I.O.S.

RRS DISCOVERY

CRUISE 145

25 FEBRUARY – 24 MARCH 1984

THE STRUCTURE OF THE UPPER OCEAN AT THE END OF WINTER IN THE REGION 40-47°N, 13-16°W

CRUISE REPORT NO. 166
1984

NATURAL ENVIRONMENT RESEARCH COUNCIL

INSTITUTE OF OCEANOGRAPHIC SCIENCES

INSTITUTE OF OCEANOGRAPHIC SCIENCES

Wormley, Godalming,
Surrey, GU8 5UB.
(0428 - 79 - 4141)

(Director: Dr. A.S. Laughton FRS)

Bidston Observatory,
Birkenhead,
Merseyside, L43 7RA.
(051 - 653 - 8633)

(Assistant Director: Dr D.E. Cartwright FRS)

Crossway,
Taunton,
Somerset, TA1 2DW.
(0823 - 86211)

(Assistant Director: M.J. Tucker)

When citing this document in a bibliography the reference should be given as follows:

POLLARD, R.T. *et al* 1984 RRS *Discovery* Cruise 145: 25 February - 24 March 1984. The structure of the upper ocean at the end of winter in the region 40-47°N, 13-16°W. *Institute of Oceanographic Sciences, Cruise Report*, No. 166, 47pp.

INSTITUTE OF OCEANOGRAPHIC SCIENCES

WORMLEY

RRS DISCOVERY

Cruise 145

25 February - 24 March 1984

The structure of the upper ocean at the end of winter in the region 40-47°N, 13-16°W

Principal Scientist

R.T. Pollard

CRUISE REPORT NO. 166

1984

CONTENTS Page

Tables

Figures

SCIENTIFIC PERSONNEL

R.T. Pollard	IOS (Wormley) Principal Scientist
S.G. Alderson	" "
J.W. Cherriman	" "
C.H. Clayson	" "
T.H. Guymer	" "
V.A. Lawford	" "
J.A. Moorey	" "
G.R.J. Phillips	" "
R.A. Phipps	" "
R.M. Sharpington	" "
K. Sherrocks	" "
J. Smithers	" "
P.K. Taylor	" "
I. Waddington	" "
E. Cooper	RVS (Barry)
Miss D. Jones	" "
Mrs. K.J. Thomas	Southampton University/IOS
R.G. Williams	University of East Anglia

SHIP'S OFFICERS

S.D. Mayl	Master
N.A. Jonas	Chief Officer
J.J. Price	2nd Officer
P.G. Pepler	3rd Officer
C.A. Langley	Radio Officer
R.M. Morris	Purser Catering Officer
I.G. McGill	Chief Engineer
P.J. Byrne	2nd Engineer
G.L. Parker	3rd Engineer
F.P. March	4th Engineer
N. Davenport	5th Engineer
F.P. Sharpe	Senior Electrical Engineer

SCIENTIFIC OBJECTIVES

1. Observe the structure of the upper ocean at the end of winter at two sites with different seasonal characteristics. Observe the physical and biological changes at those sites at the start of the seasonal heating cycle.

The sites chosen were around 40° 15'N, 15° 0'W and 45° 45'N, 13° 40'W. At the southern site the mixed layer depth was 150-200m, and the Drifting Spar moved northwards in a frontal structure at an average speed of over 14 cm/s. At the northern site the mixed layer was 250-300m deep, and the spar moved east then south at 10-15 cm/s.

2. Deploy two surface and two subsurface moorings for recovery on Cruise 146. Deploy a deepsea tide gauge for a deep water trial. Test shipborne surface meteorological instrumentation and provide surface fluxes for objective (1).

All these objectives were accomplished, but the surface and subsurface moorings set at the northern site were subsequently lost on Cruise 146. The southern toroid was recovered drifting nearly a degree south of its deployed position. The southern subsurface mooring and the tide gauge were recovered normally.

NARRATIVE

RRS Discovery sailed from Gibraltar at 1045/56 (all times GMT, day 56 = 25th February, 1984) after a two-hour delay to repair the aft crane. After a full depth calibration CTD at 37° 8'N, 10° 58'W close to the 4500m depth contour, it was decided to set course directly towards 40° N 15° W, a course which should pass through two eddies, apparent on surface temperature enhanced satellite images. (See Fig. 1 for Cruise track plot). After deep and shallow CTDs (10986/7) in the supposed centre of an eddy, the SeaSoar was deployed at 1500/58, but had to be recovered at 0300/59 to repair the propeller. The oxygen sensor was knocked off during recovery. By 0600 the SeaSoar was redeployed and towed successfully until 2000/59, during which time a routine for processing the data through to contoured sections was established.

Overnight, Aanderaa Thermistor Chains (ATCs) were calibrated by holding them, bundled up, at 50m in the mixed layer, during a CTD cast (10988). Surface and subsurface moorings and a tide gauge were deployed during daylight on day 60, after which the SeaSoar was deployed and towed continuously for 48 hours towards 47° N, 13° W. It was recovered at 2300/62, 11 n.m. short of that position after passing a suitable mooring position, and a line of CTDs (10992-4) on a near-reciprocal course was completed in time to deploy the northern subsurface mooring from 1500/63.

Further ATCs were calibrated overnight in parallel with a triangle of 2000 dbar CTDs (10996-9), one of which had to be prematurely terminated (at 1370 dbar) because of a connector failure. The northern surface toroid mooring was deployed on the afternoon of day 64, and further CTDs completed overnight while the spar was prepared. A strong easterly wind and swell prevented deployment on day 65, so a series of meteorological observations was made close to the toroid, followed by a CTD yoyo for 2.5 hours (ended again by a connector failure) and two more CTD casts overnight.

Geostrophic calculations suggested an eastward set, so the spar was deployed east of the surface and subsurface moorings at 1000/66, the swell and wind having abated a little. After steaming past the spar at several ranges to fix it and check the acoustic ranges obtainable, the SeaSoar was deployed at 1630/66 and a triangular survey relative to the drifting spar (Fig. 2) was made, yoyoing to over 350m until 0930/68. The survey consisted of an outer triangle with 24 n.m. sides, surveyed once in 24 hours, and a nested inner triangle with 12 n.m. sides, surveyed three times in a day. After a horizontal tow round the inner triangle from 0930/68 to 1420/68, the full survey pattern was repeated, although adverse wind and swell made control of the SeaSoar difficult except on the downwind legs.

The survey finally ended and the SeaSoar was recovered at 0930/70. The spar was inspected and the rubber dinghy used to invert the pitch-roll buoy, which had overturned. After moving 6.5 n.m. upwind of the spar, a CTD cast to 1500m (11010) was made, followed by yoyoing to 60m as the ship drifted, lying to, back past the spar. After relocating the spar at 0330/71, another yoyo was begun, attempting to hold position relative to the spar. This proved difficult in the absence of a light on the spar, and by 1709/71, when the yoyo ceased, Discovery had drifted from 1500m to over 4000m away from the spar.

The yoyos had shown features extending to 600m so it was decided to attempt to find such a feature east of the spar, and do very close spaced deep CTDs across it. However, after two stations to 2000m 3 n.m. apart (11012-13), it was decided not to continue, as the feature was proving elusive, and there was concern about the increasing wind and our ability to find the spar, which had begun to drift rapidly (1 kt) southwards. Discovery therefore steamed on course 242° past the spar, locating it satisfactorily, and did a final CTD to 2000m (11014) west of it before returning to recover it at 0900/72.

After a difficult recovery in worsening seas and a wind said by the bridge to be gusting to force 10 in squalls, course was set to check the moorings before leaving the northern area. The ship was virtually hove to on passage towards the moorings, and by the time the vicinity of the toroid was reached at 1800/72 it was impossible to see it, though it was located acoustically. CTD or SeaSoar deployment was impossible, but after securing all gear, the Master was prepared to turn and run south (190°) before the wind.

Shortly before 1200/73, a sudden increase in sea surface temperature showed that we had reached the front at 43.5°N across which I wished to do a line of CTDs. The swell had lengthened enough to be reasonably comfortable, so a line of CTDs was completed (11015-11020) ending at 1600/74. The SeaSoar was then deployed running south with the wind, and towed successfully past the southern moorings, followed by a survey around them (1446/75-0508/76) to determine the structure before redeploying the spar buoy.

The tide gauge and subsurface moorings were easily located, but the acoustics on the toroid mooring had failed, and a box search failed to locate it. It was decided to continue the scientific programme, with a faint hope of coming across the toroid during our surveys (see Moorings). The spar was redeployed very close to the subsurface mooring (1348/76), whence it drifted northwards as predicted from the preceding survey.

While the SeaSoar hydraulics were being repaired, a meteorological balloon was released, and various courses run to fix the relative positions of the subsurface mooring and spar buoys. The SeaSoar was deployed at 1730/76 but had to be recovered to remake a termination, being redeployed at 2338/76. The sea surface temperature fish was also deployed at 2354/76, long running problems with the computer logging having at last been partially resolved.

A nested triangle survey (Fig. 3) similar to that described above was run from 0012/77 to 0556/78, followed by three further circuits of the inner triangle, alternately towing as near horizontally as possible at several levels and yoyoing. The final leg was extended to the west and the SeaSoar recovered at 2140/78 to do a line of CTDs (11022-11024) back past the spar, perpendicular to the main frontal current.

The line of CTDs was terminated prematurely at 0730/79 as we were making negligible headway into an increasing wind. Instead, the SeaSoar was deployed before conditions worsened further, and towed in triangular and later diamond shaped circuits around the spar, alternately yoyoing and towing horizontally, until 1840/81. The CTD line was continued (11025-11027) from 1930/81-0223/82 and a short CTD yoyo (0600-0759/82) done near the spar before recovering it at 0847/82.

