to survey the front south of the Outer Silver Pit. This course crossed the edge of the pit, where particular care had to be taken when the depth rapidly decreased. Depths less than 30m were avoided by this track, but for depths greater than 30m sea-soaring was conducted with confidence to about 5m from the bed. Undulation periods of the order of 3 min. were used. At the end of the zig-zag path, at 10.48 on 14 July, an attempt was made to calibrate the seasoar CTD by comparison with the CTD at about 2m depth. Then a course was set for the end position of a cross-frontal transect to be repeated over two tidal cycles.

These repeated north-south sea-soar sections, with end points 53° 55'N and 54° 05'N, both on 01° 10'E, were begun at 17.00 on 14 July and completed at 19.13 on 15 July. A seasoar CTD calibration was done at 19.30 and then Challenger steamed north to 54° 11'N ready for a westward sea-soar track towards Flamborough Head. Sea-soar was redeployed at 22.14 on 15 July. It was learnt that another Argos buoy had been taken to Bridlington by a fishing boat. This, no. 3944, had started in the centre of the square near Flamborough Head. Argos positions confirmed this, and also revealed that the buoy had been carried out to sea again on the trawler.

Cross-frontal transects, parallel to the FA-FC line and repeated for two tidal cycles, were begun at 01.15 on 16 July. After a longer section, end points for the repeated run were selected as 54° 05'N 00° 15'E and 53° 57.8'N 00° 02.8'E. After the first tidal cycle, with the southern turn at 17.22 on 16 July the section was moved 2 n.m. seaward to cover a strong bottom front not seen in some of the sections because of tidal advection. The sections were completed and the sea-soar recovered at 07.50 on 17 July.

The three surviving Argos buoys in the Flamborough area were then recovered, at 09.27, 11.16 and 12.29 on 17 July. The known Argos positions

together with radio direction-finding equipment were used to locate them. It was found that the Decca position recording had not been successful. A course was then set for the Argos buoy positions near the Dogger Bank. Two were recovered, at 19.55 and 21.24. One, which had been failing to give Argos fixes, no. 3940, gave one and was sighted at 22.13. It was decided to hove to near this position and recover the buoy at dawn. The recovery took place at 06.23 on 18 July. The final two buoys were recovered at 08.32 and 09.25.

A course was then set for site DA, where the thermistor chain mooring was recovered at 11.30. CTD 2404 was done at this site between 12.08 and 12.18, and the thermistor chain mooring was replaced at 12.34. The thermistor chain at DB was recovered at 13.18, CTD 2405 was done at this site between 13.24 and 13.35 and the thermistor chain mooring was replaced at 14.00. The ADCP at DB was recovered at 14.40. Then a sea-soar survey near DA and DB in a box pattern was done, beginning at 15.20. At 21.20 on 18 July the CTD in the seasoar became faulty and the survey was interrupted. When the CTD had been replaced by the one which had been used for profiling the sea-soar was relaunched, at 23.38. A course for FC, with the sea-soar still operating, was begun at 00.19 on 19 July.

On arrival at site FC at 07.41 on 19 July, the sea-soar was recovered. Transducer acoustic range testing took place from 09.00, and it was found that signals could be picked up at a range of 6 n.mi. The ADCP at FC was recovered at 13.21. Then at FB the thermistor chain was recovered at 14.29 and replaced at 15.13. At FA the surface pellet floats were replaced as the original ones had been on too short a line so they were below the surface, as mentioned above. Then a zig-zag sea-soar track was begun, at 19.30 on 19 July, towards the previously repeated section location on 01° 10'E. This longitude was reached at 03.58 on 20 July. Then a northerly course was taken, and from the section obtained it was decided to repeat the tidal cycle transects across the front with the same end points as before (on 14-15 July). That had been just after neap tides (13 July), while spring tides were to occur on 22 July.

The repeated sea-soar sections were completed at 07.41 on 21 July. While they were being done the faulty CTD was repaired. This was tested at 09.33 to 09.43 on 21 July, with a calibration sample, and was found to be working correctly. The sea-soar was found to have lost a plate from the end of one of its wings, and was generally in need of servicing. Over 140 hours of sea-soar data had been obtained, corresponding to about 1000 n.mi.

It had been determined that the ADCP at FC had not worked. This instrument was fitted with a different transducer and temporarily deployed at 08.58 on 21

July near the end of the sea soar section line as a test. Range testing of acoustics was done until 12.15 and the ADCP was recovered at 12.43 and found to have worked successfully. Then a course was set for Great Yarmouth and Challenger docked at 05.00 on 22 July. The total distance covered during the cruise was 1982 n.mi.

