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NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE FOR MARINE ENVIRONMENTAL RESEARCH

CRUISE REPORT

UOR OPERATIONS

USNS LYNCH

Norwegian Sea, Barents Sea and Greenland Sea

August 1 - 22 1986

J Aiken

Institute for Marine Environmental Research

October 1986

INSTITUTE FOR MARINE ENVIRONMENTAL RESEARCH

VESSEL	**USNS LYNCH**			
PERIOD	1 August to 22 August 1986			
PERSONNEL	R Howarth	Senior Scientist	NOSC	San Diego
	G Ivanoff		"	" "
	G Edwards	Visibility Lab	SIO	San Diego
	G Nolten	" "	"	" "
	C Trees	" "	"	" "
	J Aiken	IMER	Plymouth	England

ITINERARY: (All times in BST)

Mon 28 July	IMER Scientific equipment transported to Glasgow by Laboratory van.
Tue 29 July	Aiken travelled to Glasgow by sleeper train.
Wed 30 July	Scientific equipment loaded on board LYNCH and cruise preparations started.
Thur 31 July	Cruise preparations continued.
Fri 1 Aug	0900 LYNCH departed Glasgow, fuelled and made passage to the scientific area; see cruise track, Appendix 1.
Sat 2 Aug	1300 Station 1; see station list Appendix 2. 1600 - 1900 UOR test deployments (no instruments).
Sun 3 Aug	1140 UOR Tow 1 and vertical profile to Station 2; see tow list Appendix 3. 1300 - 1600 Station 2 1648 Vertical Profile (VP) and UOR Tow 2. 1918 End UOR Tow 2.
Mon 4 Aug	1022 UOR Tow 3 and VP at Station 3. 1230 - 1545 Station 3. 1555 UOR Tow 4. 1947 End UOR Tow 4.
Tue 5 Aug	1230 - 1600 Station 4. 1619 VP from Station 4; UOR Tow 5. 1900 End UOR Tow 5.
Wed 6 Aug	1020 UOR Tow 6; VP to Station 5. 1230 - 1600 Station 5. 1610 VP from Station 5; UOR Tow 7. 1925 End UOR Tow 7.

Thur 7 Aug	1103 UOR Tow 8; VP to Station 6.
	1230 - 1530 Station 6.
	1549 VP from Station 6; UOR Tow 9.
	1625 End UOR Tow 9.
	1647 UOR Tow 10.
	1911 End UOR Tow 10.
Fri 8 Aug	1019 UOR Tow 11; VP to Station 7.
	1230 - 1530 Station 7.
	1532 VP from Station 7; UOR Tow 12.
	1950 End UOR Tow 12.
Sat 9 Aug	0833 UOR Tow 13; VP to Station 8.
	1100 - 1400 Station 8.
	1405 VP from Station 8; UOR Tow 14.
	1821 End UOR Tow 14.
Sun 10 Aug	0732 UOR Tow 15; VP to Station 9.
	0945 - 1430 Station 9.
	1435 VP from Station 9; UOR Tow 16.
	1851 End UOR Tow 16.
Mon 11 Aug	0725 UOR Tow 17; VP to Station 10.
	0930 - 1230 Station 10.
	1245 VP from Station 10; UOR Tow 18.
	1251 End UOR Tow 18.
Tue 12 Aug	0727 UOR Tow 19; VP to Station 11.
	0930 - 1230 Station 11.
	1237 VP from Station 11; UOR Tow 20.
Wed 13 Aug	0238 End UOR Tow 20.
	0840 Double VP before Station 12 (Tow 21).
	0930 - 1500 Station 12.
	1516 VP from Station 12; UOR Tow 22.
	1953 End UOR Tow 22.
Thur 14 Aug	0727 UOR Tow 23; VP to Station 13.
	0930 - 1300 Station 13.
	1345 VP from Station 13; UOR Tow 24.
	1745 End UOR Tow 24.
Fri 15 Aug	0718 UOR Tow 25; VP to Station 14.
	1100 - 1415 Station 14.
	1429 VP from Station 14; fixed depth Tow 26.
	1550 End UOR Tow 26.
	1923 UOR Tow 27.
Sat 16 Aug	1052 End UOR Tow 27; VP to Station 15.
	1100 - 1500 Station 15.
	1500 VP from Station 15; UOR tow 28.

Sun 17 Aug	0850 End UOR Tow 28; VP to Station 16. 0915 - 1230 Station 16. 1244 VP from Station 16;fixed depth and Undulating Tow 29. 1427 End UOR Tow 29. 2008 UOR Tow 30. 2045 Abort Tow 30; fog and ice.
Mon 18 Aug	0813 UOR Tow 31 and VP to Station 17. 1100 - 1345 Station 17. 1409 VP from Station 17; UOR Tow 32. 1942 End UOR Tow 32.
Tue 19 Aug	0823 UOR Tow 33 and VP to Station 18. 1100 - 1345 Station 18. 1354 VP from Station 18; UOR Tow 34. 1858 End UOR Tow 34.
Wed 20 Aug	0819 UOR Tow 35 and VP to Station 19. 1115 - 1300 Station 19. 1307 VP from Station 19; UOR Tow 36. 1810 End Tow 36.
Thur 21 Aug	0800 - 1010 Station 20. 1012 VP from Station 20; UOR Tow 37. 1442 End UOR Tow 37. Cruise activities completed.
Fri 22 Aug	1200 LYNCH Docked in Trondheim PM Equipment packed for shipment and unloaded from LYNCH.
Sat 23 Aug	0630 Aiken travelled back to UK.
EQUIPMENT: (IMER)	UOR610 (ARE) + Chlorophyll, temperature depth and light sensors. UOR610 spares. UOR611 (IMER) + sensors and spares. SWTP Computer and MDTR playback. LA120 Printing terminal. COMPAC Computer (APL/JHU). Towing cables (3 reels). Towing blocks Strain gauges (Hydraulic + electronic) UOR trolley. Sundry tools, test equipment and deployment gear.
OBJECTIVES:	1. To measure the bio-optical properties and associated hydrographic structures of the waters throughout the cruise area (Eastern North Atlantic, Norwegian Sea, Barents Sea and Greenland Sea.

METHODS:

1. At stations throughout the cruise area, timed close to local solar noon, the vertical structure (to 200 m if possible) of downwelling irradiance and water transmission were measured at several wavelengths with:

1.1 The Marine Environmental Radiometer (MER); downwelling irradiance at 410, 441, 465, 488, 520 540, 560 and 589 nm.

1.2 The Visibility Laboratory Irradiance Meter (VLIM); downwelling irradiance at 493 nm.

1.3 The Visibility Laboratory Spectral Transmissometer (VLST); transmission at 5 wavelengths.

2. At each station, the vertical structure (to 500 m or 250 m in shallow waters) of Temperature Conductivity and Salinity was measured (or computed) using a vertical cast of the Neil-Brown CTD. Water samples were taken at 12 depths and water filtered for analysis of chlorophyll concentration and accessory pigments by HPLC; samples were frozen for subsequent laboratory analysis.

The UOR chlorophyll sensor was calibrated with 10ml samples from each bottle; see Appendix 2/2.

3. Continuous measurements of surface chlorophyll concentration (pumped surface water to Turner fluorometer) and temperature (IMER thermister probe) were made along the cruise track and water samples filtered (at least 4 per day and more frequently in frontal regions) for chlorophyll and accessory pigment analysis (by HPLC).

4. The UOR mark 2 was towed at full speed (ca

10

knots, 5m.s^{-1}), set to undulate from surface to 50 m, up-to and away from each station position, to make measurements of depth, temperature chlorophyll and light (upwelling and downwelling sensors as detailed in Figure 1), in support of the primary objective. Immediately adjacent to each station, the UOR was towed in a slow oblique profile astern of the vessel (at 2 to 4 knots) to acquire data, uncorrupted by any artefact of the high-speed towing operations, for comparison with the station data.

The UOR tow cable was turned end-for-end about mid-way through the cruise (after ca 700 miles).

EQUIPMENT FAILURES AND EQUIPMENT PERFORMANCE:

The UOR failed to undulate on tow 1 (vessel's speed less than 8kt in heavy seas), tow 2 (servo' pressure sensor blocked) and tow 3 (tail plane crank uncoupled, shortly after deployment) and stopped undulating during tow 8 (pin sheared in servo' motor/gearbox linkage). The undulation amplitude was limited to ca 20m for tows 4-7 (due to excessive weight of the fully loaded UOR and extra lead ballast in UOR610). Fixed "wings" were fitted for subsequent tows and the UOR undulated satisfactorily through the programmed depth range (surface to 50m); tows 8 to 37, 1276 miles out of a total distance of 1411 miles (>90%).

Data acquisition was generally satisfactory; System A failed for only tows 32 and 33, due to faulty contacts on the power supply board (>95% success); System B failed for part of tow 17 (1 bad battery cell) tow 18 (dry joint in power supply wiring) and tow 28 (corroded sea-water switch contact), giving an 82% data acquisition success.

An analysis of sensor and data logger performance is given in Appendix 4. There were some failures of individual light sensors, mainly due to the cable (domestic grade p.v.c.) becoming brittle in sub-zero temperatures.

Temperature, chlorophyll concentration, depth, downwelling blue (450 nm) light and green light (550nm) were recorded for most of the cruise (except the tape recorder failures, tow 32 and part tow 33) amounting to over 95% of the towed distance. Likewise downwelling light blue irradiance (488 nm) and downwelling hemispherical irradiance (488 nm) were recorded for all tows, except the System B tape recorder failures (tows 17, 18 and 28), amounting to 82% data acquisition success. There were 12 or more sensors operational for 30 of the 37 tows amounting to about 75% of the total time. Of the potential 0.9M data points recorded (150 h at 6000.h^{-1}) about 11.5% were lost through data recorder failures, and a further 13% through sensor failures. Since upwelling light was immeasurable at depths greater than 20m for much of the time with shallower limits in dull conditions or at night, the number of useful

data points recorded was ca 0.5 to 0.6M.

Overall the performance of the UOR in arctic, sub-zero temperature waters was extremely satisfactory; battery capacity for all sensors was more than adequate even for the longest tow (17 h 50 mins).

The tape relay module gave persistent problems throughout the cruise, which was a handicap to the efficient examination of the data while at sea, but nevertheless adequate performance was achieved.

RESULTS:

The UOR was deployed 37 times (see tow list, Appendix 3) covering a distance of 1411 nautical miles (total time almost 150 h); the total cruise distance, station 1 to station 20, was ca 3500 nautical miles. The successful tows produced a total of 1472 vertical profiles and undulations (equivalent to double oblique profiles). In addition the UOR was towed at a fixed depth (ca 2-3 m) for part of tow 26 and tow 29 (total time ca 1 h), to measure the spatial variation of near-surface reflectance ratios (25-50 m resolution).

The results obtained provided a good coverage of the cruise area and provide sufficient data to describe the varied and contrasting hydrographic structures and associated biological conditions encountered, notably between the temperate oceanic waters of the Eastern North Atlantic and the Norwegian Sea (stations 1 to 6 and 19 to 20; tows 1 to 10 and 35 to 37) and the arctic waters of the Barents Sea and the Greenland Sea (stations 7 to 18 and tows 11 to 34); both contrasting geographic areas are known to be complex with multiple current systems and fronts arising from variations of both salinity and temperature structures.