By 1003/82 the spar had been fully and smoothly recovered, and the SeaSoar was redeployed at 1036 after clearing the poop. The plan was to carry out a final survey of the northward continuation of the front. However, indicators of its position proved elusive, and a single salp fouled the conductivity sensor to the extent that the SeaSoar had to be recovered to remove it. This was done from 1653-1724/82 (a total of 30 minutes to recover and redeploy) and the survey continued for a short while, before altering course at 1930/82 towards Oporto.

A worsening westerly wind made it necessary to bring forward the recovery time of the SeaSoar to 1700/83, the PES fish having been retrieved at 1545/83. A final CTD for calibration purposes was attempted, but a connector failed with only 300m of wire out. As this was probably sufficient for calibration, all three sample bottles were fired in the mixed layer before ending the station.

Computer logging, thermosalinograph and navigation were ended at 0047/84 at 9° 07'W, and RRS Discovery entered Leixoes harbour, near Oporto, at 0740/84 to end Cruise 145.

MOORINGS (Cherriman, Waddington)

A surface and a subsurface mooring were deployed at each of the two working areas (40° N, 15° W and 46° N 13° W), four in all (Table 1). A tide gauge was also set at the southern site for IOS Bidston. The surface moorings carried meteorological packages and thermistor chains to span the mixed layer (Fig. 4). The subsurface moorings were instrumented with current meters (Fig. 4) to extend downwards the current measurements made in the surface layer from the drifting spar.

Prior to deployment, the thermistor chains were calibrated by hanging them, bundled up, at 50m in the mixed layer from the forward A frame during CTD casts. The test tapes used were immediately replayed and computer analysed. Several hardware faults were revealed by this process, demonstrating the value of shipboard processing.

The toroids were assembled on the Port side container space with a view to dropping the extension grating and deploying by just taking the weight on the crane and "walking" the toroid through the gate and over the side, the whole package being lifted at an angle to keep the crane hook well away from the anemometers etc. This worked well as both toroids were put into the water without mishap. The crane was released from the lifting strop by personnel in the rubber boat for the Southern toroid, but for the Northern one the weather was unsuitable to launch the boat, and the toroid was released by the "NO LOAD" release. Both methods were successful.

The deployments went smoothly but on the Southern toroid when the anchor was falling to the sea bed the acoustic signal made a switch (see acoustic section). The anchor appeared to bottom out normally, however, and since the toroid was still in position after 6 hrs or so, we left for the Northern area. On return 16 days later, a visual search was made for four hours, as the acoustics were likely to have failed. Although the toroid was not found, later examination of the corrected track plots revealed that we might have been searching a mile or two too far south. This highlighted the poor quality of realtime dead-reckoning. (The area was re-searched unsuccessfully on Cruise 146, but the toroid was in fact later found by chance during a SeaSoar survey drifting 53nm south of its deployed position).

The subsurface moorings were deployed from the much improved forward "A" frame anchor first without mishap.

A tide gauge was deployed successfully for Bidston from the forward crane on the Southern site.

DRIFTING SPAR (Waddington, Pollard, Phillips)

The 12 metre spar buoy and current meter string were deployed and recovered from the after deck on two occasions (Fig. 5, Table 1). Previous deployments, JASIN '78, had involved trawl winch, crane, trawling 'A' frame and ship's capstan. This equipment with the exception of the ship's capstan has been superceded by an improved lift crane, crane davit and hydraulic auxiliary winch. By utilising the auxiliary winch port wing drum and routeing a 14mm diameter polyprop tail rope around the deck sheaves a good lead was obtained through the crane davit system.

As the SeaSoar winch was located on the starboard side the spar buoy was housed on deck supports on the port side. This then meant craning the buoy from port to starboard to deploy.

Deployment 1451 on day 66 was accomplished with 5 VACMs, 4 VAECMs and 10 kHz transponder deployed by the "anchor first" method. The current meter string was held on a stopper rope at the davit head whilst the spar buoy was transferred by crane across the deck. The buoy was then attached to the current meter string and lowered into the water on a tail rope around the capstan.

Once in the water the tail rope was paid away quickly allowing the spar to drift off from the ship for ballasting checks. Adjustment was then made by hauling the spar to the davit by capstan where a pair of annular floats could be clamped beneath the upper flange. The spar then being correctly ballasted a rope from the surface rig was led around the stern and attached to the spar bridle. The surface marker buoy (an old pitch-roll wave buoy) was then lifted into the water by crane and slipped. Backup buoys and ropes were manhandled over the stern. When all the surface rig was streaming well aft the spar buoy was lowered into the water and the tail rope cut away allowing the spar to drift clear of the ship.

The spar was recovered on day 72 in 30 kt winds and heavy seas. Pickup and recovery of the surface rig was done by grappling the rig forward and hauling the buoys by crane and capstan over the starboard stern rail. This proved to be an awkward operation. It was hard to manhandle the floats inboard against the drag of the spar. Also, the bow propeller cut out twice causing the ship to broach to, and considerably slowing down operations.

The spar was picked up on the davit and transferred to the crane at the rail. The crane then lifted the spar so that the current meter string could be stopped off at the davit. The spar was then transferred across the deck by crane and placed into the deck supports and securely lashed down. Recovery of the current meter string then took the form of a normal mooring recovery.

From experience gained on deployment and recovery 1451, several failings in the system were apparent:

1) The lead from the auxiliary winch to the davit was overlong for polyprop rope. Ship's pitch caused the rope to stretch under load making current meter connections awkward. This was rectified by substituting 8mm dia. steel wire as a tail.

2) The stopper rope was badly sited, on the outboard davit arm, relative to the davit sheave. The stopper rope was resited on a lug immediately above the davit sheave.

3) The marker buoy rolled over in heavy weather and required a rubber boat trip to right it. A revised harness was made with buoys at both the spar and recovery line sides of the buoy.

4) The marker buoy partially flooded causing loss of ARGOS position fixes. This failure was caused by corrosion of the clamping band on the flashing light. The light housing was sealed off from the main housing on the second deployment.

Having made the above changes, the second deployment and recovery (1452) were both accomplished smoothly.

Rope harnesses and buoyancy units performed well throughout with only minor chafing at the recovery line splices.

Spar tracking

(a) VHF. Throughout both deployments the VHF transmitter worked well with ranges up to 10 miles being achieved. Accuracy of position was possible to an arc of 30° using the rotary aerial system. A particularly useful feature was the ability to determine the beam position during passes with acoustic ranging giving beam distance and VHF giving which side of the ship.

(b) Light. The flashing light beacon was not a success with flooding on the first deployment and electronic failure on the second.

(c) Acoustic. A well mixed layer 150m or more deep produces a positive sound velocity gradient and a good surface sound channel. It was thus possible to use a standard 10 kHz transponder interrogated via the PES fish to range on the drifting spar. Ranges to 8500m were obtained using various combinations of the PES beam steering facilities with beam passes reliably obtained to 5950m. Downwind courses gave the quietest conditions and hence longest ranges. In the absence of a light on the rig, several unintentionally close passes (within 600m) were made, so an early warning system was developed. Two minute dead-reckoned ship's positions were plotted once the spar came within acoustic range, and arcs drawn to establish whether the spar was off to one side. Several arcs at multiples of 1500m had to be drawn initially until the correct range became apparent. Satellite updates shift the ship's track so caused some problems. The technique saved last minute panic on a number of passes, but clearly a reliable light would have been preferable.

Near the beam pass, the range was always checked by a precise change of interrogation rate (2%) and the ambiguity of which beam the spar was on was reliably removed by the VHF direction finder.

(d) Argos. In addition to fixing the spar position by acoustic ranging, an Argos transmitter was attached to the pitchroll buoy to give extra fixes, especially when Discovery was out of acoustic range (sometimes for 12 hours or more) and to aid relocation. The Argos system tracks by satellite, recording the fixes at Toulouse in France. Using the recently installed INMARSAT communications system, the French data base could be interrogated by telex, giving the most recent fix, which might be 4 to 12 hours behind. Occasional computer problems caused loss of updates for some hours, but in general the fixes were an important aid to tracking the spar and establishing its drift. Lack of updates also signalled a problem at the spar end, when the pitchroll float had overturned.

In summary, the combination of flashing light (when it worked), VHF transmitter, Argos and acoustic fixing proved adequate to give confidence that we could relocate such a valuable free-drifting system. The redundancy was important, with two out of four devices failing on occasion. The acoustic ranges together with corrected ship's track will be used in retrospect to obtain the best possible spar track plots.

CURRENT METERS (Waddington, Clayson, Smithers, Pollard)

The VACM current meters performed well and no problems were encountered.

Four IOS vector averaging current meters were used in conjunction with five VACMs for measurements of current shear and temperature profile below the drifting spar buoy. The current meters were similar to those used since 1978 except for the temperature measuring circuits, which were increased in precision, and the sensor heads, which were enclosed in stainless steel cages to afford a limited degree of protection. Despite the latter, one head was damaged during recovery in heavy weather after the first deployment of the spar. A further head had to be replaced after this deployment due to water adsorption in the potting resin, which caused an excessive offset: this was probably due to faulty manufacture.

After each recovery, the SeaData cassettes from all current meters were processed through the SeaData Decoder, writing the decoded output onto a computer magnetic tape. The records were then fully processed on the USER computer system through to time base corrected plots of current components and temperature. A number of minor faults came to light through this process, which could be corrected before a subsequent deployment.