RECOVERY OF MOORINGS (CRUISE 58)

The remaining moorings were planned to be recovered during Challenger cruise 58/89 (principal scientist, A.E. Hill). On 16 August the U-shaped current meter mooring at DA was recovered, but the acoustic release on the pop-up thermistor chain mooring failed to respond. A fishing marker float was situated at the exact position where the mooring was laid, so dragging at the site was ruled out because of the standing instruction not to interfere with fishing gear. Hence the thermistor chain at DA was not recovered. Both moorings at DB were recovered at 16 August. The moorings at FA, FB and FC were all recovered on 17 August, so the thermistor chain at DA was the only instrument lost. The Argos buoys were used again on cruise 58 and although failed Decca fixes did corrupt the data, the return was adequate. This was a significant improvement over their performance on cruise 56.

ACKNOWLEDGEMENTS

My sincere thanks are due to the Master of the Challenger, the officers and crew and the scientists, who all worked hard and conscientiously during the cruise. In particular, we had the benefit of invaluable support from four RVS scientists, who made the sea-soar operation a success and provided a constant supply of plots which made sense of the stream of incoming data.

Table 1. CTD Station List

	time	position	depth	time	position	depth	temp	salinity
2354	89 190 02.10	53 50.3N 0 17.9E	17	190 02.18	53 50.3N 0 17.9E	38	12.97	34.166
2355	89 190 03.06	53 54.9N 0 14.1E	44	190 03.13	53 54.9N 0 14.1E	48	13.09	34.164
2356	89 190 04.05	53 59.2N 0 9.9E	45	190 04.12	53 59.1N 0 10.0E	45	13.09	34.171
2357	89 190 09.34	54 3.3N 0 16.8E	55	190 09.40	54 3.3N 0 16.8E	56	13.63	34.110
2358	89 190 13.24	54 8.9N 0 23.9E	56	190 13.30	54 8.9N 0 23.8E	56	14.00	34.317
2359	89 190 19.41	54 7.8N 0 25.0E	54	190 19.46	54 7.9N 0 25.1E	54	14.07	34.255
2360	89 190 20.31	54 4.6N 0 30.8E	55	190 20.36	54 4.6N 0 31.3E	55	14.09	34.269
2361	89 190 21.18	54 1.1N 0 37.0E	45	190 21.24	54 0.7N 0 36.7E	45	13.34	34.188
2362	89 190 22.09	53 57.6N 0 31.4E	46	190 22.13	53 56.4N 0 30.1E	46	14.01	33.624
2363	89 190 22.55	53 53.9N 0 25.0E	48	190 23.01	53 53.8N 0 25.0E	46	12.33	35.288
2364	89 190 23.51	53 58.1N 0 18.6E	52	191 00.03	53 58.4N 0 18.9E	52	13.23	34.137
2365	89 191 00.48	54 1.2N 0 25.1E	53	191 00.57	54 1.1N 0 25.0E	53	12.22	35.494
2366	89 191 01.39	54 4.3N 0 18.4E	53	191 01.48	54 4.3N 0 17.8E	53	11.77	35.889
2367	89 191 02.22	54 7.8N 0 12.4E	55	191 02.29	54 7.9N 0 12.3E	54	13.06	34.222
2368	89 191 03.19	54 11.5N 0 6.3E	54	191 03.31	54 12.1N 0 5.0E	54	14.00	33.994
2369	89 191 04.08	54 14.7N 0 0.4E	56	191 04.15	54 14.8N 0 0.4E	54	13.32	34.186
2370	89 191 05.01	54 18.3N 0 6.7E	57	191 05.10	54 18.2N 0 6.7E	54	14.16	33.772