In the temperate waters, where surface temperature ranged from ca 13°C west of the Hebrides to ca 10°C in the Norwegian Sea, there were marked variations of vertical structure. At station 2 to the west of the Hebrides, there was a slight temperature inversion, near-surface to 10m and a deep mixed layer to 40/50m; see for example Figures 2a and b. Chlorophyll$_3$ concentrations were moderately high at ca 2.5mg.m^{-3} in the mixed layer and almost totally absent in the deep water below 50m. Further north, the surface mixed layer was generally shallower, the thermocline (sometimes) sharp and narrow, which supported phytoplankton populations with chlorophyll concentrations up to 5 mg.m^{-3}; see Figures 2c and d.

The complex nature of the structures is illustrated by the final tow (tow 37) from station 20 towards the Norwegian coast, where there was evidence of frontal or current structures.(See Figures 3a and b). At the start of the tow, the temperature contours sloped steeply downwards from the surface, the surface mixed layer deepened from ca 10 to ca 30m, indicating a possible frontal crossing just before the start of the tow. After about 20 miles along the tow there was a sharp increase in temperature subsurface, indicating a sub-surface front (or current system); the 10, 11 and 12°C isotherms rose by 20m in about 2 miles. The associated chlorophyll structures changed in sympathy with the temperature structure the chlorophyll maximum was broad and deepened in the first part of the tow; after the "front", the concentration in the shallow mixed layer (to 15m) was low (ca .5mg.m^{-3}) but increased sharply in the thermocline to values >4mg.m^{-3} at a depth of 20-50m, declining deeper down the water column. These structures are similar to those measured in the arctic waters.

Incident surface light was high throughout the tow (bright sun, clear cloudless sky), so that sunlight penetrated throughout the water column to >50m, though the penetration of blue light (450nm) was noticably attenuated by the patches of chlorophyll in the thermocline of concentration >2.5mg.m^{-3} (see Figure 3c); as expected green light (550nm) was attenuated much less by the high chlorophyll patches (see Figure 3d).

As mentioned above, the temperature and chlorophyll structures measured in arctic waters were generally substantially different in character from the temperate zone; notably the surface mixed layer, which was usually fresher/lower salinity (presumably due to the influence of ice-melt water) was very low in chlorophyll concentration (<0.5mg.m^{-3}) to the extent that one would speculate that nutrients had been depleted by previously high levels of near-surface primary production; (see for example Figure 4). Below the surface mixed layer chlorophyll concentrations were abundant, often exceeding 5mg.m^{-3} in the peak in the thermocline.

The typical temperature structure comprised a shallow mixed layer (ca 10 - 15m) of temperature 4°C -> 8°C and a very sharp thermocline which exhibited a temperature inversion by 40m, on occasions; frequently the temperature dropped

below 0°C (as low as -1.5°C), sometimes rising above 0°C again in the temperature inversion, indicative of complex seasonal events or advective processes.

Figure 4a and b shows the computer contoured vertical sections of temperature (°C) and chlorophyll concentration ($mg.m^{-3}$) for tow LA88620 between stations 11 and 12 at the eastern end of the Barents Sea; the data are plotted as a "reverse" tow with the eastern/southern end of the tow on the right hand side. Temperatures ranged from >6.5°C at the start (southern end; mixed layer depth 20m) to 7.5°C at the end (M.L.D. 10m); there were substantial parts of the water column with temperature below 0°C.

For most of the tow, chlorophyll concentrations exceeded 1.5 $mg.m^{-3}$ in the peak values in the thermocline, generally at depths below 40m. Only at the start of the tow (0 to -5 miles) was there no substantial thermocline peak although from -8 to -18 miles the maximum chlorophyll concentrations were recorded at the maximum depth of the measurements ca 53m; it is possible that the maximum concentrations may have been deeper. Examination of the chlorophyll section would seem to indicate a change of vertical structure after about -75 miles, not obvious from the temperature section; the 0.5 $mg.m^{-3}$ contour which had "defined" the depth of the surface mixed layer from 0 to -75 miles, deepened to below 30 m for the remainder of the tow and the concentrations of chlorophyll in the thermocline increased to generally >3.5 $mg.m^{-3}$ from only occasionally >2.5 $mg.m^{-3}$ for the first part.

The associated vertical sections for downwelling and upwelling blue (450 nm) and green (550 nm) light do not provide any evidence in support of the change of structure after -70 miles; upwelling blue light was not measured after -55 miles and upwelling green light not measured after ca -70 miles, because of the decline of downwelling light throughout the tow corresponding to the "night-time" period; so an analysis of Reflectance will yield no more in formation.

During the cruise, it was possible to make some comparisons between the optical measurements by the sensors deployed on station, by the Visibility Laboratory of Scripps Institute of Oceanography and the measurements made by sensors attached to the UOR. Figure 5a and b shows the measurements of downwelling irradiance at 493 nm by the VLIM

at 40m in each case. The UOR chlorophyll measurements (not shown) almost "mirrored" the "k" profile increasing from a very low value ca 0.2 $mg.m^{-3}$ in the surface mixed layer to a maximum value of ca 1.6 $mg.m^{-3}$ in the thermocline at between 35 and 40m, falling below 0.5 $mg.m^{-3}$ by 45m and to less than 0.1 $mg.m^{-3}$ below 50m.

The measurements at station 12 (Figure 6a and b) gave comparable measurements again; k(VLIM)/k(MER) were 0.063 and 0.056 in the surface mixed layer (to 20m) increasing to maximum values of 0.155 and 0.139 at about 40m and decreasing thereafter. The UOR measurements (Figure 6c) gave surface measurements 0.055/0.06 for k488 increasing to a value of 0.135 at 40m (the maximum depth of the measurements); this was at the same depth as the maximum recorded chlorophyll concentrations, ca 3.5$mg.m^{-3}$ in the thermocline at sub zero temperatures (see Figure 6d). Note the surface mixed layer chlorophyll concentration was extremely low at ca 0.2$mg.m^{-3}$.

CONCLUSIONS:

The preliminary assessment of the comparative measurements of the vertical attenuation of light by the UOR and on station by conventional methods was extremely encouraging, though some areas of concern were identified.

1. The range and sensitivity of the UOR sensors was somewhat limited for this low light, northern latitude and improvement would be beneficial; the sensors deployed had very narrow band filters (10 nm ½-width) and the photodiodes were not optimised for each spectral range. The detection limits could be improved by using wider band filters of 20 - 40nm ½-width which would not seriously degrade the spectral resolution within the sensitivity required for ocean colour studies; blue-enhanced photodiodes would improve the spectral sensitivity for blue measurements.
2. The depth range of the undulator (typically 0 - 55m for this cruise) was slightly shallower than the optimum for all aspects of ocean colour studies; 0 to 75m would be superior which can be achieved by the present UOR.

3. The simultaneous measurement of chlorophyll concentrations alongside the optical measurements is extremely valuable for the interpretation of the data; in situ measurements of other pigment concentrations would be an additional advantage.

Prepared by:

J. Aiken October 1986

Approved by B L Bayne

Circulation

Internal:	Bayne
	Joint
	Williamson
	Aiken
External:	
NERC HQ	Woods
	Pugh
	White
IOS Wormley	Edwards (MIAS)
MBA	Denton
	Holligan
Cruise Personnel	as listed
APL	Keith Peacock
File	OPS 2.14

List of Appendices

Appendix 1. Cruise track, USNS LYNCH, 1 August to 22 August 1986. Station positions are numbered 1 to 20 and circled. UOR tows are indicated by bold sections.

Appendix 2. Station list, USNS LYNCH, 1 August to 22 August 1986.

Appendix 3. (5 sheets). UOR Tow lists, USNS LYNCH, 1 August to 22 August 1986.

Appendix 4. (4 sheets). Sensor and data logger performance analysis, USNS LYNCH, 1 August to 22 August 1986.

Figure Legends

Figure 1. UOR Mark 2 schematic and sensor suite.

Figure 2. Micro-computer generated vertical profiles of a) Temperature (°C) and b) Chlorophyll concentration ($mg.m^{-3}$) for UOR oblique profile at Station 2, 3 August 1986; c) and d) as Figure 2a) and b) but for Station 4, 5 August 1986.

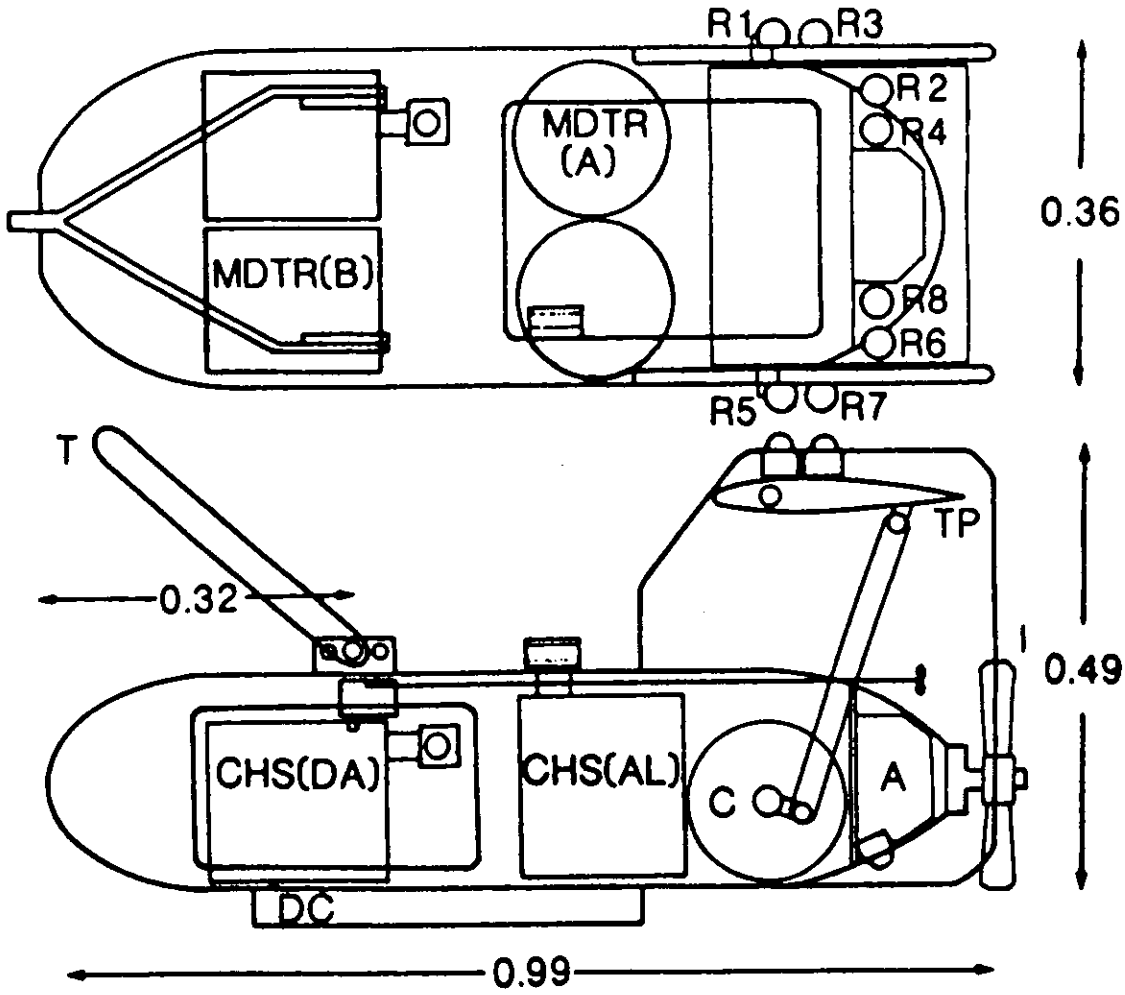
Figure 3. Computer contoured vertical sections of a) Temperature (contours 0.5°C) and b) Chlorophyll concentration (contours, 0.5, 1.5, 2.5, 3.5$mg.m^{-3}$) for Tow L88637 in the Norwegian Sea, 21 August 1986; vertical sections of blue light (450 nm) and d) green light (550 nm) for Tow L88637 (contour intervals 0.5 $\log_{10}$ $\mu W.cm^{-2}$)

Figure 4. Vertical sections of Temperature (°C and chlorophyll concentration ($mg.m^{-3}$) for Tow L88620 in the Barents Sea, 12-13 August.