CTD CASTS (Smithers, Moorey, Pollard)

With one exception, all CTD casts were made with the "new" deep CTD, carrying the normal sensors and oxygen. The exception, station 10986, was done with the new shallow CTD with a 650 dbar full scale pressure sensor. This was a calibration cast before using the shallow CTD exclusively in the SeaSoar.

Calibration of the deep CTD conductivity was not straightforward, as it drifted during the cruise by an amount equivalent to about 0.03psu in salinity. There was also a depth variation amounting to about 0.005 psu change between 50 and 1000 dbar. However, bottle samples were routinely taken at 50, 200 and 2000 dbar to allow later correction. The temperatures were compared with reversing thermometer readings at 50 and 2000 dbar, and agreed within a few millidegrees on average. Oxygen samples were taken on a number of casts but correction of the CTD oxygen values was not attempted during the cruise.

In all, 5 full depth casts were made, 23 casts to 2000 dbar and several shallow yoyos (Table 2 and Fig. 6). Four stations were prematurely aborted or delayed by cable problems, generally caused by failure of Brantner connectors.

All data were archived on the Digidata tape deck attached to the deck unit, as well as being passed to the S1 computer. In addition to a live profile plot, the data were transferred to the USER computer at the end of each cast, where they were edited and replotted, and geostrophic calculations made when appropriate.

During the cruise, programs were written for a BBC "B" microcomputer, to sample the data at about 5Hz and display a calibrated profile plot or plot against time on a monitor. The facility will be used on future cruises when the full computer system is not available.

SEASOAR (Lawford, Smithers, Pollard)

The SeaSoar was used extensively on the cruise (Tables 3,4), on passage legs and for repeated surveys in the vicinity of the drifting spar buoy (Tables 5,6 and Figs. 2,3). Indeed, it was in the water and sampling for 332.6 hours, or just under 14 days, representing 50% of the total cruise time.

On most of the runs SeaSoar was operated in its yoyo mode, oscillating from the surface to depths from 350 to 400m at a ship's speed between 7.5 and 9 knots. Oscillation period was between 10 and 14 minutes. Runs 4, 7 and 8 (Table 3) involved triangular surveys around a free floating spar buoy. On some legs of these surveys the tow speed dropped to below 4 knots due to strong headwind and sea. Control of the vehicle becomes very limited at speeds below 6 knots. On some of these legs horizontal towing was attempted, but unless the towspeed was greater than 8 knots control was very poor. However at above 8 knots $\pm$5m depth could be attained.

Prior to the ship leaving Gibraltar, a new hydraulic control was fitted to the SeaSoar cable capstan. Unfortunately this was irreparably damaged by a reversal of the oil flow from its supply - the aft ring main. Control of the capstan for the cruise has been via the Moog controls as on previous cruises.

At the last refit the HIAB crane normally used for launching SeaSoar had been combined with the 15 ton Crane/davit. This combination worked well and once the intricacies of the controls had been mastered it allowed adequate and safe handling of the vehicle.

However, the davit can only be manoeuvred relatively slowly, and on the first recovery, the SeaSoar was hauled clear of the water by the capstan operator before the HIAB arm was sufficiently outboard. The SeaSoar jarred against the side of the ship, and it was found that the CTD had slid backwards in its brackets, knocking off the oxygen sensor. The sensor head was recovered, but the SeaSoar operated without oxygen for the remainder of the cruise. On subsequent recovery, the capstan was stopped while the SeaSoar was still well outboard (to prevent snatching) while the davit and arms were manoeuvred into final recovery position.

The safety of the operator when mounting and dismounting the davit was considered to be insufficient, particularly when the davit was rotated around away from the fore and aft position. Sketches are being prepared showing an extension of the operators platform which should alleviate this problem.

The new towing shoe was fitted to the aft rail of the poop deck. This guides the cable over the rail and is designed to be easily removable - two bolts only - and to leave a clear rail over which nets may be handled.

The new sheave, designed to handle the faired cable was not a success. A redesign of the sheave surface will be necessary.

At the end of Run 3 the new plastic cased Hydraulic Unit was fitted. This operated satisfactorily for the remainder of the cruise. There is however a slight oil leak from the main outer casing which made it necessary to change the oil in that compartment twice. This leak has proved difficult to stop completely.

The new towing bridle and wings have shown no sign of wear and tear. The only vehicle damage throughout the cruise was a cracked 'cowtail' at the front of the towing bridle, which had to be replaced.

After Run 8, the angle of attack of the upper tail plane was changed to about 5 degrees up in an effort to affect body pitch angle. Also a small vertical fin of 250 cm^2 was fitted to the top of the tail plane. These alterations both had small beneficial effects. The first did reduce the rate of change of depth of the vehicle as it started down. The fin reduced the maximum roll of the vehicle - which occurs during the upper half of the ascent - to almost a half. The SeaSoar design will be altered accordingly.

The system was deployed and recovered under quite severe conditions during this cruise. It was found best to launch the vehicle with the ship travelling downwind at 6 knots, and to recover at 4 knots also in a downwind direction. This technique had the effect of reducing the cable snatch considerably which made for much faster and safer operations than previously. On one occasion the vehicle was recovered and redeployed with the loss of only 45 minutes of data.

SeaSoar was launched 10 times (Table 3), but had to be recovered before the planned time only 3 times. After 11 hours of the first run control of the vehicle was partially lost due to the welds on two of the impellor blades fracturing and allowing the blades to twist. Just after launching for the 6th time a cable fault developed - in the CTD circuit which became open circuit. When the vehicle was recovered a new termination was fitted to the sea cable, but further investigation showed the fault to be in a plug on the cable capstan. Just after launch on Run 9 the conductivity cell became contaminated. Recovery a few hours later showed salp firmly wrapped around the sensor head. All other recoveries were at the planned end of run.

At the start of the cruise, the new shallow CTD was calibrated with a 600m cast on the midships winch (10986, Table 2). During all SeaSoar runs, the CTD data were read into the S1 sampling computer, averaged to one value per second and calibrated. T/S curves and profiles of temperature, salinity, density, and chlorophyll were plotted every two hours on a flatbed plotter, and a live time series plot provided a check on system performance and conductivity cell fouling. The SeaSoar frequently surfaced momentarily as it turned at the top of each sawtooth, which helped to keep the sensor clean. Whenever fouling occurred, the SeaSoar was deliberately surfaced until the cell recovered its calibration. This worked on all but one occasion (Table 3).

Every two hours, the calibrated CTD data were transferred by RL01 demountable disc to the USER computer along with navigation and other data. The EM log data were integrated to give RELDIST, the distance run relative to water and RELDIST was merged with the CTD data (after further editing) using the common TIME variable. Contour plots could thus be generated with PRES and RELDIST as the independent variables. These proved invaluable in making logistic decisions, such as when to break off a survey, or which areas to resurvey.

The final data files (Table 4) were archived, and will save many man-months of effort ashore.

Triangular surveys

The SeaSoar survey pattern run around the drifting spar was arranged as two nested triangles (figs. 2 and 3). It was designed to give information on the horizontal structure of the upper ocean in the vicinity of the spar in three directions, with the inner triangle repeated about three times in a day to resolve diurnal changes, and with the outer triangle surveyed once per day to extend spatial coverage as far as possible.

The triangle was orientated such that one inner leg (C) was downwind, and the A and B legs consequently tacking with the wind 60° on either beam. The pattern was surveyed in the order ABCDE-BCAFG-CABHJ. At 8 kts, 12 n.m. sides (22 km) were chosen so that a complete survey took about a day.

The spar buoy could not, unfortunately be in the centre of the pattern because of limited acoustic ranges. It was chosen to be 1.5 n.m. from the ship at the close beam-on positions. Because navigation had to be relative to the spar, allowance was made for windage (leeway) but not current set, and turning points were determined from distance run (relative to water) measured from the ship's log. At 8 kts, turning at 10° per minute, 120° turns were begun 1.3 n.m. before the end of leg (fig. 2, detail). Whenever a beam-on acoustic range to the spar was obtained, the log value was noted and the distance run to the next turning point and along the next track recalculated, if necessary, to return to the correct tracks relative to the spar.

ROUTINE SURFACE METEOROLOGICAL DATA (Guymer, Williams, Alderson, Taylor)

a) WMO observations and synoptic summary of weather

Routine observations were made at 03, 09, 15 and 21Z, according to WMO standards and included wind speed and direction, air temperatures, sea surface temperature, pressure and visual estimates of waves and clouds. By combining these data with the observations of the bridge officers made on the main synoptic hours a 3-hourly time series was maintained. Particular attention was paid to cloud observations because these data are required for parameterising components of the surface radiation budget. The observations were useful, in conjunction with facsimile charts for giving a broad overview of the weather during the cruise.

At the beginning a ridge of high pressure extended from North Europe towards the Azores and a depression moving east along 35N gave E or NE winds as it became slow moving in the western Mediterranean. This situation was typical of the whole cruise. A blocking anticyclone centred at about 50N, 20W became established on 1 March (day 61) giving easterlies which strengthened to 30kt by 5 March (65) as a depression deepened near the Azores. A large swell originating from the Bay of Biscay was also observed. The high continued to dominate the eastern Atlantic and Europe for the next few days, intensifying and becoming centred over the UK before moving westwards on 10/11 March (70/71) and allowing a cold front to move southwards through the area early on 12th (72) bringing a change from the easterlies to strong, showery northerlies. The depression associated with the front became slow moving over northern Spain and filled only slowly, winds eventually moderating to below 15kt on 16th (76).