2371	89 191 05.53	54 14.9N 0 12.9E	54	191 06.02	54 14.8N 0 13.1E	58	13.56	34.181
2372	89 191 06.44	54 11.3N 0 19.1E	56	191 06.52	54 11.3N 0 19.2E	56	13.69	34.218
2373	89 191 12.22	54 24.4N 0 18.1E	46	191 12.30	54 24.8N 0 18.6E	45	16.04	33.688
2374	89 191 13.39	54 31.5N 0 30.2E	58	191 13.46	54 32.2N 0 31.2E	57	-0.06	53.852
2375	89 191 15.05	54 38.4N 0 43.0E	68	191 15.14	54 38.6N 0 43.1E	68	15.06	34.418
2376	89 191 16.27	54 45.1N 0 55.6E	72	191 16.36	54 45.2N 0 55.6E	72	13.98	34.397
2377	89 191 18.59	54 50.0N 0 55.6E	45	191 19.05	54 49.9N 0 55.8E	64	14.45	34.446
2378	89 191 19.47	54 50.0N 1 4.2E	53	191 19.51	54 49.9N 1 4.3E	53	14.45	34.455
2379	89 191 20.30	54 50.0N 1 12.7E	47	191 20.34	54 50.1N 1 12.8E	46	14.37	34.506
2380	89 191 21.17	54 49.9N 1 21.4E	30	191 21.21	54 50.3N 1 21.6E	30	14.28	34.634
2381	89 191 22.04	54 54.9N 1 21.4E	29	191 22.07	54 55.0N 1 21.4E	29	14.58	34.652
2382	89 191 22.52	54 55.1N 1 12.3E	45	191 22.56	54 55.0N 1 12.1E	24	14.31	34.609
2383	89 191 23.39	54 54.9N 1 3.7E	57	191 23.47	54 54.7N 1 3.7E	57	14.50	34.492
2384	89 192 00.35	54 55.0N 0 53.9E	64	192 00.44	54 55.2N 0 54.3E	63	14.74	33.891
2385	89 192 01.25	55 0.1N 0 55.9E	63	192 01.34	55 0.1N 0 56.7E	64	14.52	34.505
2386	89 192 02.15	55 0.0N 1 3.9E	57	192 02.23	55 0.1N 1 3.6E	57	14.75	34.328
2387	89 192 03.08	55 0.0N 1 12.4E	53	192 03.15	55 0.1N 1 12.6E	53	14.18	34.610
2388	89 192 04.03	55 0.0N 1 21.4E	7	192 04.08	54 60.0N 1 21.3E	7	14.24	34.616
2389	89 192 05.51	54 53.9N 1 11.0E	48	192 05.58	54 53.8N 1 11.2E	48	14.09	34.531
2390	89 192 08.35	54 55.2N 1 4.3E	58	192 08.40	54 55.2N 1 4.4E	58	14.29	34.503
2391	89 192 23.43	54 36.0N 0 37.5E	69	192 23.51	54 36.0N 0 37.5E	69	14.94	34.297
2392	89 193 00.31	54 35.9N 0 47.8E	68	193 00.39	54 35.9N 0 47.8E	67	14.89	34.405
2393	89 193 01.14	54 35.8N 0 54.7E	64	193 01.21	54 35.9N 0 54.8E	63	14.40	34.371
2394	89 193 02.05	54 35.7N 1 3.6E	57	193 02.12	54 35.9N 1 8.9E	56	13.98	34.397
2395	89 193 02.45	54 35.8N 1 10.9E	41	193 02.50	54 36.0N 1 12.0E	39	13.60	34.487
2396	89 193 03.39	54 35.9N 1 20.1E	37	193 03.43	54 35.9N 1 20.1E	36	14.49	34.594
2397	89 194 12.11	54 50.1N 1 9.8E	47	194 12.17	54 49.5N 1 10.0E	47	14.16	34.280
2398	89 194 13.00	54 45.2N 1 10.0E	47	194 13.05	54 44.4N 1 9.9E	46	14.03	34.505
2399	89 194 13.46	54 40.1N 1 10.0E	42	194 13.50	54 39.6N 1 10.1E	41	14.17	34.568
2400	89 194 14.34	54 35.1N 1 10.0E	52	194 14.39	54 34.8N 1 9.8E	53	14.07	34.587
2401	89 194 15.30	54 30.0N 1 9.9E	70	194 15.38	54 29.9N 1 9.8E	70	13.82	34.530
2402	89 194 16.21	54 25.0N 1 9.8E	47	194 16.25	54 24.9N 1 9.7E	51	13.80	34.550
2403	89 194 17.07	54 20.1N 1 9.7E	60	194 17.16	54 19.7N 1 9.5E	61	13.95	34.434
2404	89 199 12.15	54 54.7N 1 10.3E	49	199 12.22	54 54.2N 1 10.4E	49	14.97	34.634