Figure 5. Downwelling irradiance measurements and the computed values of attenuation coefficient 'k' at Station 11 in the Barents Sea, 12 August 1986 by:
a) the Visibility Laboratory Irradiance Meter (VLIM) at 493nm;
b) the Marine Environmental Radiometer (MER) at 499nm;
c) the UOR at 488nm; last 2 undulations before Station 11;
d) the UOR at 488nm; slow oblique profile (upcast) at Station 11.

Figure 6. Downwelling irradiance and computed values of 'k' at Station 12 on the Barents Sea, 13 August 1986 by:
a) the VLIM at 493nm;
b) the MER at 488n;
c) the UOR at 488nm; slow upcast at Station 12; and
d) UOR measurements of Temperature and Chlorophyll, co-incident with the upcast Figure 6c.

U.O.R. Mark 2 for Ocean Colour



U O R mark 2 : Sensor suite

Miniature Digital Tape Recorder: System A
Channel 0 ..... Elapsed time
1 ... Depth (pressure sensor)
2 ... Downwelling blue light π (450nm)
3 ... Upwelling blue light 2π (450nm)
4 ... Chlorophyll fluorescence
5 ... Temperature (thermistor probe)
6 ... Downwelling green light 2π (550nm)
7 ... Upwelling green light 2π (550nm)

Miniature Digital Tape Recorder: System B
Channel 0 ..... Elapsed time
1 ... Depth
2 ... Downwelling light-blue light 2π(488nm)
3 ... Upwelling light-blue light 2π (488nm)
4 ... Downwelling light-blue irradiance (488nm)
5 ... Upwelling light-blue irradiance (488nm)
6 ... Downwelling green irradiance (550nm)
7 ... Upwelling green irradiance (550nm)

Figure 1. UOR Mark 2 schematic and sensor suite.

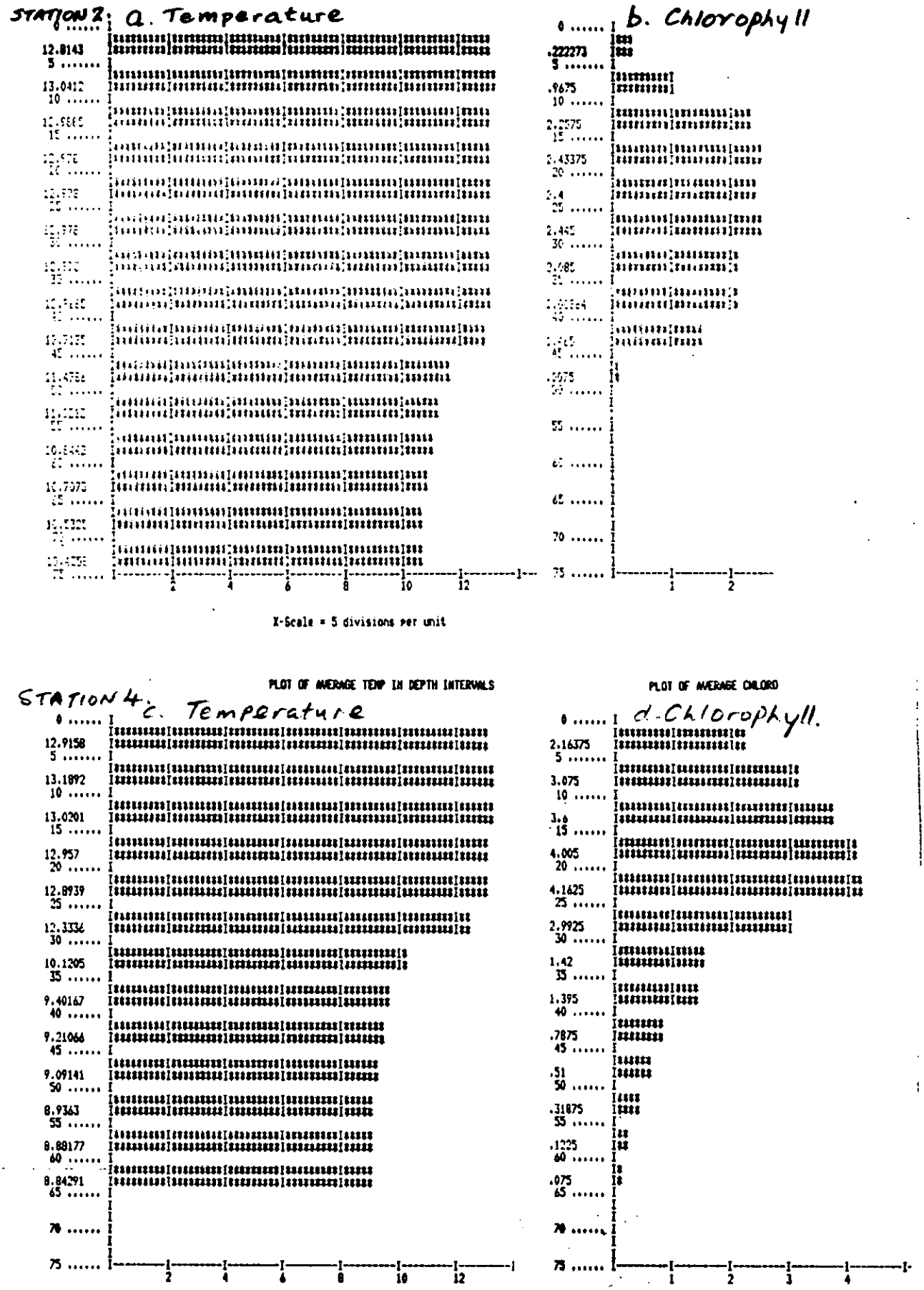


Figure 2. Micro-computer generated vertical profiles of a) Temperature (°C) and b) Chlorophyll concentration ($mg.m^{-3}$) for UOR oblique profile at Station 2, 3 August 1986; c) and d) as Figure 2a) and b) but for Station 4, 5 August 1986.

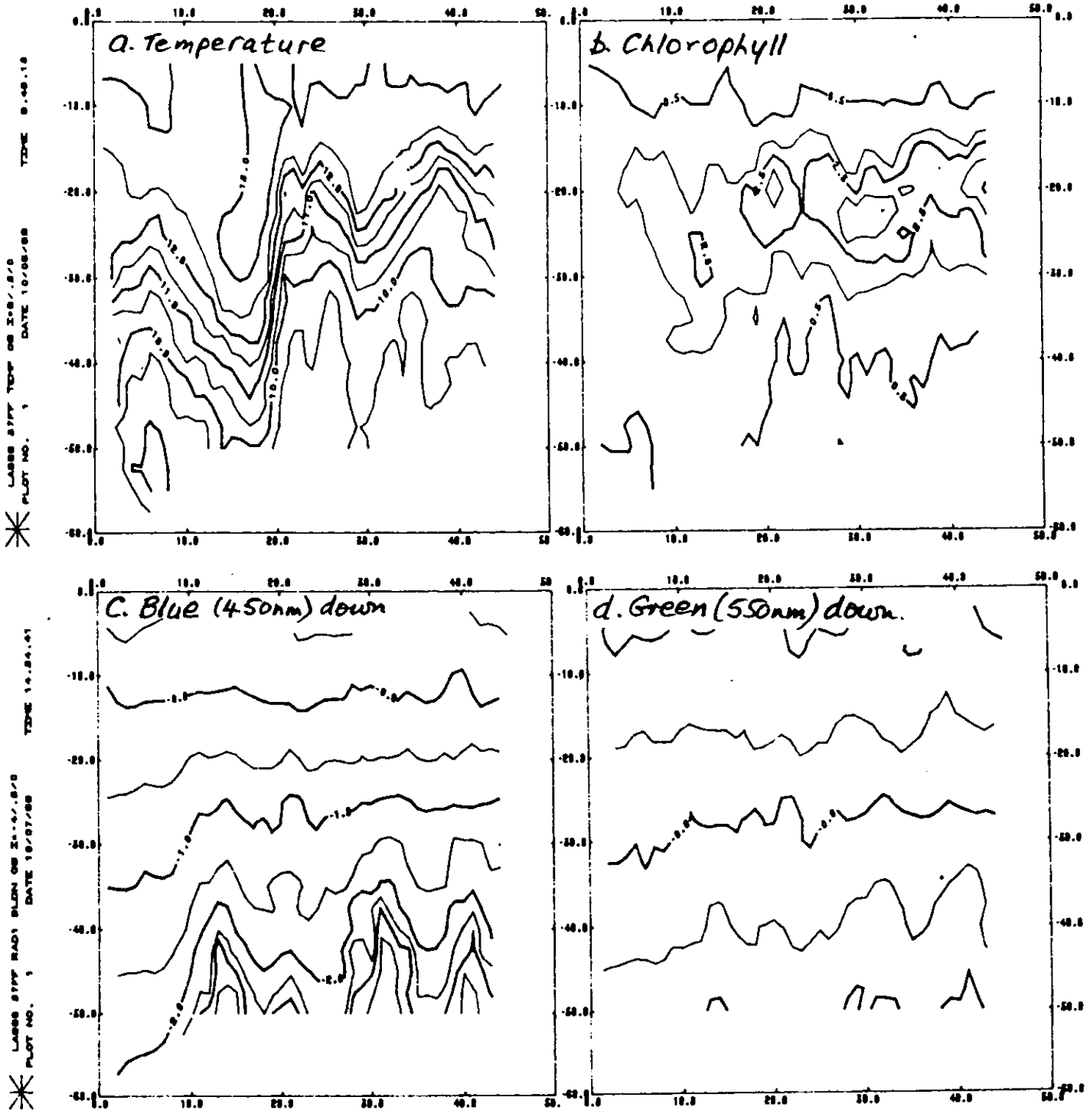


Figure 3. Computer contoured vertical sections of a) Temperature (contours 0.5°C) agd b) Chlorophyll concentration (contours, 0.5, 1.5, 2.5, 3.5mg.m^{-3}) for Tow L88637 in the Norwegian Sea, 21 August 1986; vertical sections of blue light (450 nm) and d) green light (550 nm) for Tow L88637 (contour intervals 0.5 $\log_{10}$ μW.cm^{-2}).