Increasing high cloud in the southwest and strengthening easterly winds on 17 March (77) heralded the approach of a depression from the SW. Ahead of it an occluded front moved through from the south bringing a temporary change to light southeasterlies and clear skies but, as the depression tracked NE just to the south of our position, the front moved south again and on 20th March (80) there was a change to strong NE winds with a significant drop in air temperature and humidity. This period had the highest fluxes of sensible and latent heat loss from ocean to atmosphere (in excess of 150 wm^{-2} for the total). On the 20th March (80) the synoptic pattern began to change dramatically. The block which had dominated the weather type on the cruise gave way and a mobile westerly type of flow in the NW Atlantic extended eastwards so that after calm, sunny conditions under a weak, transient ridge on 21/22 March (81/82) rough weather, preceded by a very marked long period swell prevailed as an eastwards course was set for Oporto. Generally, the wind was from between N and E throughout the cruise and the air was colder than the sea by $\sim 2^{\circ}$C. Wet-bulb depressions of 2-3°C were typical and total precipitation was rather low, falling mainly as showers.

(b) Computer-logged values

One other purpose of the observations in (a) was to evaluate the performance of the shipboard automatic-logging system which recorded 1 min values of wind, pressure, dry bulb, wet bulb, hull temperature and solar radiation on the 11/34 computer. It was noticed early in the cruise that the relative wind direction was in error by about 70° on the 'plot' printout and by

55° on the dial readout. A check revealed that calibration coefficients had not been changed since Cruise 132 on which an intensive effort had been made to retrieve accurate winds so it would appear that the vane mount itself had been realigned, possibly during refit. If so this is a tedious error which means that all winds since the refit are in error, including wind speed (because of the vector addition needed to compute true wind from relative winds). It will be necessary to recompute the winds. To rectify the situation on the current cruise a constant was added to the calibration file at 0530Z Day 67 on the basis of comparisons with the special series of wind measurements also being conducted on the cruise (see p.21).

Other variables appeared to have reasonable values. Comparisons were made between the screen temperatures on the wheelhouse top, the bridge deck screens and an Assmann psychrometer and generally exhibited consistency within 0.2°C. The bridge officers had noted a discrepancy between the R.A.S.T.U.S digital readout of air temperatures in the bridge screens and those obtained from the mercury thermometers in the same locations and therefore were using only the latter in their meteorological reports. R.A.S.T.U.S. dry bulbs were 0.4°C too low on port and 0.5°C low on starboard. Wet bulbs were 0.9°C low (port) and 1.0°C low (starboard). Our measurements confirm the wet-bulb wicks were not moistened at all during the cruise. Problems were also encountered at times from unstable R.A.S.T.U.S. readouts. The 3-hourly values on the log sheets must therefore be viewed with caution; hull temperatures logged on the computer appear reliable though they may need to be corrected to give a temperature equivalent to a bucket measurement.

A preliminary analysis of the computer-logged air temperatures shows great sensitivity to the relative wind direction; however, the variations appear to be repeatable and, given the large amount of intercomparison data plus the measurements made by extra wind sensors mounted near the thermometers it should prove possible to quantify the errors. This is particularly important if such measurements are to be used in calculating turbulent fluxes by the bulk parameterization method. Fluxes were computed in this way, using the computer-logged values, for several periods of interest and, together with radiation estimates, were compared with changes in heat content of the upper ocean. In the two detailed SeaSoar surveys, surface transfers were too small to account for the observed cooling of the water, particularly in the second where less than 10% could be accounted for. A proper evaluation of the surface flux data must await comparison with data from the meteorological buoy and a thorough analysis of the intercomparisons made on board Discovery. Daily and weekly plots of all variables were produced on the Calcomp, and the 1-minute data for the whole cruise are reproduced in Fig. 7. They must however be used with caution in the light of the above discussion.

RADIOSONDE ASCENTS (Taylor, Thomas, Guymer)

Radiosondes using Helium filled balloons were released during the cruise in a collaborative experiment involving IOS and the Rutherford Appleton Laboratories. Each ascent was timed to coincide with an overpass of the meteorological satellites NOAA7 and NOAA8 which use Advanced Very High Resolution Radiometers (AVHRR) to provide estimates of the sea surface temperature (SST). The accuracy of the satellite SST is degraded by uncertainty in estimating the amount of atmospheric water vapour and by failure to entirely eliminate cloud contaminated data. The water vapour measurements provided by the radiosondes will be used, together with the SST measurements obtained during this cruise, to quantify the errors in the satellite SST values and to evaluate alternative satellite data retrieval schemes.

Of the 28 radiosonde ascents (Table 7), 22 were timed to be coincident with NOAA7 overflights since this satellite carries a 'split-window' AVHRR, that is one having two channels in the same transmission window thus allowing more accurate water vapour correction. 16 ascents were conducted in daylight to allow evaluation of cloud clearance techniques using the visible wavelength AVHRR channel. Ascents were only conducted for overpasses if less than 6 eighths total cloud cover was expected.

It is expected that the detailed satellite SST data obtained as part of this experiment will also be of value for defining the horizontal extent of SST features associated with the oceanic mixed layer structures studied during the cruise.

AIRFLOW EXPERIMENTS (Taylor, Guymer, Thomas)

Estimation of the fluxes of momentum, sensible heat and latent heat between the sea and the air using the bulk aerodynamic formulae requires accurate measurements of the mean wind, air temperature and humidity. For the greatest accuracy it is necessary to adjust the measurements to take into account the height of the instruments and this correction is a function of stability. However, it is well known that the presence of the ship disturbs the airflow causing uncertainty with regard to the true height to which the measurements refer and often causing the exposure of the instrument to be far from ideal. For climate research and for the calibration of oceanographic satellites there is a need for more accurate flux estimates than hitherto, and it was therefore decided to investigate the effect of airflow disturbance on the routine meteorological measurements logged by the computer system on RRS Discovery.

Anemometers and wind vanes were mounted in the following positions:-

(a) 4m above and 0.5m forward of the front edge of the foremast platform midway between the mast and the ship's port anemometer.

(b) above the port and starboard thermometer screens on the wheelhouse top ('Monkey Island'). A vane at about 1.0m and anemometer 0.5m above each screen.

(c) a further anemometer 2.65m above the port wheelhouse top screen.

(d) above the starboard bridge deck screen, an anemometer at 0.8m and wind vane at 0.4m above the screen top.

Data from these instruments were recorded on a Microdata logger at one minute intervals throughout the cruise. Variations of the wind between the different positions will be correlated with changes in relative wind, and differences between the port and starboard computer logged dry bulb and wet bulb depression values. For these comparisons the readings of the foremast anemometer will be used as a standard, an estimate of the error in this will be made using comparisons with the data from the surface mooring.

Measurements of the windflow in the region of the bow were made with additional anemometers mounted on a horizontal pole at distances either of 4m and 2m, or at 5m and 3m forwards of the bow. In each case a wind vane was mounted 1m inboard of the aft anemometer. Readings were taken for varying relative winds by noting the 1 minute averaged values on the display of the Portalogger data recording units (Table 8). A separate series of measurements was made with the pole mounted vertically in the bow. In this case the anemometers were at 4.8m and 1.8m above the bow plate with a wind vane midway between them. 1.4m standoff arms were used to place the instruments approximately 0.4m forward of the bow. Unfortunately this series of readings was terminated when, during a squall, a wave broke over the bow and broke the lashings of the Portalogger units. The loggers were swept into the anchor machinery and suffered mechanical damage.

In order to visualise the flow over the bow, foredeck and ship's superstructure, a series of six smoke flares were ignited and photographs taken of the smoke stream from different angles. These experiments clearly indicated that, for the relative wind on the ship's bow, the air reaching the wheelhouse top screens may have originated from a level at or below the top of the bow.

SHIP-BORNE WAVE RECORDER (Guymer, Thomas)

The wave-recorder was operated on many occasions during the cruise (see Table 9) although on some of these the vessel was steaming. Maximum wave heights were about 7.5m crest-to-trough. These data will be of use in describing the general sea-state conditions which prevailed and in studies relating to possible sea-state dependence of coefficients in the bulk parameterization of surface turbulent fluxes. However, use of the SBWR is not facilitated by its cramped position behind the gravimeter which makes it difficult to annotate and change the chart. Also, while there is provision to link the SBWR to the ship's computer this has not so far been done. In view of the increasing interest in instrumentally-obtained wave records for the purpose of validating satellite microwave measurements of wave-height and wave-length, it is highly desirable that the SBWR facility on Discovery should be exploited to the full.

THERMOSALINOGRAPH (Cooper, Phipps)

Throughout the cruise, the temperature at the non-toxic intake and the salinity of the non-toxic supply were monitored with a Plessey Thermosalinograph sampling every ten seconds. Only one of the pumps driving the non-toxic supply is operational, and there have been several minor leaks in the pipework.

A requirement to log salinity to three decimal places required modification to the sampling program at the start of the cruise, and a constant salinity offset was applied to bring the computer logged value to approximately the right calibrated value. Bottle samples were tapped off the supply every 2 or 4 hours during SeaSoar surveys to allow later calibration.

SEA SURFACE TEMPERATURE/PRESSURE FISH (Lawford, Clayson, Cooper, Jones)

Considerable trouble was experienced in computer logging of the SST fish through the FM interface. These unfortunately precluded its use during the northern survey, but logging of the temperature-only fish was eventually achieved.

In retrospect, the primary problem was that changes to the sampling programs necessitated by the change to a 20K executive on cruise 132 had not been completed nor documented. Attempting to start sampling before the most recent software was in use resulted in four crashes of the S1 computer. Care had been taken to avoid periods of CTD or SeaSoar logging, so only about ten minutes of navigation and thermosalinograph data were lost on each occasion.