Table 2. Instruments and Moorings

CHALLENGER 56/89 FRONTS - 6 JULY 1989 TO 22 JULY 1989

RCM's

INSTRUMENT	STARTTIME	STOPTIME	RIG	NOTES
568 -4S	07.50.00 11/7/89		DB-B	10 MIN SAMP.
3277 -4	06.00.00 9/7/89		FB-M	10 MIN SAMP.
3559 -5S	07.30.00 11/7/89		DB-M	10 MIN SAMP.
7570 -4	02.10.00 11/7/89		DA-B	10 MIN SAMP.
9634 -8P	02.50.00 11/7/89		DA-M	10 MIN SAMP.
9643 -8P	19.40.00 8/7/89		FA-T	10 MIN SAMP.
9650 -8P	19.30.00 8/7/89		FA-M	10 MIN SAMP.
9652 -8P	19.20.00 8/7/89		FA-B	10 MIN SAMP.
9780 -7P	07.00.00 9/7/89		FB-B	10 MIN SAMP.

THERMISTOR LOGGERS

852 -TR2	03.30.00 11/7/89	11.44.47 18/7/89	DA	15 MIN SAMP.
852 -TR2	11.59.46 18/7/89		DA	15 MIN SAMP.
853 -TR2	10.45.00 9/7/89	14.44.46 19/7/89	FB	15 MIN SAMP.
853 -TR2	14.59.46 19/7/89		FB	15 MIN SAMP.
1146 -TR7	08.40.00 11/7/89	13.25.08 18/7/89	DB	05 MIN SAMP.
1146 -TR7	13.45.00 18/7/89		DB	05 MIN SAMP.
1147 -TR7	09.50.00 9/7/89		FC	05 MIN SAMP.