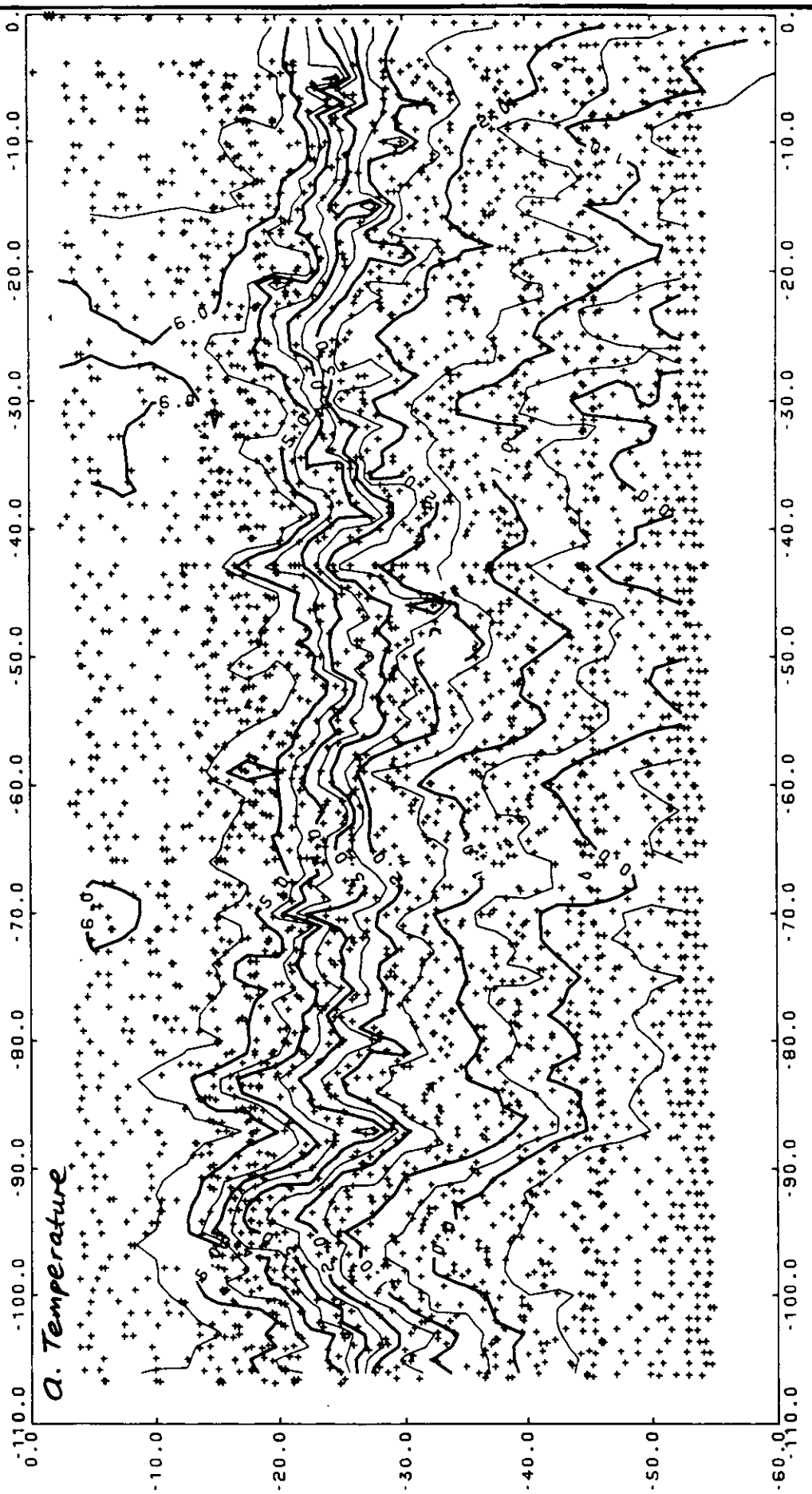


Figure 4. Vertical sections of Temperature (°C) and chlorophyll concentration (mg.m^{-3}) for Tow L88620 in the Barents Sea, 12 - 13 August.

Q. Temperature

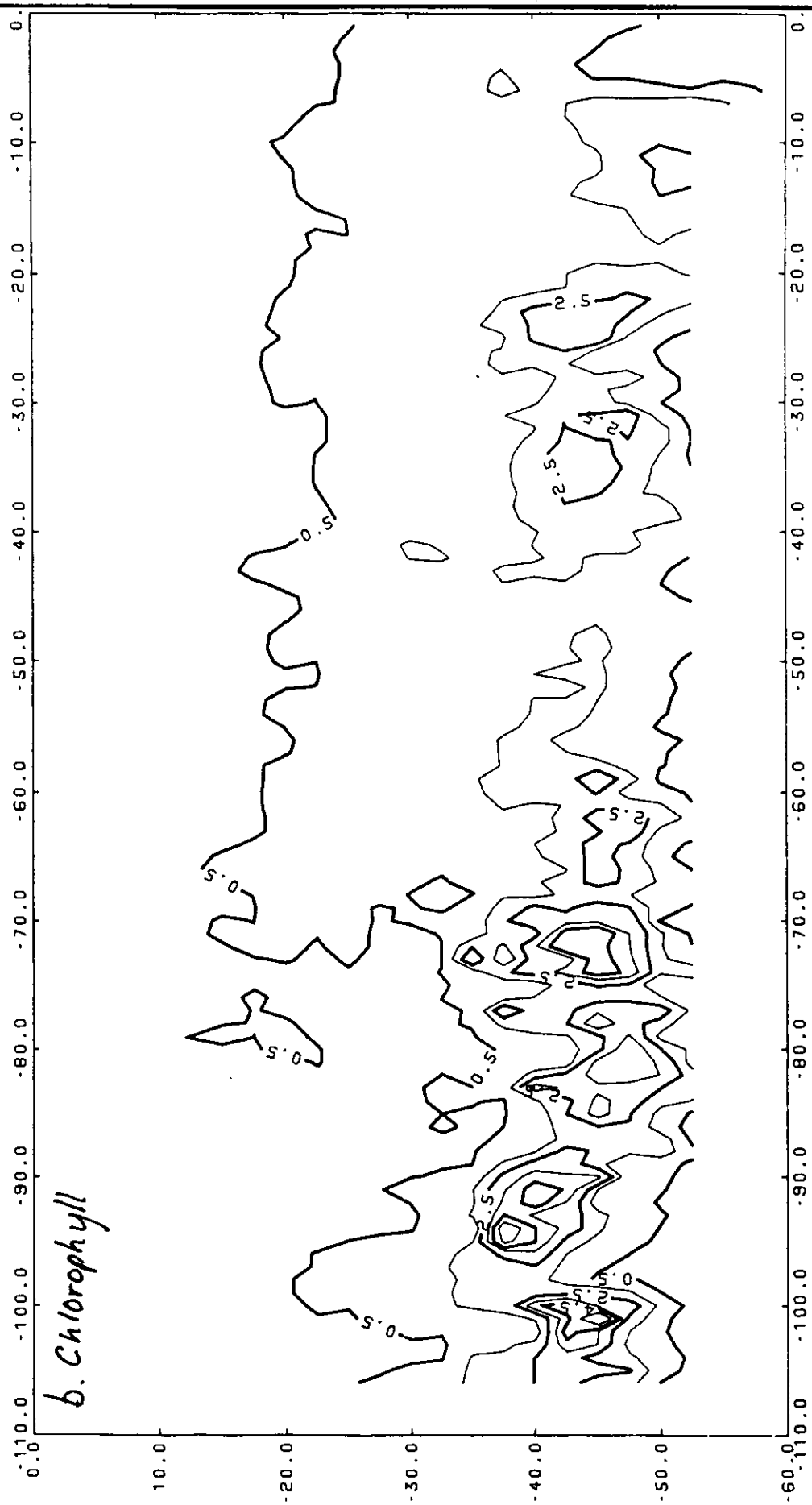


Figure 4. Vertical sections of Temperature (°C) and chlorophyll concentration ($mg.m^{-3}$) for Tow L88620 in the Barents Sea, 12 - 13 August.

b. Chlorophyll

Station 11 12Aug.1986

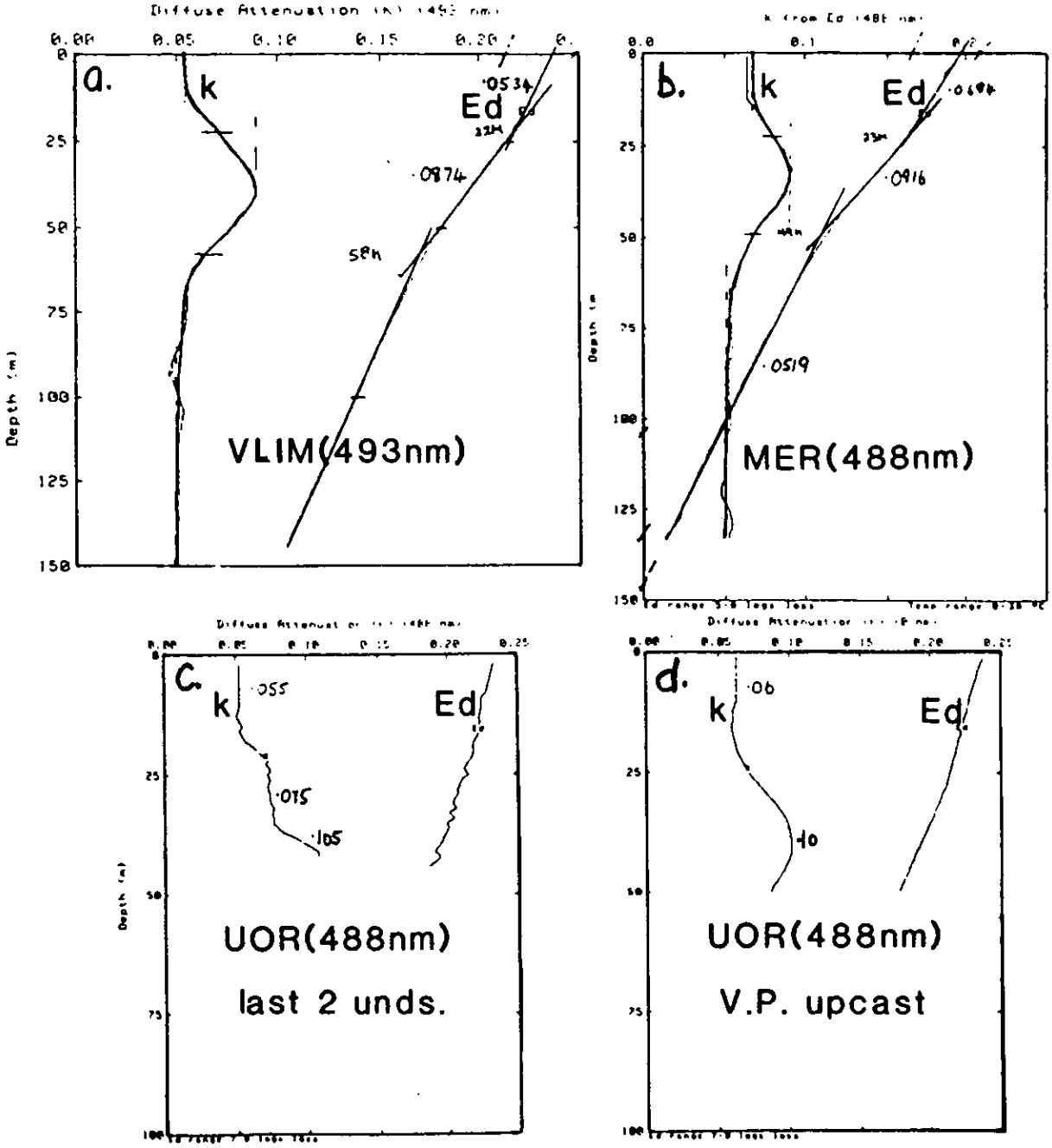


Figure 5. Downwelling irradiance measurements and the computed values of attenuation coefficient 'k' at Station 11 in the Barents Sea, 12 August 1986 by:
a) the Visibility Laboratory Irradiance Meter (VLIM) at 493nm;
b) the Marine Environmental Radiometer (MER) at 499nm;
c) the UOR at 488nm; last 2 undulations before Station 11;
d) the UOR at 488nm; slow oblique profile (upcast) at Station 11.