The new pressure/temperature fish had not been completed at the start of the cruise, and the electronics were found not to fit the housing. The temperature-only fish could be used, however, and worked satisfactorily during the second spar deployment (at the south site) until cable damage caused progressive failure. After the cable termination had been repaired, the fish was redeployed for a short time during the final SeaSoar front survey period.

COMPUTER (Cooper, Jones, Pollard)

The S1 computer sampled continuously throughout the cruise apart from the short crashes mentioned above. The USER system worked continuously with no crashes.

In addition to the usual navigational and meteorological data logging, a Plessey thermosalinograph, a Neil Brown CTD, a Batfish and, eventually, a Sea-surface temperature fish were also logged by the S1 computer.

During normal operation, the S1 copes very well, the 'shuffler' being idle for most of the time, except when large coreloads such as PIP and RTL are used. Their use invokes the shuffler, causing occasional data loss when the raw sampling programs can't get enough processor time. When the FM interface is being sampled however, the system's response is noticeably slower, so careful consideration should be given to the advisability of sampling two FM interfaces concurrently.

Nearly all data were transferred to the USER system and extensively processed as described elsewhere. In particular, several tasks previously done by the S1 system were transferred to the PSTAR applications suite on the USER system, which was more versatile and relieved the load on the S1. PNEWDR and PEDSAT replaced the old S1 EDTNAV program, allowing corrected navigation to be recalculated several times if necessary.

Externally logged data from various instruments such as current meters, VACMs and thermistor chain loggers were also processed on the USER system. Also, the bathymetry in corrected meters (Carter's corrections) was typed into the system.

The hardware functioned with only minor troubles throughout the cruise. The only system to cause concern was the HP2100 Satellite Navigation computer. This was temperamental at the start of the cruise, but once the connectors were cleaned, it gave no further problems.

A small data loss was caused by a malfunction of the thermosalinograph chart recorder, otherwise, the integrity of the data has been maintained.

Table 1a

Mooring deployments

Station	Mooring number	Type	Deployment day/time	Latitude °N	Longitude °W	Depth corr.m
10989	368	toroid	60/1300	40° 20.02	15° 01.37	5365
10990	369	subsurface	60/1852	40° 15.36	15° 02.45	5365
10991		tide gauge	60/2230	40° 17.52	15° 03.30	5362
10995	370	subsurface	63/1830	45° 43.76	13° 46.25	4825
11000	371	toroid	64/1930	45° 49.00	13° 39.00	4823

Table 1b

Spar deployments

Station	Deployment number	Set/recover	Day/time	Latitude (N)	Longitude (W)	Duration
11006	1451	S	66/1312	45° 49.6	13° 29.8	5d 20h
		R	72/0858	45° 30.9	12° 59.9	
11021	1452	S	76/1350	40° 15.5	15° 01.2	5d 19h
		R	82/0847	40° 53.0	14° 57.0	

Table 1c

Spar instrumentation

Deployment 1451			Deployment 1452		
Instrument	Number	Depth (m)	Instrument	Number	Depth (m)
VACM	627	15	VACM	629	20
VAECM	1	25	VAECM	2	48
VAECM	4	35	VAECM	3	76
VACM	668	45	VACM	429	96
VAECM	3	65	TXP		105
VACM	673	85	VAECM	4	115
VAECM	2	105	VAECM	1	135
VACM	429	125	VACM	627	155
VACM	629	145	VACM	673	175
TXP		195	VACM	668	195

Table 2

CTD Stations

Number	Day/Time	Lat.(N)	Long.(W)	Depth	Notes
10985	57/2207	37 08.5	10 58.4	4671	Calibration cast
10986	58/0651	37 30.1	11 32.0	600	Calib. of shallow CTD
10987	58/1031	37 32.7	11 32.2	5188	In eddy near 10986
10988	60/0110	40 14.5	15 00.4	5400	Near S moorings
10992	63/0043	46 52.7	13 03.4	2000	Triangular survey
10993	63/0552	46 29.9	13 14.7	2000	north of north
10994	63/1332	45 41.6	13 43.9	2030	moorings
10996	63/2230	46 00.8	14 05.1	2000	"
10997	64/0244	46 19.4	14 28.8	1370	" (cable fault)
10998	64/0704	46 24.3	13 51.9	2000	"
10999	64/1140	46 05.2	13 32.0	2000	"
11001	65/0315	45 27.9	13 16.0	2041	Dogleg SE of N mooring
11002	65/0740	45 07.1	13 35.2	1550	" (cable fault)
11003	65/1926	45 48.6	13 39.0	400	Yoyos keeping station
to	65/2104	45 49.3	13 39.5	yoyo	by north toroid
11004	65/2303	45 53.7	13 38.5	2000	Between 10994 and 999
11005	66/0455	45 45.2	13 07.2	2000	Course 112 from 11004
11007	70/1358	45 47.0	12 56.5	1500	East of spar
11008	70/1426	45 47.0	12 56.3	600	Yoyos drifting past
to	71/0122	45 44.1	13 06.8	yoyo	spar
11009	71/0336	45 42.3	13 02.4	600	Yoyos keeping station
to	71/0722	45 41.1	13 01.6	yoyo	by spar
11010	71/0800	45 40.9	13 01.4	2000	Deep cast by spar
11011	71/0829	45 40.9	13 01.4	600	Yoyos keeping station
to	71/1730	45 40.0	13 00.2	yoyo	fairly near spar
11012	71/2158	45 41.8	12 42.1	2000	East of spar
11013	72/0011	45 39.0	12 45.3	2000	ditto
11014	72/0423	45 26.4	13 16.6	2000	West of spar
11015	73/1243	43 21.3	14 19.8	2000	Line of CTDs across
11016	73/1649	43 29.6	14 16.9	2000	outcrop of
11017	73/2213	43 37.4	14 15.0	4511	12 deg. (to bottom)
11018	74/0304	43 45.7	14 05.0	2000	isotherm
11019	74/0641	43 53.6	13 58.4	2000	"
11020	74/1414	43 11.7	14 25.0	5356	" (to bottom)
11022	78/2245	40 43.1	15 14.8	2000	Line of CTDs along
11023	79/0144	40 41.1	15 05.2	2000	110 line past spar
11024	79/0643	40 39.8	14 50.9	2000	"
11025	81/2008	40 49.9	14 56.2	2000	Second line as above
11026	81/2254	40 47.5	14 46.9	2000	"
11027	82/0132	40 45.4	14 36.0	2050	"
11028	82/0600	40 51.7	14 57.0	300	Yoyo close to spar
to	82/0759	40 51.6	14 57.3	yoyo	
11029	83/1750	41 07.3	10 27.8	300	Final calib. cast, ended by cable fault

Table 3

SeaSoar Deployments

Run No.	Day/Time in	Day/Time out	Duration (hrs)	Type of Run	Reason Out
1	58/1510	59/0230	11.3	Yoyo to 350m. 8 knots. Passage leg.	Partial loss of control due to the weld on two of the impellor blades cracking.
2	59/0600	59/2200	14.0	Yoyo to 350m. 8 knots. Passage leg.	End of run.
3	60/2330	62/2300	47.5	Yoyo to 375 m. 8-9 knots. Passage leg and survey.	End of run.
4	66/1650	70/0930	88.7	Yoyo around triangles and some horizontal tows. Generally low speed 4-8 knots.	End of run.
5	74/1630	76/0510	36.7	Yoyo to 400m. 8-9 knots. Passage leg.	End of run.
6	76/1730	76/1930	2.0		Cable fault. Eventually found to be at capstan.
7	76/2340	78/2120	45.7	Yoyo to 390m. and short horizontal tows around triangle.	End of run.
8	79/0920	81/1820	57.0	Yoyo to 390m. and short horizontal tows around triangle.	End of run.
9	82/1050	82/1650	6.0	Yoyo to 380m. - across front.	Conductivity probe contaminated. Cured by removal of salp.
10	82/1720	83/1700	23.7	Yoyo to 360m. 8-9 knots. Passage leg.	End of run.
			332.6		

Table 4

SeaSoar computer run numbers

Run SS1450--	Day/Time Start	End	Distance Run (km) Start	End	Comments
		On passage from 35° 34N 11° 32W to 40° 10N 15° 00W			
01	58/1331	58/1900	592.8	653.6	
02	58/1827	58/2302	645.2	715.2	
03	58/2218	59/0240	704.9	766.2	
04	59/0240	59/0958	766.2	836.3	
05	59/0911	59/1344	824.2	895.9	
06	59/1305	59/1736	885.5	955.8	
07	59/1621	59/2158	945.1	1021.2	
		On passage from 40° 17N 15° 03W to 46° 51N 13° 04W			
08	60/2216	61/0400	1120.9	1189.8	
09	61/0330	61/0742	1175.7	1246.0	
10	61/0700	61/1130	1235.7	1305.1	
11	61/1051	61/1517	1294.9	1365.1	
12	61/1441	61/1900	1355.3	1425.1	
13	61/1824	61/2234	1415.2	1485.2	
14	61/2158	62/0200	1475.2	1545.1	
15	62/0125	62/0533	1534.8	1605.8	
16	62/0452	62/0922	1595.0	1666.0	
17	62/0841	62/1309	1655.7	1725.4	
18	62/1232	62/1700	1715.4	1785.4	
19	62/1600	62/2100	1770.4	1843.4	
20	62/2033	62/2300	1835.0	1871.3	
		Triangular survey, north site			
21	66/1644	66/2150	2634.9	2705.1	A1,B1,C1
22	66/2116	67/0234	2695.7	2766.0	C1,D1,E1,B2
23	67/0128	67/0700	2755.0	2826.2	B2,C2,A2
24	67/0607	67/1138	2815.0	2885.6	A2,F1,G1,C3
25	67/1058	67/1626	2875.0	2945.8	C3,A3,B3,H1
26	67/1542	67/2037	2934.9	3005.0	B3,H1,J1,A4,B4
27	67/1948	68/0052	2994.7	3065.1	B4,C4,D2,E2
28	68/0012	68/0556	3054.9	3125.0	E2,B5,C5
29	68/0507	68/0940	3115.0	3177.0	C5,A5,B6,C6
30	68/0940	68/1420	3177.0	3241.0	C6,A6,B7
31	68/1420	68/1916	3241.0	3305.0	B7,C7,A7
32	68/1823	69/0023	3294.9	3365.4	A7,F2,G2,C8
33	68/2343	69/0541	3355.2	3425.3	C8,A8,B8,H2
34	69/0500	69/1016	3414.9	3485.2	H2,J2,A9
35	69/0923	69/1510	3475.2	3547.7	A9,B9,C9,D3
36	69/1510	69/1720	3547.7	3567.0	E3,HORIZ
37	69/1700	69/2007	3535.1	3605.1	B10,C10
38	69/1928	70/0032	3594.8	3665.7	C10,A10,B11,H3
39	69/2353	70/0438	3655.2	3725.0	H3,J3,A11
40	70/0353	70/0900	3715.3	3785.0	A11,B12,C11
41	70/0801	70/0940	3775.0	3791.7	

SeaSoar computer run numbers
Table 4 cont.