THERMISTOR CHAINS -ALL 25 METRES EX.TIME CONSTANT.

1648	RIG FB CONNECTED	11.15 9/7/89
1685	RIG FC CONNECTED	12.37 9/7/89
1701	RIG DB CONNECTED	09.00 11/7/89
1702	RIG DA CONNECTED	04.00 11/7/89 -lost

S4's

1195	03.20.00 11/7/89	DA-T	10 MIN SAMP.
1196	07.00.00 11/7/89	DB-T failed	10 MIN SAMP.
1258	08.10.00 9/7/89	FB-T	10 MIN SAMP.

DOPPLERS

POLDOP7	16.10.00 9/7/89	13.26	19/7/89	FC	375P
POLDOP9	11.30.00 11/7/89	14.42	18/7/89	DB	375P

RIG DEPLOYMENT INFORMATION

FA CM's	IN WATER	53:59:87N 00:09:43E	45M	05:09 9/7/89
	RECOVERED			
FB CM's	IN WATER	54:03:45N 00:17:42E	56M	09:06 9/7/89
	RECOVERED			
FB THERM	IN WATER	54:03:94N 00:16:57E	54M	11:39 9/7/89
	RECOVERED	54:04:43N 00:16:59E		14:29 19/7/89
	IN WATER	54:03:72N 00:16:71E		15:13 19/7/89
	RECOVERED			
FC THERM	IN WATER	54:08:17N 00:24:46E	56M	13:03 9/7/89
	RECOVERED			
FC DOPPLER	IN WATER	54:08:71N 00:24:17E	57M	16:34 9/7/89
	RECOVERED	54:09:71N 00:24:09E		13:19 19/7/89
DA CM's	IN WATER	54:53:98N 01:11:70E	46M	05:35 11/7/89
	RECOVERED			
DA THERM	IN WATER	54:54:10N 01:10:61E	47M	06:19 11/7/89
	RECOVERED	54:54:00N 01:10:66E		11:26 18/7/89
	IN WATER	54:54:17N 01:10:89E		12:34 18/7/89
	RECOVERED			
DB CM's	IN WATER	54:54:90N 01:04:43E	56M	08:18 11/7/89
	RECOVERED			
DB THERM	IN WATER	54:55:18N 01:04:80E	56M	09:16 11/7/89
	RECOVERED	54:55:22N 01:04:80E		13:15 18/7/89
	IN WATER	54:55:05N 01:04:06E		14:34 18/7/89
	RECOVERED			
DB DOPPLER	IN WATER	54:55:18N 01:04:06E	57M	11:55 11/7/89
	RECOVERED	54:55:05N 01:04:06E		14:34 18/7/89

Table 3. Argos Buoys

No.	Position Launched	Time Launched	Position Recovered	Time Recovered
3946	54° 14.89'N 00° 12.72'E	08.01 10.7.89	54° 18.16'N 00° 23.73'E	11.16 17.7.89
3949	54° 11.11'N 00° 07.11'E	08.45 10.7.89	Taken to Bridlington by trawler	
3944	54° 14.83'N 00° 06.74'E	09.24 10.7.89	Taken to Bridlington by trawler	
3948	54° 18.16'N 00° 06.73'E	09.54 10.7.89	54° 15.11'N 00° 12.99'E	12.29 17.7.89
3945	54° 14.72'N 00° 00.55'E	10.32 10.7.89	54° 09.77'N 00° 13.22'E	09.27 17.7.89
3943	54° 57.49'N 01° 08.29'E	12.49 11.7.89	55° 23.31'N 01° 07.21'E	21.24 17.7.89
3940	55° 02.50'N 01° 08.21'E	13.26 11.7.89	55° 17.38'N 01° 08.87'E	06.23 18.7.89
3947	55° 00.05'N 01° 12.49'E	13.54 11.7.89	55° 15.85'N 01° 01.13'E	19.55 17.7.89
3942	54° 57.57'N 01° 16.95'E	14.23 11.7.89	55° 06.37'N 01° 28.71'E	09.25 18.7.89
3941	55° 02.56'N 01° 16.97'E	14.58 11.7.89	55° 08.80'N 01° 26.15'E	08.32 18.7.89