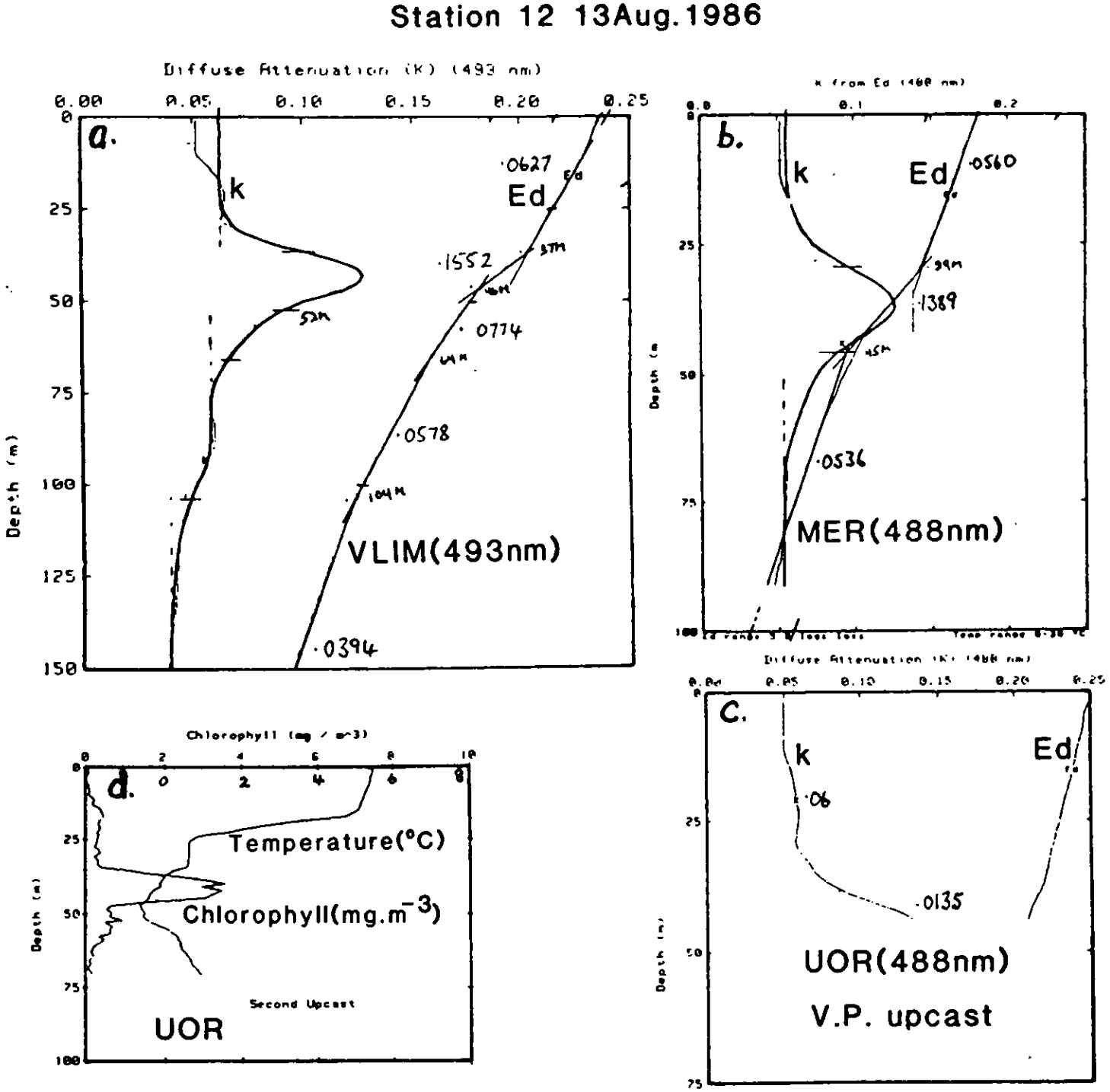
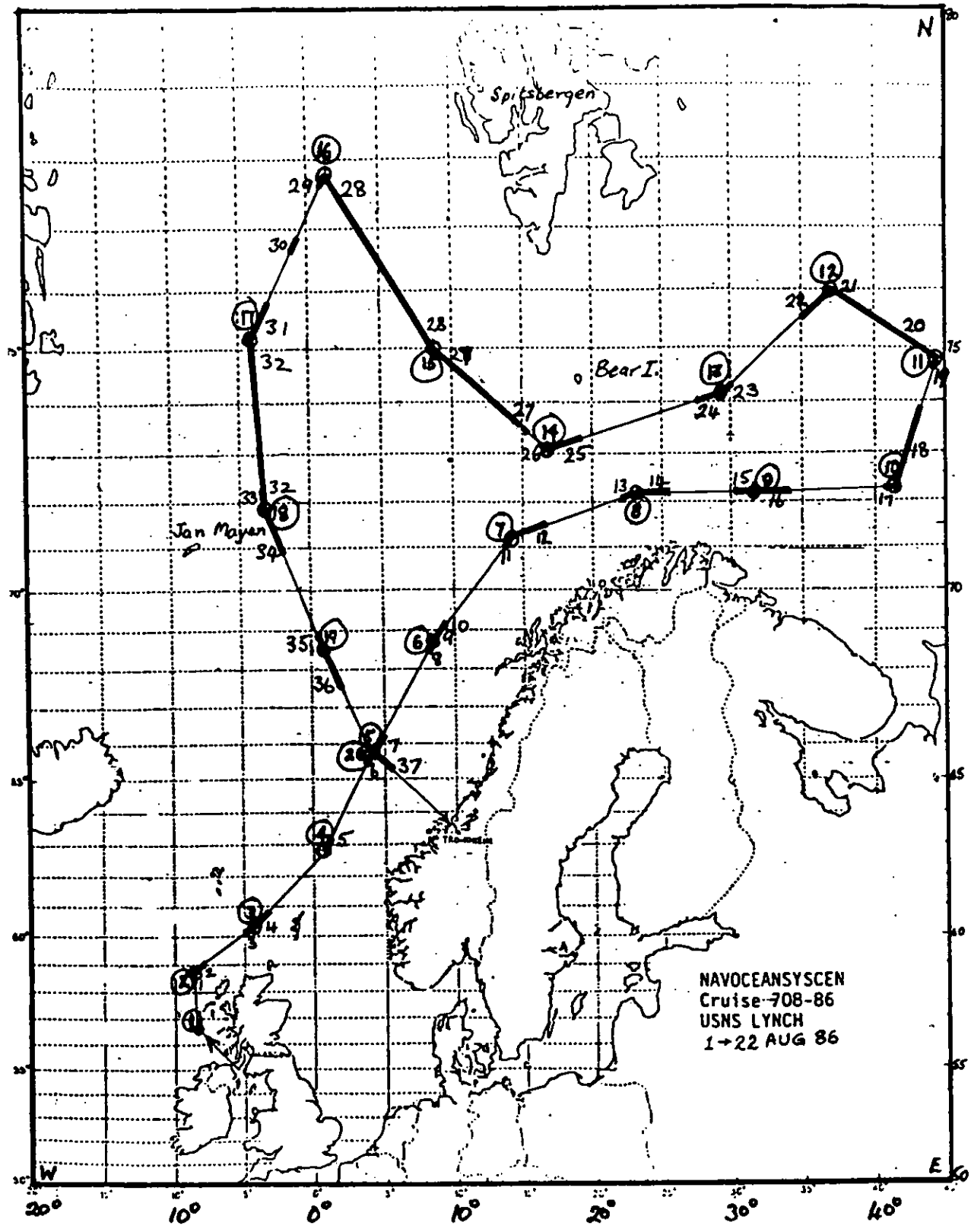


Figure 6. Downwelling irradiance and computed values of 'k' at Station 12 on the Barents Sea, 13 August 1986 by:
a) the VLIM at 493nm;
b) the MER at 488nm;
c) the UOR at 488nm; slow upcast at Station 12; and
d) UOR measurements of Temperature and Chlorophyll, co-incident with the upcast Figure 6c.

Appendix 1. Cruise track, USNS LYNCH, 1 August to 22 August 1986. Station positions are numbered 1 to 20 and circled. UOR tows are indicated by bold sections.



Appendix 2. Station list, USNS LYNCH, 1 August to 22 August 1986.
Sheet 1

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE FOR MARINE ENVIRONMENTAL RESEARCH

Sta. Time BST.	Sta. No.	Date	Latitude N	Longitude W/E	Dist. (nmi)	UOR Tows before	UOR Tows after
13.00 16.00	1	2 Aug.	58° 35'	8° 54 W	0.0	—	—
13.00 16.30	2	3Aug.	58° 43.542'	8° 45.300'W	134.1	LY88601	LY88602
12.30 15.45	3	4Aug.	60° 53.550'	5° 58.570'W	323.0	03	04
12.30 16.00	4	5Aug.	62° 48.576'	0° 54.824'E	511.7	—	05
12.30 16.00	5	6 Aug.	65° 42.47'	4° 10.247'E	707.4	06	07
12.30 15.30	6	7Aug.	68° 42.610'	8° 16.204'E	912.0	08	09
12.30 15.30	7	8Aug.	71° 23.35'	14° 09.67' E	1113.6	11	12
11.00 14.00	8	9 Aug.	72° 16.404'	23° 02.323'E	1289.0	13	14
09.45 14.30	9	10Aug.	72° 16.691'	31° 58.376' E	1451.2	15	16
09.30 12.30	10	11Aug.	72° 19.386'	41° 35.166'E	1627.3	17	18
09.30 12.30	11	12Aug.	74° 41.488'	44° 31.962'E	1778.7	19	20
09.30 15.00	12	13Aug.	76° 00.255'	37° 00.441'E	1918.6	21	22
09.30 13.00	13	14Aug.	74° 17.026'	29° 06.402'E	2079.7	23	24
11.00 14.15	14	15Aug.	73° 06.753'	16° 58.808'E	2296.6	25	26
11.00 15.00	15	16Aug.	75° 04.533'	8° 18.099'E	2484.2	27	28
09.15 12.30	16	17Aug.	77° 45.224'	1° 37.717' E	2671.9	28	29
11.00 14.00	17	18Aug.	75° 19.410'	3° 58.578'W	2856.8	31	32
11.00 13.45	18	19Aug.	71° 51.726'	3° 07.059'W	3066.1	33	34
11.15 13.00	19	20Aug.	68° 50.280'	1° 04.430'E	3236.3	35	36
08.00 10.00	20	21Aug.	65° 42.285'	4° 10.818'E	3470.5	—	37

Appendix 2. Station list, USNS LYNCH, 1 August to 22 August 1986.