Run SS1450--	Day/Time Start	End	Distance Run (km) Start	End	Comments
	On passage from 43° 9'N 14° 27'W to 40° 0'N 14° 45'W				
42	74/1654	74/2116	4556.2	4625.1	
43	74/2038	75/0100	4615.4	4684.2	
44	75/0023	75/0447	4675.1	4745.1	
45	75/0409	75/0833	4734.9	4805.2	
46	75/0754	75/1210	4794.6	4865.3	
47	75/1134	75/1603	4855.2	4925.3	
48	75/1520	75/2015	4915.2	4985.0	
49	76/1932	86/0043	4974.9	5045.9	
50	76/0001	76/0449	5035.8	5105.2	
51	76/1708	76/0505	5095.1	5109.0	
	Triangular survey, south site				
52	76/1746	77/0141	5205.0	5275.3	A1
53	77/0100	77/0537	5264.7	5335.0	A1,B1,C1
54	77/0455	77/0924	5324.7	5395.4	C1,D1,E1
55	77/0847	77/1204	5385.3	5455.6	E1,B2,C2,A2
56	77/1237	77/1700	5445.7	5513.6	A2,F1,G1
57	77/1629	77/2100	5505.5	5575.1	G1,C3,A3,B3
58	77/2105	78/0055	5542.8	5624.3	B3,H1,J1
59	78/0055	78/0540	5624.3	5687.0	H*:A4,B4,C4
60	78/0556	78/1031	5691.1	5756.8	A5,B5,C5
61	78/1030	78/1500	5756.8	5825.4	H*:A6,B6,C6
62	78/1450	78/2133	5822.8	5924.4	A7,B7,C7,A8
	Continuation of south site survey				
63	79/0907	79/1100	5984.5	6010.4	A9,B9
64	79/1100	79/1700	6010.4	6081.5	H*:B9,C9,A10
65	79/1550	79/1900	6062.9	6109.3	A10,B10
66	79/1900	79/2135	6109.3	6122.9	H*:B10
67	79/2135	80/0035	6126.1	6161.7	C10
68	80/0035	80/0640	6161.7	6242.5	H*:A11,B11,C11 yoyo A12
69	80/0640	80/1203	6242.5	6310.0	B12,H2,J2
70	80/1157	80/1339	6300.0	6334.2	A13
71	80/1339	80/1945	6334.2	6415.5	H*:B13,H3,J3,A14
72	80/1945	81/0112	6415.5	6486.2	B14,H4,J4
73	81/0112	81/0920	6486.2	6600.0	H*:A15,B15,H5,J5, A16,B16
74	81/0933	81/1428	6600.0	6670.3	B16,C12,A17,B17
75	81/1351	81/1830	6660.3	6725.9	B17,H6,J6
	On passage from 40° 52'N 14° 58'W to 41° 6'N 10° 31'W				
76	82/1036	82/1454	6832.2	6895.7	
77	82/1412	82/1900	6885.8	6953.7	
78	82/1830	82/2300	6945.7	7019.4	
79	82/2211	83/0224	7005.8	7075.3	
80	83/0149	83/0607	7065.8	7135.3	
81	83/0530	83/0955	7125.0	7195.0	
82	83/0920	83/1352	7185.9	7255.2	
83	83/1313	83/1700	7245.6	7298.9	

*Note: H: means Horizontal.

Table 5

SeaSoar survey, Northern area

Run	Day	Start Time	End Time	Leg/Course	Start Reldist
21	66	1756	1937	A1/150	2651
		1948	2114	B1/030	2674
22		2126	2239	C1/270	2697
		2246	0006	D1/210	2719
23	67	0017	0219	E1/090	2742
		0224	0400	B2	2763
		0412	0520	C2	2786
24		0532	0712	A2	2805
		0718	0920	F1/090	2829
		0931	1048	G1/330	2851
25		1054	1208	C3	2873
		1218	1356	A3	2894
26		1407	1546	B3	2915
		1552	1710	H1/330	2935
		1722	1839	J1/210	2959
27		1845	2039	A4	2982
		2050	2252	B4	3006
		2304	2325	C4	3035
		2325*	2353*	C4/255	3043
28		2353	0021	C4/270	3052
	68	0026	0204	D2	3060
		0216	0417	E2	3084
29		0424	0602	B5	3107
		0615	0727	C5	3127
		0740	0928	A5	3150

* course adjustment as too far N

Table 5 cont.

Run	Day	Start Time	End Time	Leg/Course	Start Reldist
30		0939	1059	B6	3175
		1111	1226	C6	3197
		1239	1416	A6	3220
31		1428	1604	B7	3240
		1616	1725	C7	3262
32		1738	1927	A7	3284
		1935	2154	F2	3307
		2207	2330	G2	3330
33		2336	0045	C8	3353
	69	0058	0228	A8	3372
		0239	0446	B8	3391
34		0454	0616	H2	3413
		0629	0748	J2	3435
35		0756	0951	A9	3458
		1003	1136	B9	3481
		1148	1255	C9	3502
		1301	1435	D3	3522
36,37		1447	1710	E3	3544
		1715	1859	B10	3565
38		1912	2021	C10	3588
	69	2033	2211	A10	3611
		2222	2352	B11	3634
39		2358	0111	H3	3655
	70	0124	0240	J3	3678
40		0247	0440	A11	3700
		0452	0617	B12	3727
		0629	0739	C11	3751
41				end	3770

Table 6

SeaSoar survey, Southern area

Run	Day	Start	End	Leg/Course	Start Reldist	Comments
55	77	0013	0105	C0/050	5253	
53		0116	9248	A1/290	5267	
		0259	0427	B1/170	5294	
54		0439	0602	C1/050	5320	
		0608	0739	D1/350	5342	
55		0754	0921	E1/230	5368	
		0927	1047	B2	5395	
		1049	1237	C2	5419	
56		1249	1416	A2	5447	
		1422	1531	F1/230	5471	
57		1542	1713	G1/110	5492	
		1719	1838	C3	5517	
		1848	2009	A3	5538	
58		2021	2141	B3	5565	
		2147	2331	H1/110	5585	
	78	2343	0055	J1/350	5607	
59		0101	0204	A4	5626	
		0220	0403	B4	5645	
		0415	0540	C4	5666	
60		0556	0715	A5	5688	Horiz
		0729	0852	B5	5713	Horiz
		0904	1026	C5	5735	Horiz
61		1038	1154	A6	5757	
		1206	1322	B6	5781	
		1334	1448	C6	5802	
62		1459	1604	A7	5823	Horiz
		1617	1736	B7	5844	Horiz

Table 6 cont.

Run	Day	Start	End	Leg/Course	Start Reldist	Comments
		1748	1904	C7	5866	Horiz
		1917	2118	A8	5886	
				end	5925	
			(CTD	Survey)		
	79					
63		0923	1042	A9	5985	
64		1054	1312	B9	6009	
		1327	1549	C9	6037	
65		1601	1720	A10	6064	Yoyo
		1726	1855	B10	6087	Yoyo
66			2120		6110	Engine Failure
67	80	2142	0035	C10	6126	Yoyo
68		0043	0157	A11	6162	Horiz
		0209	0321	B11	6184	Horiz
		0333	0523	C11	6206	Horiz
		0541	0640	A12	6225	Yoyo
69	80	0653	0809	B12	6245	Yoyo
		0816	0955	H2	6268	Yoyo
		1006	1155	J2	6289	Yoyo
70		1204	1327	A13	6309	Yoyo
71		1335	1453	B13	6332	Horiz
		1500	1630	H3	6353	Horiz
		1642	1825	J3	6377	Horiz
		1835	1945	A14	6397	Horiz
72		1959	2112	B14	6420	Yoyo
		2120	2252	H4	6440	Yoyo
	81	2304	0100	J4	6462	Yoyo
73		0107	0224	A15	6484	Horiz
		0236	0352	B15	6506	Horiz
		0400	0525	H5	6527	Horiz

Table 6 cont.