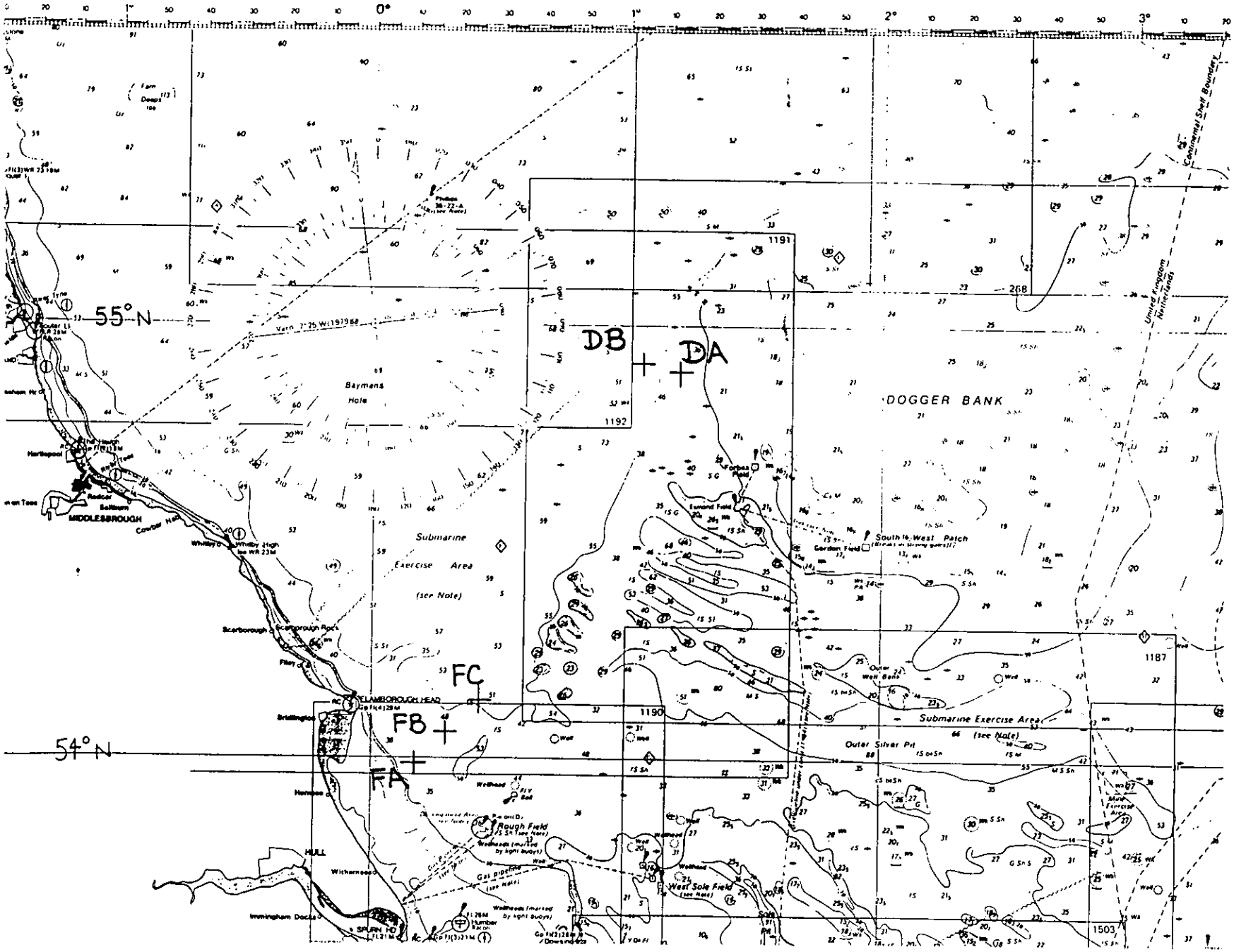


Figure 1. Area of cruise