Sheet 2

NATURAL ENVIRONMENT RESEARCH COUNCIL

INSTITUTE FOR MARINE ENVIRONMENTAL RESEARCH

Sta. Time BST	Sta. No.	Date	Latitude N	Longitude W/E	Dist. (nmi)	STATION CHLORO. SAMPLES	STATION TEMPERATURES 5m/20m/50m
13.00 / 16.00	1	2 Aug.	56° 35'	8° 54' W	0.0	—	12.51/11.37/11.3
13.00 / 16.30	2	3 Aug.	58° 43.542'	8° 45.300' W	134.1	—	12.51/12.4/11.3
12.30 / 15.45	3	4 Aug.	60° 43.550'	5° 58.570' W	333.0	—	11.7/11.3/9.8
12.30 / 16.00	4	5 Aug.	62° 48.376'	0° 54.824' E	511.7	—	11.46/9.05/8.7
12.30 / 16.00	5	6 Aug.	65° 42.47'	4° 10.247' E	707.4	✓ 12*	11.36/11.3/8.9
12.30 / 15.30	6	7 Aug.	68° 42.610'	8° 16.204' E	912.0	—	9.75/9.7/7.7
12.30 / 15.30	7	8 Aug.	71° 25.35'	14° 09.67' E	1113.6	—	
11.00 / 14.00	8	9 Aug.	72° 16.404'	23° 02.323' E	1289.0	✓ 12	8.6/8.53/6.1
09.45 / 14.30	9	10 Aug.	72° 16.691'	31° 58.576' E	1451.2	✓ 12	9.44/6.4/4.9
09.30 / 12.30	10	11 Aug.	72° 19.385'	41° 35.166' E	1627.3	✓ 12	8.35/8.28/3.2
09.30 / 12.30	11	12 Aug.	74° 41.488'	44° 31.962' E	1778.7	✓ 12	6.96/6.36/0.7
09.30 / 15.00	12	13 Aug.	76° 00.255'	37° 00.441' E	1918.6	✓ 12	5.5/1.47/-1.2
09.30 / 13.00	13	14 Aug.	74° 17.026'	29° 06.402' E	2079.7	✓ 12	8.25/7.74/4.8
11.00 / 14.15	14	15 Aug.	73° 06.755'	16° 58.808' E	2296.6	✓ 12	8.80/7.8/6.3
11.00 / 15.00	15	16 Aug.	75° 04.533'	8° 18.099' E	2484.2	✓ 12	6.97/6.51/4.3
09.15 / 12.30	16	17 Aug.	77° 45.224'	1° 57.717' E	2671.9	✓ 12	4.66/4.6/1.26
11.00 / 14.00	17	18 Aug.	75° 19.410'	3° 58.578' W	2856.8	✓ 12	4.48/3.83/-1.4
11.00 / 13.45	18	19 Aug.	71° 51.726'	3° 07.059' W	3066.1	—	5.8/3.0/0.2
11.15 / 13.00	19	20 Aug.	68° 50.480'	1° 04.450' E	3233.2	✓ 12	10.2/10.16/7.3
08.00 / 10.00	20	21 Aug.	65° 42.285'	4° 10.818' E	3470.5	✓ 12	12.01/11.48/8.4

* typical depths 0, , 10, 15, 20, 25, 30, 35, 40, 50, 75, 100, 150m

Appendix 3. (5 sheets). UOR Tow lists, USNS LYNCH, 1 August to 22 August 1986.
Sheet 1

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE FOR MARINE ENVIRONMENTAL RESEARCH

TOW No.	TIME BST	EVENT	LAT (N)	LONG (W)	TOW TIME	TOW LENGTH (miles)	No. & KINDS.	Miles/ Knd.	SPEED (knots)	COMMENTS	DATA
LY88601 3/8/86	11.40	L	58° 36.8	08° 50.1			V.P.		8.2	Not undulating	Good
	12.44	R	58° 42.0	08° 46.1	1h04	5.6	F.D. / V.P.	—	7.5	Speed too low? 200m	
LY88602 3/8/86	16.48	L	58° 44.7	08° 41.3			V.P.		9.5	Slow profile 200m wire	
	18.00		58° 50.3	08° 29.7			F.D.			Not undulating (wire is) reduce to 60m cable	
	18.30		58° 53.2	08° 22.0					9.1		
	18.52									Slow for V.P. 200m	
	19.18	R	58° 56.9	08° 13.0	2h30	19	~~V.P.~~	—		recover at 15m.min⁻¹	Good
LY88603 4/8/86	10.22	L	60° 32.	04° 26.4			V.P.		10.2	200m out not ll	
	10.55		60° 35.3	04° 18.3					10.1	reduce to 40m out	
	12.04						F.D.			200m out; reduce to 4kt	
	12.21	R	60° 43.1	03° 59.0	1h59	17.4	V.P.	—		recover at 15m.min⁻¹ Crank uncoupled	Good
LY88604 4/8/86	15.55	L	60° 42.6	04° 02.9			V.P.		3kt 9.4kt	100m V.P — 200m out	
	17.00		60° 48.2	03° 50.8					9.5kt	Undulates 3 min/pend	
	18.00		60° 54.3	03° 36.2					9.6kt		
	19.30		61° 02.8	03° 13.3			80			slow to 4kt for recovery	
	19.46	R	61° 3.6	03 10.9	3h52	33	V.P.				Good
LY88605 5/8/86	16.19	L	62° 48.6	01° 03.2E			V.P.		3kt	100m V.P	
	16.27								10.2	200m out	
	16.45									Undulates 3 min/pend	
	18.45								9.9	150m out	
	19.00	R	63° 07.1	01° 19.1E	2h41	20	47 V.P.		10.4	slow for V.P	Good
LY88606 6/8/86	10.20	L	65° 25.7	03° 50.6E					9.9kt	200m wire out	
	10.38								10	3 min undulations	
	12.00								9.9	bring in to 70	
	12.23	R	65° 42.5	4° 10.25E	2h03	18.6	43 V.P.			Pay out to 160m Slow V.P at 2kts	Good
LY88607 6/8/86	16.10	L	65° 45.4	4° 12.8E			V.P.		2.3	Launch at 2kt pay out 150m for V.P Increase to full	
	16.23										
	17.30		65° 55.8	4° 25.8E					10.3	4 turns / undulation	
	18.27								10.7	reduce to 120m out	
	19.10									Slow to 3kt for V.P.	
	19.25	R	66° 11.64	04° 45.16E	3h15	29.3	43 V.P.				Good

Appendix 3. (5 sheets). UOR Tow lists, USNS LYNCH, 1 August to 22 August 1986.
Sheet 2

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE FOR MARINE ENVIRONMENTAL RESEARCH

TOW NO.	TIME BST	EVENT	LAT (N)	LONG (E)	TOW TIME	TOW LENGTH (miles)	No. of VNDs.	Miles/ Und.	SPEED (knots)	COMMENTS	DATA
LY88608 7/8/86	11.03	L	68° 33.8	08° 0.2E						200 m 4kt → full FIT WINGS + LARGE TAIL PLANE	
	11.20								11.1	undulations 4½ mins	
	11.35						7		11.4	Stopped undulating	
	11.58						+ F.D.			Slow to 4kt for V.P	
	12.10	R	68° 62.4	08° 16.0	1h 07	10	V.P.			Gearbox/motor pin sheared	Good
LY88609 7/8/86	15.49	L	68° 43.95	08° 26.05E			V.P.			4kt → full speed 200 m	
	16.00								10.4	undulating 1¼ mins (wrong setting)	
	16.14									Slow for recovery	
	16.25	R	68° 48.3	08° 35.7	0h 46	6	21				Good
LY88610 7/8/86	16.47	L	68° 49.3	08° 37.6E						4kt → full 200 m out	
	17.00		68° 51.0	08° 40.8E					11.1	undulating 6 mins/und. + 200m to 220m	
	18.58									Slow to 4 kt for V.P	
	19.11	R	69° 09.1	08° 10.0E	2h 24	23	22 V.P.				Good
LY88611 8/8/86	10.19	L	71° 13.18	13° 28.0E					9.3kt	Full Sped. 200 m	
	11.09	A/c	71° 20.4'	13° 43.6					9.9	A/c 034 & 072	
	11.54									Slow to 4kt for V.P	
	12.10	R	71° 23.3'	14° 08.2E	1h 51	17	14 V.P.				Good
LY88612 8/8/86	15.32	L	71° 23.02	14° 11.67E			V.P.		2kt	150 m at 15 m. min⁻¹ V.P.	
	15.53								9.8kt	227 out	
	17.00								9.5kt	undulating 7 mins	
	18.00								9.2		
	19.33									Slow to 4 kt for VP	
	19.50	R	71° 36.2	16° 10.8E	4h 18	40	36 V.P.				Good
LY88613 9/8/86	08.33	L	72° 13.7	22° 42.8E						2 at 6kt → full 200 m out	
	08.45								9.7	undulating 6 mins	
	10.00	A/C	72° 18.0	23° 26.3E					9.5	A/c 180 back to Stripes.	
	10.30									Reduce to 4kt for V.P.	
	10.47	R	72° 16.4	25° 06.8E	2h 14	20	21 V.P.				Good
LY88614 9/8/86	14.05	L	72° 15.4	23° 01.4E			V.P.			2 at 4kt for V.P.	
	14.20								10.2	→ full / shadow 200 m out	
	16.00										
	18.08									Commence recovery at 6kt for V.P.	Good
	18.21	R	72° 16.5	25° 16.0E	4h 16	41	41 V.P.				

Appendix 3. (5 sheets). UOR Tow lists, USNS LYNCH, 1 August to 22 August 1986.
Sheet 3

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE FOR MARINE ENVIRONMENTAL RESEARCH

TOW No.	TIME BST	EVENT	LAT (N)	LONG (E)	TOW TIME	TOW LENGTH (miles)	No. of UNDs.	Miles/ Und.	SPEED (knots)	COMMENTS	DATA
LY88615	0732	L	72° 16·9	31° 37·0E					10·2	2nd at 7kt → full layout 220m	
10/8/86	08·52	A/C	72° 16·4	33° 22·8E					10·4	Recip Co. 091→222	
	09·35						22			Slow to 4 kt for V.P.	
	09·46	R	72° 15·9	32° 01·8E	2h14	20·3	VP				Good
LY88616	14·35	L	72° 20·3	31° 51·5E			VP			VP 150m out at 2kt	
10/8/86	14·51								9·8	Full speed → 220m	
	16·00		72° 21·1	32° 30·6E					9·9	Co 090 Und. OK	
	18·30								10·3	Slow to 3 kt for recovery V.P.	
	18·51	R	72° 19·7	33° 58·9E	4h16	38·6	37 V.P.				Good
LY88617	07·25	L	72° 18·6	40° 56·0E					10	Full speed pay out 220m	
11/8/86	08·55	A/C	72° 19·5	41° 42·6E		16·4			10·6	Recip Co to 270	
	09·07						17				Take A ✓
	09·21	R	72° 19·5	41° 35·7E	1h56		VP			3 kt for V.P at recovery	Take B ½
LY88618	12·45	L	72° 22·2	41° 32·2E			VP		2	2 watch at 2kt for V.P	
11/8/86	13·00		72° 23·1	41° 33·1E					10·4	225m cable out	
	15·00								10·9	Undulating OK	
	17·00								11		
	19·00								11·1		Take A ✓
	21·43								11·0	Slow to 4kt for recovery	Take B ✗
	21·51	R	73° 51·3'	43° 18·95E	9h06	94·3	106				
LY88619	07·27	L	74° 29·1'	44° 15·7E					11·2k	2nd at 4kt → full 230m out	
12/8/86	08·57	A/C	74° 48·8	44° 30·8E						Recip Co to 199	
	09·07						18			Commence recovery V.P at 2 kt	Good Take A ✓
	09·21	R	74° 41·45	44° 28·8E	1h54	17·6	VP				Take B ✓
LY88620	12·37	L	74° 41·65	44° 31·32E			VP		2	2nd at 2kt for V.P.	
12/8/86	12·53		74° 42·34	44° 28·0E					11·0	235m out	
	15·00								11·0		
	18·00								11·1		
	21·00								11·2		
13/8/86	00·00								11·2		Good
	02·24						150			Slow to 3kt for V.P.	Take A ✓
	02·38	R	76° 00·02	37° 01·12	14h01	138	VP				Take B ✓
LY88621	08·40	L	75° 57·08	37° 04·8E			VP		4kt	150 m at 15m·min⁻¹	Good
13/8/86	09·02		75° 59·89	37° 00·6					4 kt	Surface	Take A ✓
	09·13	A/C							4kt	Pay out again	Take B ✓
	09·28	R	76° 00·26	37° 00·4	0h48	3	VP		4kt	At to recip Co. 310	