Run	Day	Start	End	Leg/Course	Start Reldist	Comments
		0535	0716	J5	6549	Horiz
		0727	0842	A16	6573	Horiz
74		0856	1011	B16	6594	Horiz,
					6604	Yoyo
		1024	1212	C12	6615	Yoyo
		1225	1353	A17	6638	Yoyo
75		1406	1522	B17	6661	Yoyo
		1527	1647	H6	6685	Yoyo
		1658	1842	J6	6706	Yoyo
				end	6722	

Table 7

Radiosonde Ascents

Ascent No.	Jday	Time Z	Lat N	Long W	Satellite Orbit	Satellite Time	Comment
145D-001	60	1001	40 18	15 01	4800	0932	NOAA8
002	60	1001	40 15	15 02	13853	1634	
003	61	1609	42 31	14 22	13867	1622	
004	62	0438	44 22	13 47	13874	0442	
005	62	1533	45 53	13 17	13881	1610	
006	63	0433	46 29	13 17	13888	0430	
007	66	0506	45 46	13 08	13931	0534	
008	66	1607	45 49	13 26	13937	1522	
009	67	1455	45 49	13 12	13951	1508	
010	71	1603	45 41	13 01	14008	1600	
011	72	0430	45 27	13 17	14015	0420	
012	72	1538	45 40	13 27	14022	1548	
013	73	1515	43 27	14 18	14036	1536	
014	74	0532	43 53	14 01	14044	0536	
015	74	1530	43 12	14 26	14050	1524	
016	75	1515	39 59	14 49	14064	1512	
017	76	0607	40 18	14 59	14072	0512	
018	76	1505	40 16	15 02	14079	1640	
019	77	0439	40 10	15 10	14086	0500	
020	78	0634	40 35	14 54	14101	0628	
021	78	0920	40 24	15 01	5056	0944	NOAA8
022	81	0820	40 53	15 01	5098	0838	NOAA8
023	81	1031	40 44	15 06	5099	7018	NOAA8
024	81	1548	40 42	15 02	14149	1538	
025	81	1952	40 54	15 04	5105	2002	NOAA8
026	82	0619	40 54	15 04	14157	0540	
027	82	0754	40 51	14 55	5112	0818	NOAA8
028	82	1527	41 03	14 44	14163	1526	

Table 8

Special Wind Measurement Runs

Series	Jday	Time Z Start	End	Comment
a	64	1230	1525	Comparison of Portaloggers 1 & 2 and Northern area toroid while latter still on ship.
b	70	1530	1600	Comparison of Portaloggers 1 & 2 and upper and lower anemometers on wheelhouse top.
	71	0916	0944	
	71	1352	1415	
c	75	1628	1700	Horizontal pole in front of ships's bow. Forward anemometer at 4 m. from ship.
	75	1941	2011	
	76	0925	0936	
	76	1013	1046	
d	76	1127	1207	As above but forward anemometer at 5m..
e	76	1335	1400	As above, outer anemometer at 4 m. approximately.
	76	1847	1856	
f	77	1454	1624	Mast mounted vertically in bow. Series ended when Portaloggers damaged - about 0810Z/79.
	77	1752	1812	
	77	2020	2035	
	78	0736	0755	
	78	0940	1001	
	78	1024	1033	
	78	1112	1235	
	78	1423	1443	
	78	1654	1710	
	79	0629	0650	
	79	0750	0756	

Table 9

Shipborne Wave Recorder Runs

Day No.	Time on	Time off	Comments
64	1422	1619	Start roll 1. Steaming.
66	0523	0543	Hove to.
66	1325	1345	" "
66	1940	2000	Steaming
67	0718	0738	"
67	1509	1536	"
67	2100	2115	"
68	0537	0557	Start roll 2. Steaming.
68	1615	1635	Steaming
68	2002	2022	"
69	0630	0652	"
69	1703	1728	"
69	2112	2134	"
70	0636	0658	"
70	1545	1603	Drifting, CTD yoyo.
70	1952	2100	" " "
71	1614	-	Hove to. Ran off end of chart.
72	1011	1046	Start roll 3. Hove to.
72	1548	1630	Steaming, 5kts.
72	1805	1825	Hove to.
73	1231	1253	" "
73	1947	2008	" "
74	0615	0635	" "
74	2102	2117	Steaming
79	1005	1030	"
80	1509	1527	"
81	1836	1858	"
81	2048	2104	Start roll 4. Hove to.
82	0930	1030	Hove to, spar recovery.
83	1748	1815	Hove to, CTD. Steaming from 1810