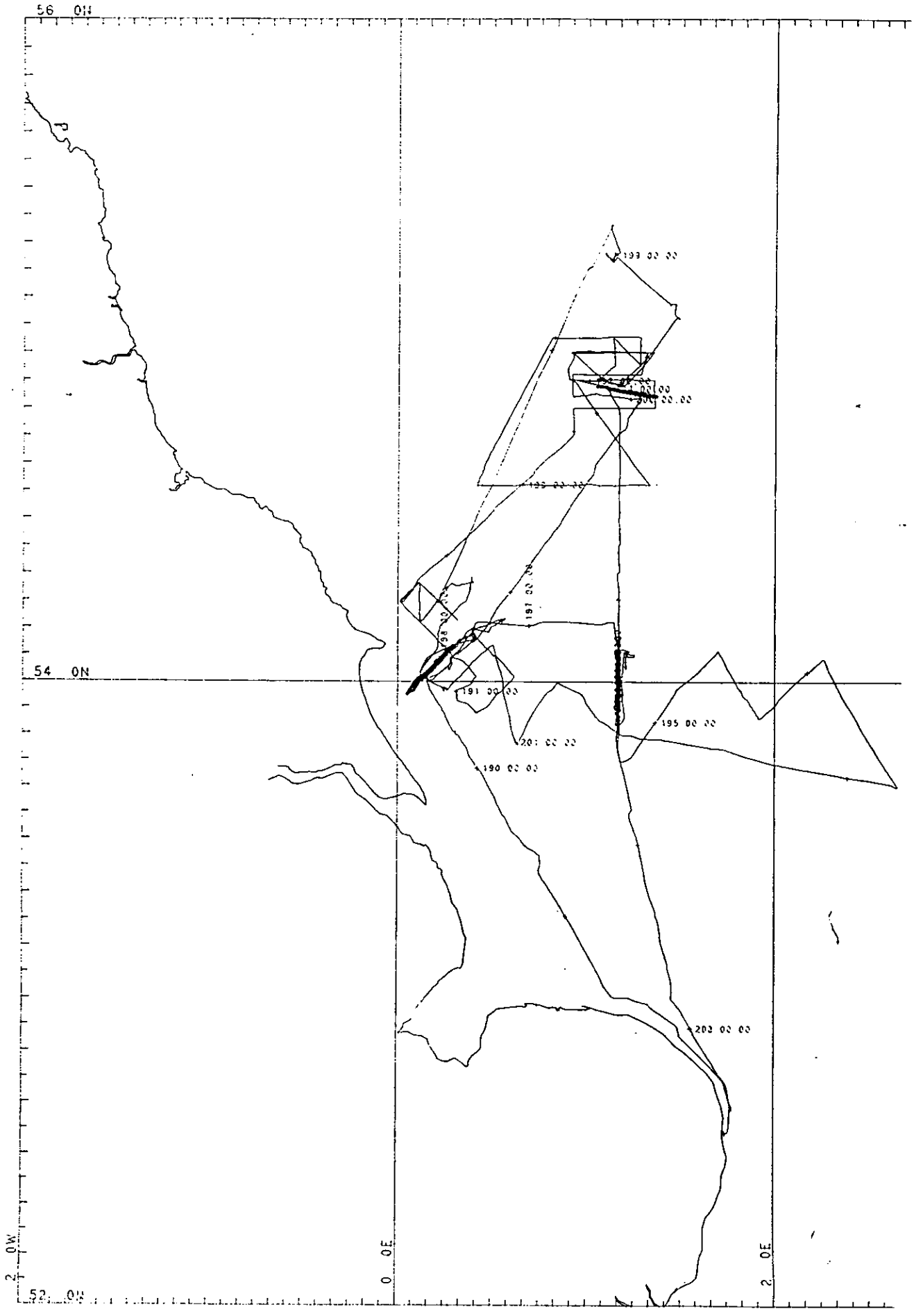
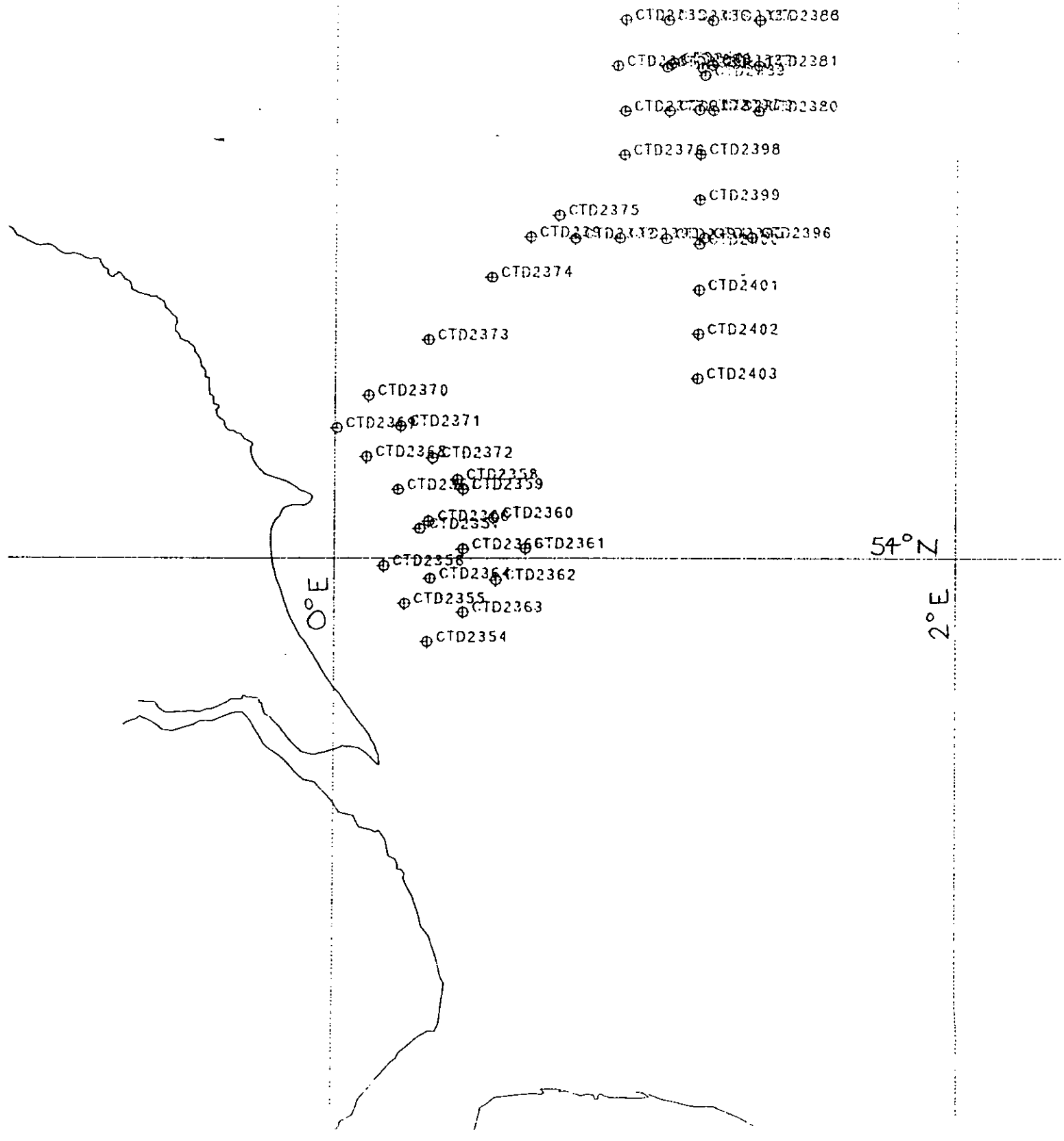