Appendix 3. (5 sheets). UOR Tow lists, USNS LYNCH, 1 August to 22 August 1986.
Sheet 4

NATURAL ENVIRONMENT RESEARCH COUNCIL
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Tow No.	Time BST	Event	Lat (N)	Long (E)	Tow Time	Tow Length (miles)	No. of Wnds.	Miles/ Knot	Speed (knots)	Comments	Data
LY88622	15.16	L	76°01.6	37°11.15E			V.P.		3.5	Pay out 150 at 15 m min⁻¹	
13/8/86	15.30								9.5	Full speed strain on 200 out	
	17.00								11.0		
	19.39						47		11.1	Slow to 4 for V.P	
	19.53	R	75°32.2	34°59.8E	4h37	43.6	V.P.				good
LY88623	07.27	L	74°21.17	30° 4.7					10.1	Full speed	
14/8/86	07.35								10.4	Strain on 210m out	
	09.03						15		10.6	Slow to 4 for V.P.	
	09.20	R	74°17.2	29° 7.0E	1h53	16	V.P.				good
LY88624	13.45	L	74° 16.78	29°12.66			V.P		3.5	150m at 15 m min⁻¹ for VP	
14/8/86	13.58								7.5		
	16.00								11.0	Strain on full speed	
	17.35								11.3	Undulations slow from 5 fathoms → 2 fathoms	
	17.45	R	74° 4.57	26° 49.9	4h00	40.7	37		11.4	tow aborted	
											good
LY88625	07.18	L	73° 18.3'	18° 52.7E					11.5	2m water at full speed	
15/8/86	07.26								11.4	→ 200 m	
	09.52		73° 09.2	17° 24.4					11.2		
	10.34						29		11.1	Slow to 4 kt for VP	
	10.49	R	73° 06.6	16° 59.4	3h31	34.7	VP				good
LY88626	14.29	L	73° 03.2	16°46.3E			VP		4	2m water pay out 180 at 4kt	
15/8/86	14.57								4	On surface again	
	15.00						VP		4	Pay out 100 at 15 m min⁻¹	
	15.14								4	on surface	
							F.D		6	Increase to 6 kt	
	15.50	R	73° 06.3	16° 17.2E	1h21	5.1				Fixed depth 2m	good
LY88627	19.23	L	73° 16.5	15° 39.0					4kt	2m at 4kt → full	
16/8/86	19.31								11.	Pay out 100 Strain on 200 out	
16/8/86	00.00								11		
	04.00								10.8		
	08.00						125		11.5	Slow to 4 kt for V.P	
	10.52	R	75° 5.34	08° 19.66	15h29	162	VP				good
LY88628	15.00	L	75° 04.9	08° 11.0E			VP		4	2m at 4k for V.P.	
16/8/86	15.11								11	full speed → 195m	
	18.00										
	22.00										
17/8/86	00.00										
	04.00										
	08.34						128		4kt		Tape A √
	08.50	R	77° 44.6	01° 42.8'E	17h50	184	VP				Tape B ... tomorrow

Appendix 3. (5 sheets). UOR Tow lists, USNS LYNCH, 1 August to 22 August 1986.
Sheet 5.

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE FOR MARINE ENVIRONMENTAL RESEARCH

TOW No.	TIME GMT	EVENT	LAT (N)	LONG	TOW TIME	TOW LENGTH (miles)	No. & WINDS.	Miles/ Knd.	SPEED (knots)	COMMENTS	DATA
LY88629	12.44	L	77°43·85	01°38·0E			V.P.		3·5	V.P 150m at 15.m⁻¹	
17/8/86	13·08								3·5	+ recover to surface	
	13·10						F.D.		6	4m out	
	13·21								11	Full speed; 200/220/150m out	
	14·27	R	77° 32·6'	01° 04·0E	1h 43	13·4	16				good
LY88630	20·08	L	76° 46·6	01° 10·2W					11	launch at full speed	
17/8/86	20·15								11	200 out; Strain on	
	20·35								11	fog + ice; about to commence recovery	
	20·45	R	76° 41·5	01° 31·3W	0h 38	7·0	7				Good
LY88631	08·13	L	75°44·5	03° 54·8W					11·3	Launch at full speed	
18/8/86	08·24								11	200 out; Strain on	
	10·00								11·2		
	10·37						28		11	Slow to 4kt for V.P.	
	10·59	R	75° 19·2	03° 58·6W	2h 46	25·2	V.P.		4		Good
LY88632	14·09	L	75° 19·8	03° 56·17W			V.P.		4	pay out 210m at 15m.min⁻¹	
18/8/86	14·24								10·3	210 out → full	
	16·00								11·1		
	18·00								11·5		
	19·33								11·3		Tape A X
	19·42	R	74° 29·3	08° 44·2W	5h 33	55	62		4	Slow to 4kt for recovery	Tape B ✓
LY88633	08·23	L	72° 15'N	03° 12·14W					6	Launch at 6 kt → full	
19/8/86	08·30								11·6	210m out at full	
	10·30						27		11·3	Slow to 3kt for V.P	Tape A ✓
	10·49	R	71° 51·12	03° 06·6W	2h 26	22	V.P.		3		Tape B ✓
LY88634	13·54	L	71° 51·53	03° 08·4W			V.P.		4	V.P. at 4kt	
19/8/86	14·10								11·2	Pay out to 215 → full	
	17·00		71° 22·95	02° 34·2W					11·2		Good
	19·45								11·4	Reduce to 8/4 for recovery	Tape A ✓
	19·58	R	70° 55·45	02° 00·0W	6h 04	62	65				Tape B ✓
LY88635	08·19	L	68° 54·2	00° 38·3E					10·8	full speed 10·8 kt	
20/8/86	08·27								10·8	215m out	Good
	10·45						27		10·7	Slow to 4kt for recovery	Tape A ✓
	11·03	R	68° 03·38	01° 04·04E	2h 44	25	V.P.		4		Tape B ✓
LY88636	13·07	L	68° 30·23	01° 02·44E			V.P.		4	V.P at 4kt	
20/8/86	13·20								10·8	Strain on; 205 out; full speed	Good
	16·00								10·7		
	18·00								11·1		Tape A ✓
	18·10	R	67° 43·9	01° 51·9E	5h 03	50	48			commence recovery	Tape B ✓
LY88637	10·12	L	66° 41·68	04° 07·82E			V.P		4	V.P at 4kt	
21/8/86	10·25								9	205 out strain on → full	
	12·00								10·5		
	14·33								10·8		
	14·42	R	65° 18·92	05° 28·3E	4h 30	45	36				Good

Appendix 4. (4 sheets). Sensor and data logger performance analysis, USNS LYNCH, 1 August to 22 August 1986.

Sheet 1

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE FOR MARINE ENVIRONMENTAL RESEARCH

SYSTEM A

TOW No.	ch0	ch1	ch2	ch3	ch4	ch5	ch6	ch7
	TIME (2 watch)	Depth	BLDN12P 450/10	BLUP2P 450/10	CHLORO min-max	Temp max-min	GNDN12P 550/10	GNUP2P 550/10
LY88601 Tape A ✓ Tape B ✓	✓ 0-64 (65)	✓ 128	✓ to 30m	✓ to 20m	✓ 0-2·5	✓ 13·06-9·99	✓ to 49m	✓ to 30m
LY88602 Tape A ✓ Tape B ✓	✓ (143)	✓ 0-113	✓ to 22	✓ to 11	✓ 0-3·2	✓ 13·5-10·1	✓? Okat start	? Okat start
LY88603 Tape A ✓ Tape B ✓	✓ 0-117 (118)	✓ 0-90	✓ to 49·5	✓ 23·3	✓ 0-4	12·8-9·0	✓?	X
LIGHTTEST PRETOW4								
LY88604 Tape A ✓ Tape B ✓	✓ 0-231 (232)	✓ 0-73 U(17-39)	✓ to 37m	X	✓ 0-10	✓ 12·5-9·5	✓ to 56m	✓ to 23m
LY88605 Tape A ✓ Tape B ✓	✓ 0-160	8-90 U(14-36) (10-31)	✓ to 58/50	X	✓ 0-6	✓ 13·2-8·9	✓ to 58/53	✓ to 18
LY88606 Tape A ✓ Tape B ✓	0-123 (124)	1·2-93 U(17-39) (4-24)	✓ to 55	X	✓ 0-5	✓ 14·4-8·8 ?	✓ to 81m	X
LY88607 Tape A ✓ Tape B ✓	0-195 (196)	✓ 1-100 U(11-35)	✓ to 27	✓?	✓ 0-5	✓ 12·8·5	✓ to 98m	?
LY88608 Tape A ✓ Tape B ✓	0-67 (68)	✓ 1-70 U(1-51)	✓ to >51	✓ ?X	✓ 0-6	✓ 10·2-7·4	✓ >51	X
LY88609 Tape A ✓ B ✓	0-32 (33)	✓ U(1-42·5)	✓ to >42	✓ to 22	✓ 0-3	✓ 10·4-8·5	✓ >42	X

SYSTEM B

	ch0	ch1	ch2	ch3	ch4	ch5	ch6	ch7
	TIME	DEPTH	LBDN12P 488/10	LBUP2P 488/10	LBONCC 488/10	LBONCC 468/10	GNDNCC 550/10	GNUPCC 550/10
LY88601 Tape A ✓ Tape B ✓	✓ 437-562 (66)	✓ 1·5-12·9	✓ to 37m	✓ to 26m	✓ to 34m	✓ to 18m	✓ to 44m	✓ to 26m (16)
LY88602 Tape A ✓ Tape B ✓	✓ 437-580 (144)	✓ 0-114	✓ to 25m	✓ to 12m	✓ 23m	X	✓ 33m	✓ 12m (14)
LY88603 Tape A ✓ Tape B ✓	437-555	✓ 1·5-9·1	to 64m	✓ to 41m	✓ to 53m	✓ to 20m	X	X (14)
LIGHTTEST PRETOW4								
LY88604 Tape A ✓ Tape B ✓	✓ 437-668 (232)	✓ 2-13·5 U(16-39)	✓ to 63m	X	✓ to 39m	✓ 8·5m	X	X (12)
LY88605 Tape A ✓ Tape B ✓	437-598	1·5-9·0 U(19-39) (15-35) (11-31)	✓ to 75	X	✓ to 30m	X	X	X (11)
LY88606 Tape A ✓ Tape B ✓	437-560 (124)	1·5-9·4 U(17-39) U(4-24)	✓ to 74	✓ to 34	✓ to 65	X	X	X (11)
LY88607 Tape A ✓ Tape B ✓	437-623	✓ 1·5-10·0 U( )	✓ to 60m	✓ to 24	✓ to 55	✓ to 16	X	X (12)
LY88608 Tape A ✓ Tape B ✓	437-504 (68)	✓ 2-7·1 U(0-5)	✓ >71m	✓ to 30m	✓ to >71	✓ to 19m	X	X (12)
LY88609 Tape A ✓ B ✓	437-469 (33)	✓ U(1·5-4·3)	✓ to 43	X	✓ to >43	✓ to 11	✓ to 43	✓ to ~10m

Appendix 4. (4 sheets). Sensor and data logger performance analysis, USNS LYNCH, 1 August to 22 August 1986.