Figure 2. Cruise track

Figure 3. CTD positions



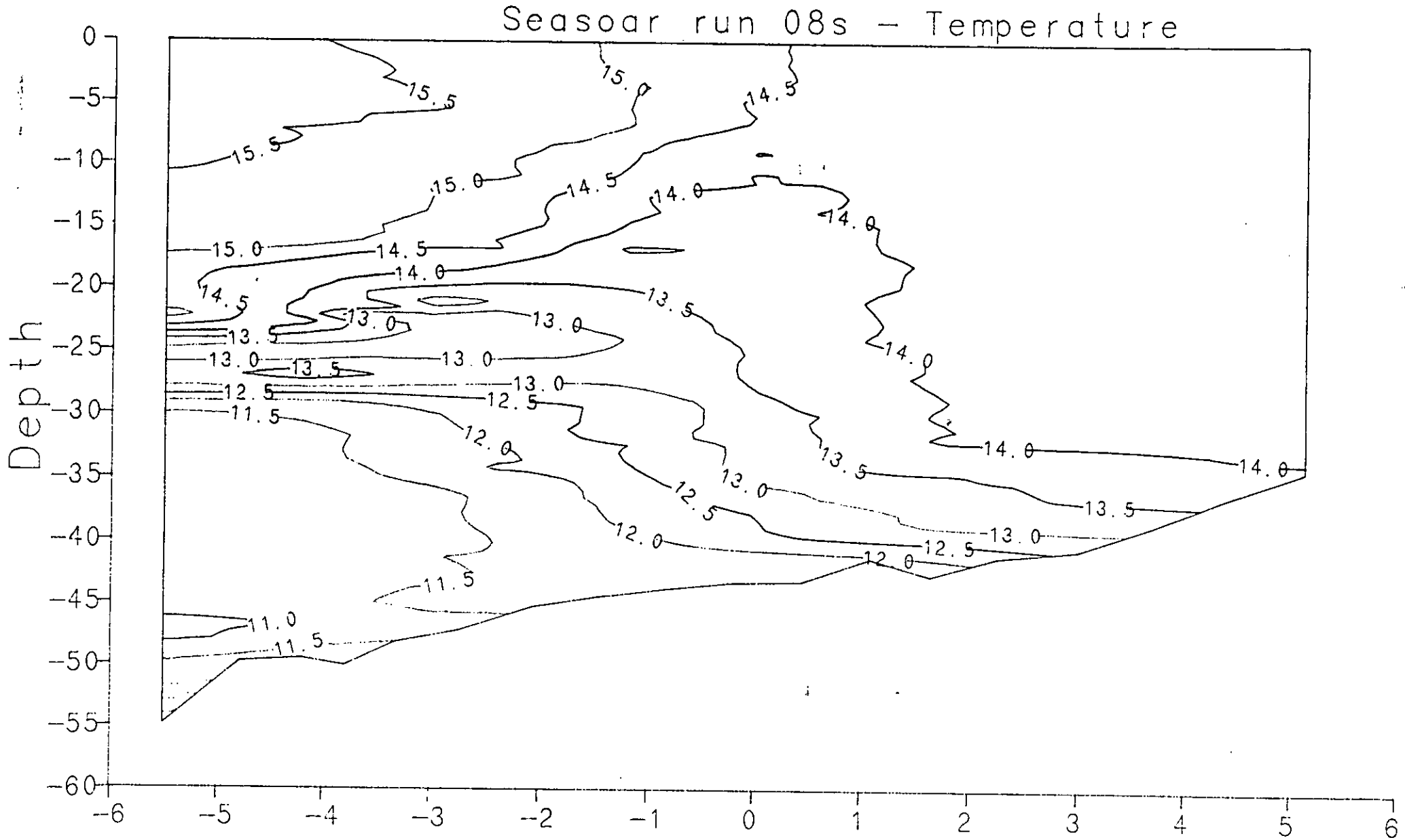


Figure 4. Typical sea-soar temperature section across front. From the repeated section on 1° 10'E, 21 July.

Figure 5. Buoy tracks from Argos positions: the set of five near Flamborough Head.

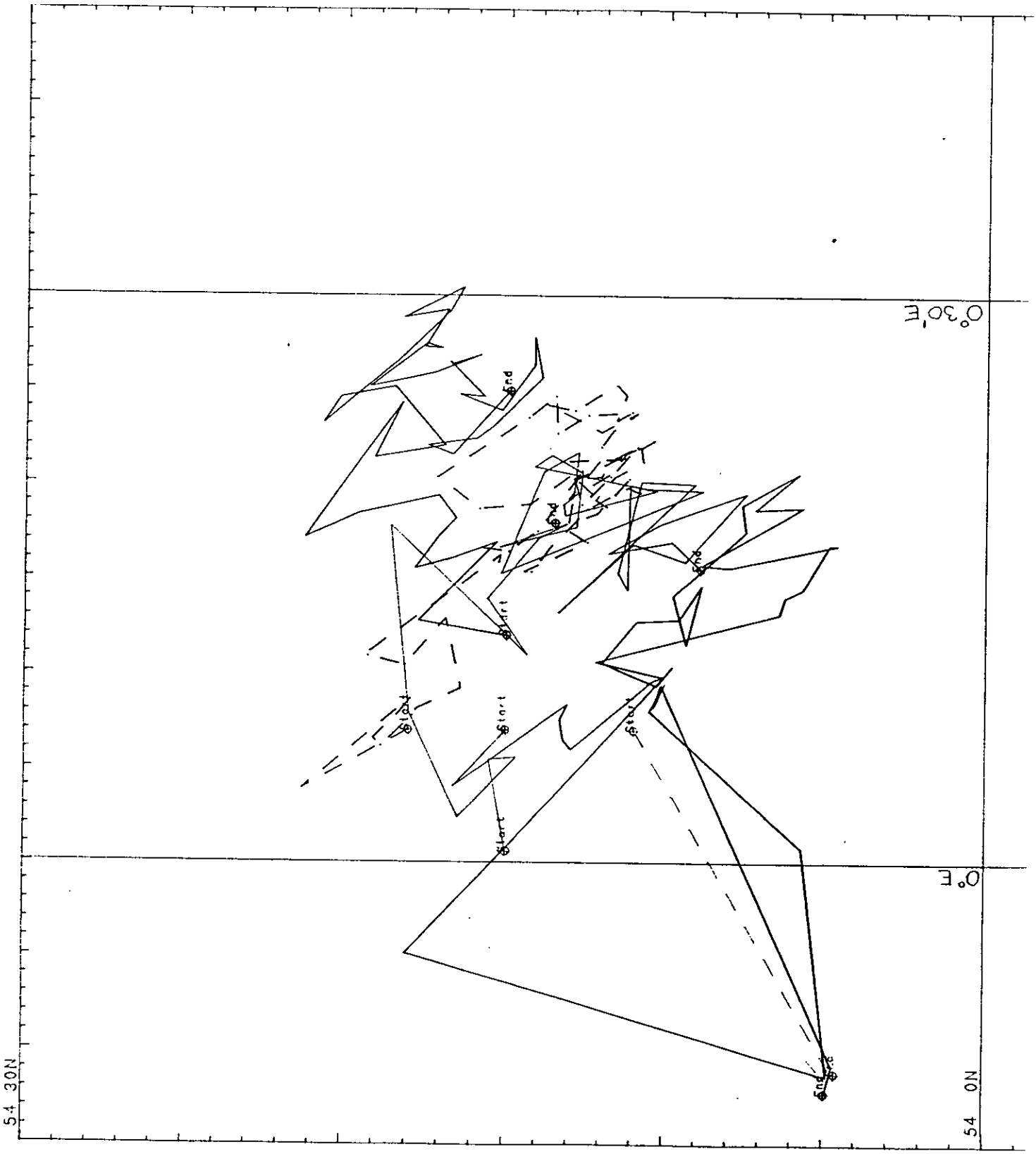


Figure 6. Buoy tracks from Argos positions: the set of five near the Dogger Bank.