Sheet 2

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE FOR MARINE ENVIRONMENTAL RESEARCH

SYSTEM A

Tow No.	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7
	TIME	Depth	BLDN2P 450/10	BLUP2P 450/10	CHLORO	Temp	GNDN2P 550/10	GNUP2P 550/10
LY88610 Tape A✓ Tape B✓	0–144 (145)	1–66 U(2-51)	✓ to 766	X	0–5 ✓	0.8–7.8 ✓	X	X
LY88611 Tape A✓ Tape B✓	0–112 (113) ✓	✓ U(2-51)	✓ to >51	X	0–5 ✓	4.0 7.6	✓ >51	X
LY88612 Tape A✓ Tape B✓	0–256 (257)	1–93 U(2.5-52)	✓ to 45	✓ to 4	✓ 0–5	10.4–6.2 ✓	to 70m ✓	to 28m ✓
LY88613 Tape A✓ Tape B✓	0–134 (135) ✓	1.38–✓ U(3-53) 1.36–41	✓ to >53	✓ to 25	✓ 0–3.1	9.4–5.4 ✓	✓ to >53	✓ to 36m
LY88614 Tape A✓ Tape B✓	✓ 0–256 (257)	46–90 U(1.5-9.5) 0–69	✓ to 61m	✓ to 8m	✓ 0–4	9.4–5.0 ✓ 8.9–4.4	✓ 74m	✓ to 30m
LY88615 Tape A✓ Tape B✓	0–133 (134)	✓ U(3-52)	✓ to >52	✓ to 16	✓ 0–3.2	10.4–6.9 ✓ 14–5 ?	✓ to >52	✓ to 25m
LY88616 Tape A✓ Tape B✓	0–255 (256)	37–97m U(6-55)	✓ to 56m at start	✓ to 14m X	✓ 0–6	✓ 10.2–3.7	✓ to 20m	✓ to 24
LY88617 Tape A✓ Tape B ½	0–115 (116)	1–86 U(3-53)	✓ to 54m	✓ to 26m	✓ 0–4 start 0–2 last	8.6–1.36 ✓	✓ to 73m	✓ to 33m
LY88618 Tape A✓ Tape B X	0–546	1–106 U(2-52.5)	✓ to 48m	✓ to 13m	✓ 0–5 deep	✓ 9–1 VP 8.8–2.5 8.1–3.1	✓ to 66m	✓ to 24m

SYSTEM B

Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7
TIME	DEPTH	LBDN2P 488/10	LBUP2P 488/10	LBDNCC 488/10	LBDNUP 488/10	GNDNCC 550/10	GNUPCC 550/10
437–581	1.5–68 U(1.5-52)	✓ to 47m at start	✓ to 18m	✓ to 39m	✓ to 11m	✓ to >52 at end	✓ to 12m (13)
726–838 ✓	1.5–52 ✓ U(3-51)	✓ to >52	✓ to 24m	✓ to >52	✓ to 10m	✓ to >52	✓ to 16m (14)
437–694	1.3–94 U(2-53)	✓ to 64	✓ to 25	✓ to 58	✓ to 14	✓ to 66	✓ to 18 (16)
✓ 437–572 (135)	✓ 1.53–U(3-53)	✓ to >53	✓ to 38	✓ to >53	✓ to 27	✓ >53	✓ to 29 (16)
437– 694 (258)	✓ 53–91 U(2-52) 103–69	✓ to 78m	✓ to 32m	✓ to 72m	✓ to 23m	✓ to 73m	✓ to 23m (16)
✓ 437–570	✓ 1.7– U(2-52)	✓ to >52	✓ to 24m X end	✓ to >52	✓ to 19m	✓ to >52	✓ to 22m (16)
437(0) → 255	✓ 4–98m	✓ to 45 X bad end	✓ to 24	✓ to 68	✓ to 14	✓ to 65	✓ to 14 (14½)
437(0) → 115	½ U(2-52)	½ to >52	½ to 21m	½ to >53	½ to 23m	½ to >52	½ to 23m (12½)
✓ 437(0)	X	X	X	X	X	X	✓ (9)

Appendix 4. (4 sheets). Sensor and data logger performance analysis, USNS LYNCH, 1 August to 22 August 1986.
Sheet 3
NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE FOR MARINE ENVIRONMENTAL RESEARCH

SYSTEM A

TOW No.	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7
	TIME	DEPTH	BLDN2P 450/10	BLUP2P 450/10	CNLCRO	Temp	GNDN12P 550/10	GNUP2P 550/10
LY88619 TapeAV TapeBV	0-113 (114)	1.4-61 U(3-53)	to 52m	to 23m	0-8	7.2-7.1	>61m	to 29m
LY88620 TapeAV TapeBV	0-841 (842)	1-98 U(3-54) 2-71	to 58m	to 17m	0-15	6.1-6	to 53	to 18m
LY88621 TapeAV TapeBV	0-47 (48)	1-77 2-71	to 51 to 51	to 21	0-4.5	6.1≥.6	to 64	to 26
LY88622 TapeAV TapeBV	0-225 (226)	1.5-87 U(4-52) 1.5-60	to 48m	to 12m	0-6.6	6.9-.6	to 61m	19.1
LY88623 TapeAV TapeBV	0-113 (114)	1-78 U(4-53)	to 60	to 21	0-6	8.8-.39	to 79	to 29
LY88624 TapeAV TapeBV	0-237 (238)	1-79 U(4-52)	to 67	to 19	0-9	9-3.9 ?	to 779	X
LY88625 TapeAV TapeBV	0-210? (211)	1-58 U(4-50)	to >58	to 31	0-2.6 ?	9.5-5.7	to >58	X
LY88626 TapeAV TapeBV	0-80 (81)	1-88 2-59 FD ~3m	to 84	not fitted	0-25	6.7? →5.7	not fitted	not fitted
LY88627 TapeAV TapeBV	0-928 (929)	1-57 U(3-51)	to 47	to 3m? X	0-6.5	10.5-4	to 57m	to 28m
LY88628 TapeAV + 0-45 TapeBX (1070)	0-1023	6-63 U(Drift 6m=6m	to 50m	X		7.3-0	to >63	to 26m

SYSTEM B

Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7
TIME	DEPTH	LBDN2P 488/10	LBUP2P 488/10	LBDNCC 488/10	LBDNUP 488/10	GNDNCC 550/10	GNUPCC 550/10
443(0) →114 (115)	1.5-69 U(4-54)	to >61?	to 30	to >61	to 78	to >61	to 24m (16)
443(0) →	1.3-96 U(3-54)	X	to 28	to 62m	to 20m	to 68m	to 80 (15)
443(0) → 48	1.3-78 1-70	X	to 28 to 28	to 52m to 54m	to 16m to 16m	to 59m to 60m	4 to 20m (15)
0-226 (227)	1.7-88 U(4-52)	X	to 21m	to 50m	28m	to 55m	to 12m (15)
443(0) →113 (114)	1-79 U(4-52)	X	to 29m	to 66m	to 21m	to 71m	to 25m (15)
443(0) →237 (238)	1-79 U(4-52)	to >79	to 30m	to 78m	to 20m	to 74m	to 22 (15)
443(0) →	1.5-58 U(5-51)	to >58	to 39m	to >58	to 27m	to >58m	to 30m (15)
443(0) →80 (81)	1.5-88.5 2-60m FD 4m	to >88	to 31	to 88	to 24	to 77m	to 15m (13)
955(512) →586 -437-0 0-417	1-57 U(4-52)	to 57	to 23m	to 54m	to 15m	to 53m	to 119m (15)
0-7 only	6-58m	to >58	to 31m	to >54	to 15m	to >58	to 27m (8 UA)

SYSTEM A

Tow No.	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7
	TIME	Depth	BLDN2P 450/10	BLUP2P 450/10	CHLORO	Temp	GNDN2P 550/10	GNUP2P 550/10
LY88629 Tape A✓ Tape B✓	0–103 (104)	1–97 U(3-50)	to 58m	X	0–9	6–0	to 76m	X
LY88630 Tape A✓ Tape B✓	0–38 (39)	✓ U(3-51)	✓ to 52m	X	✓ 0-4·3	✓ 5–1·5	✓ to >51m	X
LY88631 Tape A(-5?) Tape B✓	0?(5)–165	1·5–56 U(4-52)	✓ to >52	✓ to 45	✓ 0-5·5	5→–1·5	✓ to >52	✓ to 35m
LY88632 Tape A X Tape B✓	X	X	X	X	X	X	X	X
LY88633 Tape A FAST Tape B✓								
LY88634 Tape A✓ Tape B✓	X No clock	0–85 U(4-52) difficult	✓ to 60 replay	✓ to 40 ?	✓ 0–6	✓ 8·7±·3 ok.	✓ to 60m	✓ to 18m
LY88635 Tape A✓ Tape B✓	✓ 0–163 (164)	1–72m U(4-52)	✓ to 41m	✓ to 41m	✓ 0–35	✓ 10·8–7·2	✓ to >72m	✓ to 38m
LY88636 Tape A✓ Tape B✓	0–302 (303)	1–58m U(5-515)	✓ to >58m	✓ to >58 ?	✓ 0–3	✓ 11·2–7·7	✓ to >58	✓ to 50m
LY88637 Tape A✓ Tape B✓	✓	✓	✓	✓	✓	✓	✓	✓

SYSTEM B

Tow No.	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7
	TIME	DEPTH	LBDN2P 488/10	LBUP2P 488/10	LBONCC 488/10	LBDNUP 488/10	GNDNCC 550/10	GNUPCC 550/10
	0–103 (104)	1–98 U(4-51)	to 67m	to 37m	to 66m	to 22m	to 66m	to 24m (14)
	0–39 (40)	U(3-51)	to >52	to 18m	to >52m	to 19m	to >52	to 19m (14)
	0–165 (166)	2–58 U(3-52)	to >56	to 41m	to >56m	to 28m	to >56m	to 31m (16)
	0–334 (335)	1·5–80 U(4-53)	to 73m	to 38m	to 72m	to 33m	to 72m	to 30m (8)
	443(0) →166 (148)	1–74m U(3·5-515)	to 56m	to 26m	to 53m	to 14m	to 61m	to 23m
	443(0) →363 (364)	0–85 U(4-52)	to 50m	to 24m	to 46m	to 14m	to 55m	to 20m (16)
	443(0) →163 (164)	1·5–72m U(4-53)	to >72m	to 40m	to >72m	to 29m	to >72m	to 33m (16)
	443(0) →303 (304)	1–58 U(4-52)	to 58m	to 44m	to 58	to 33m	to >58	to 33m (16)
	✓	✓	✓	✓	✓	✓	✓	✓ (16)