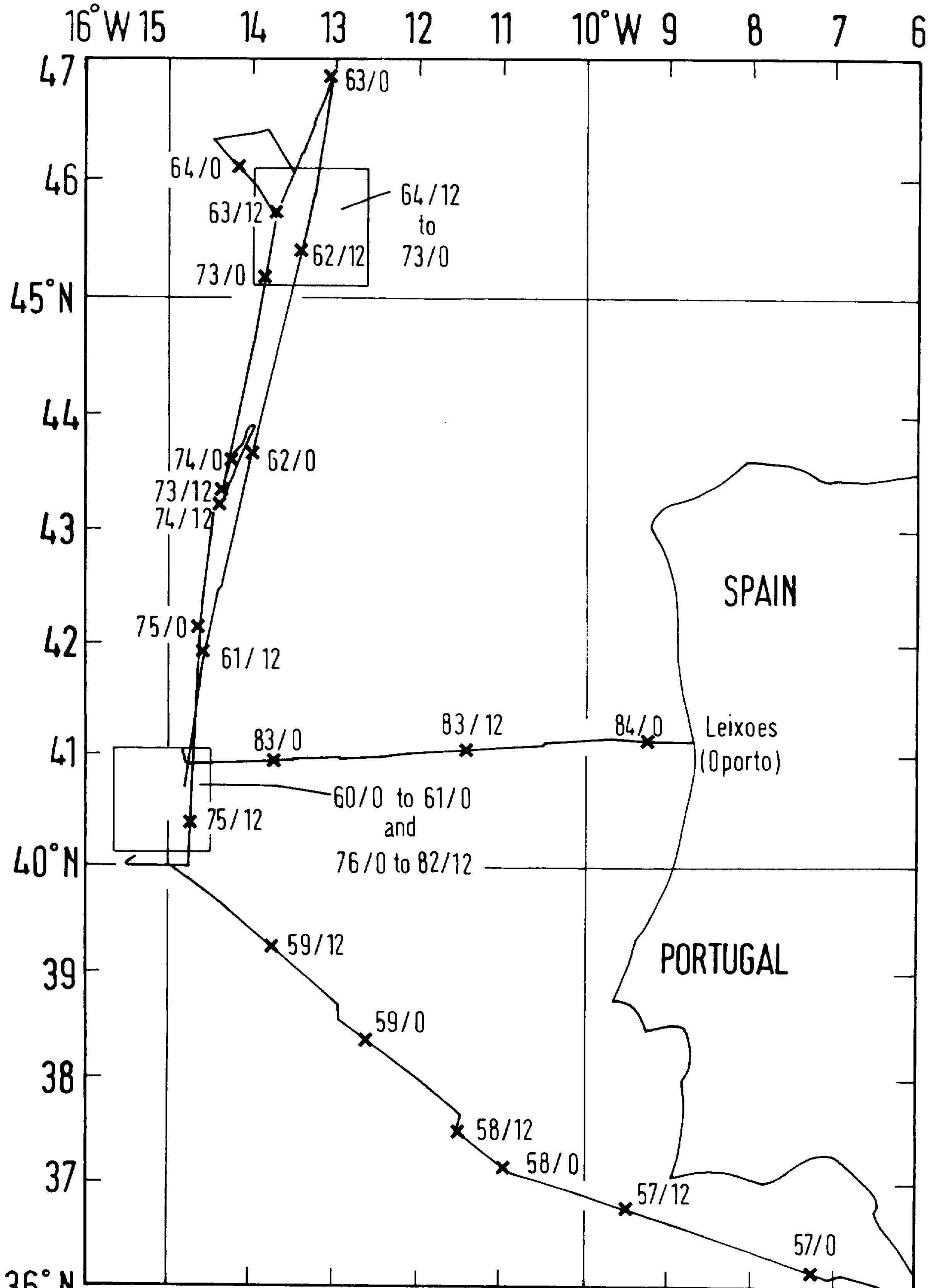

Fig.1 Cruise 145 Track Plot

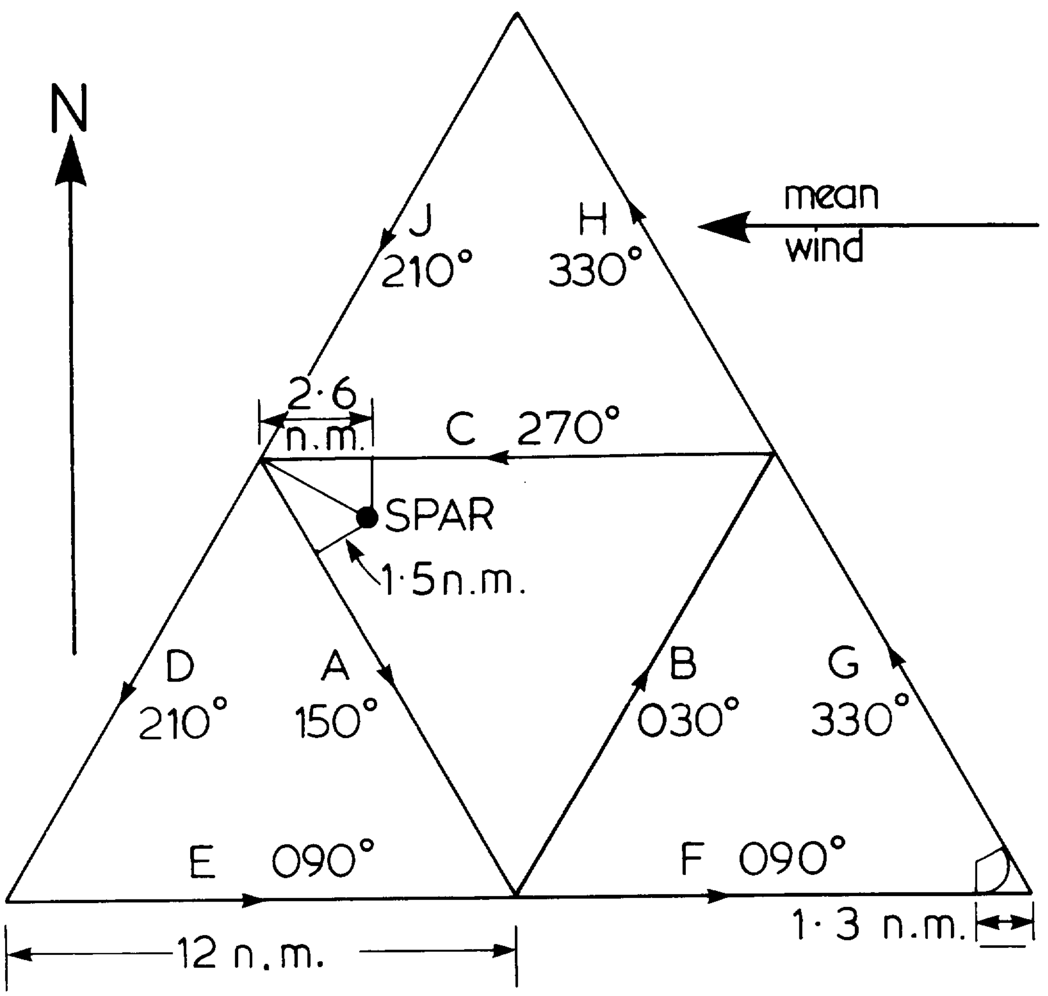

Fig. 2. Plan of North Site Sea Soar Survey

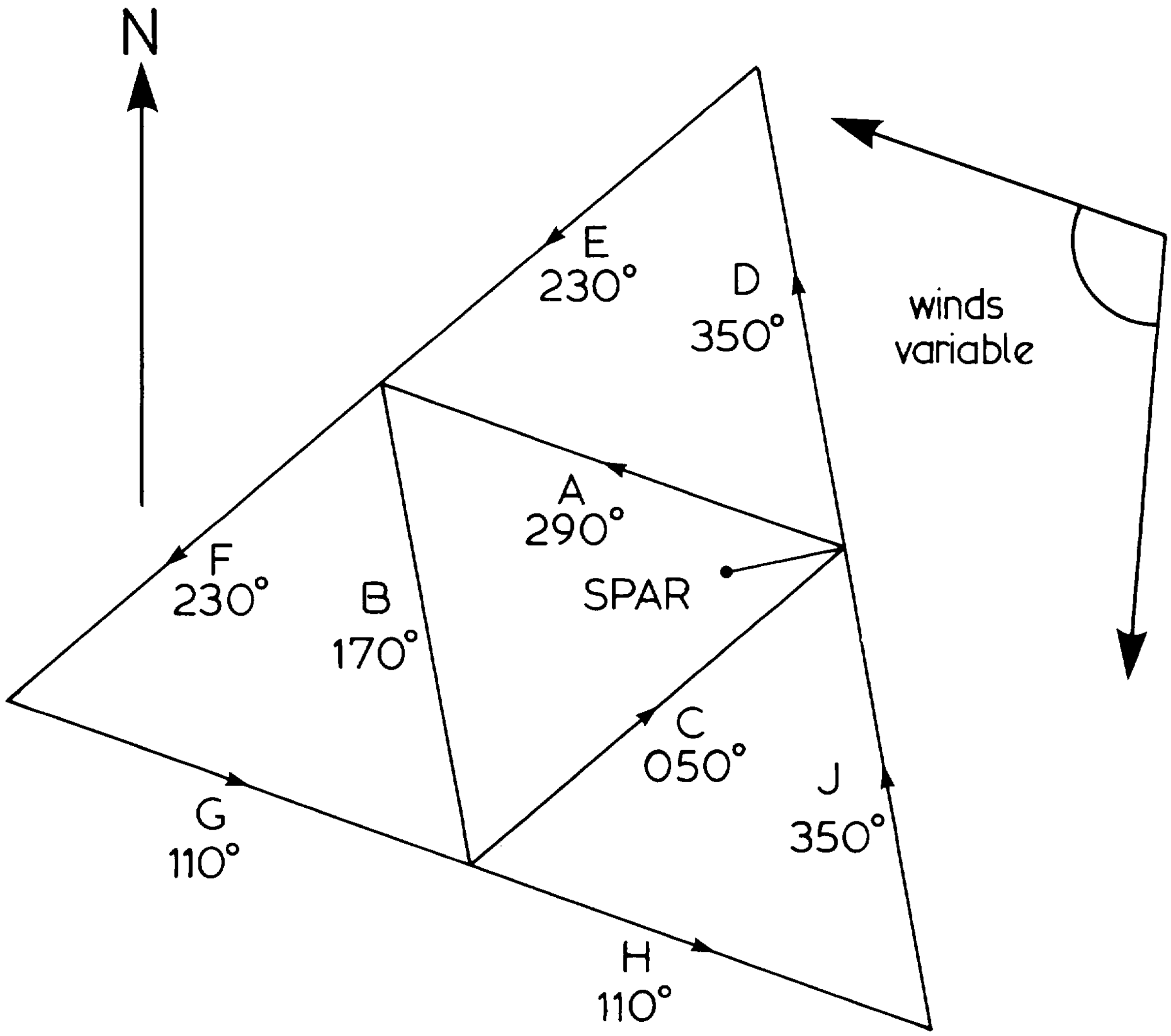

Fig. 3. Plan of South Site SeaSoar Survey

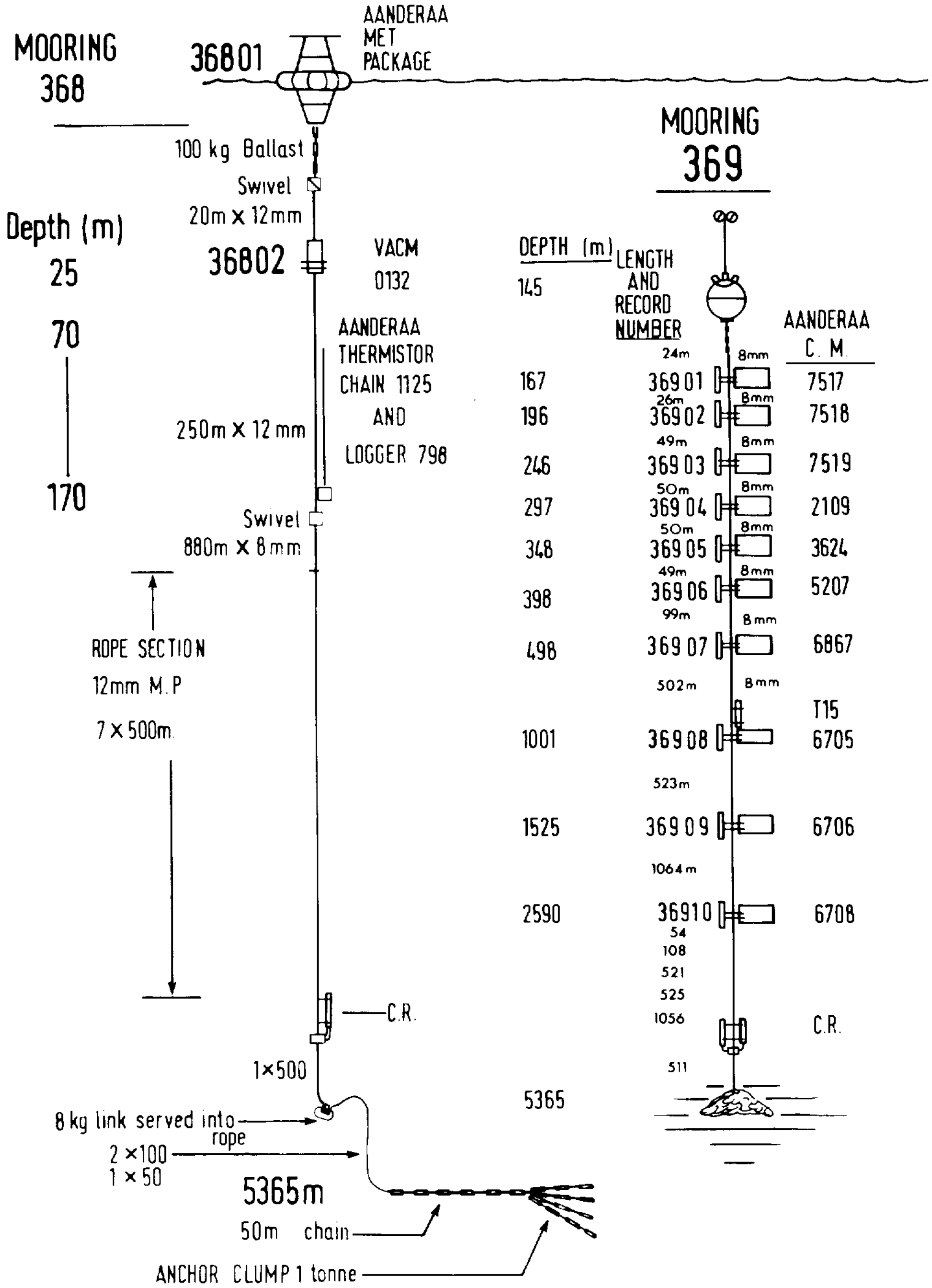

Fig. 4 (a) Moorings SOUTHERN SITE

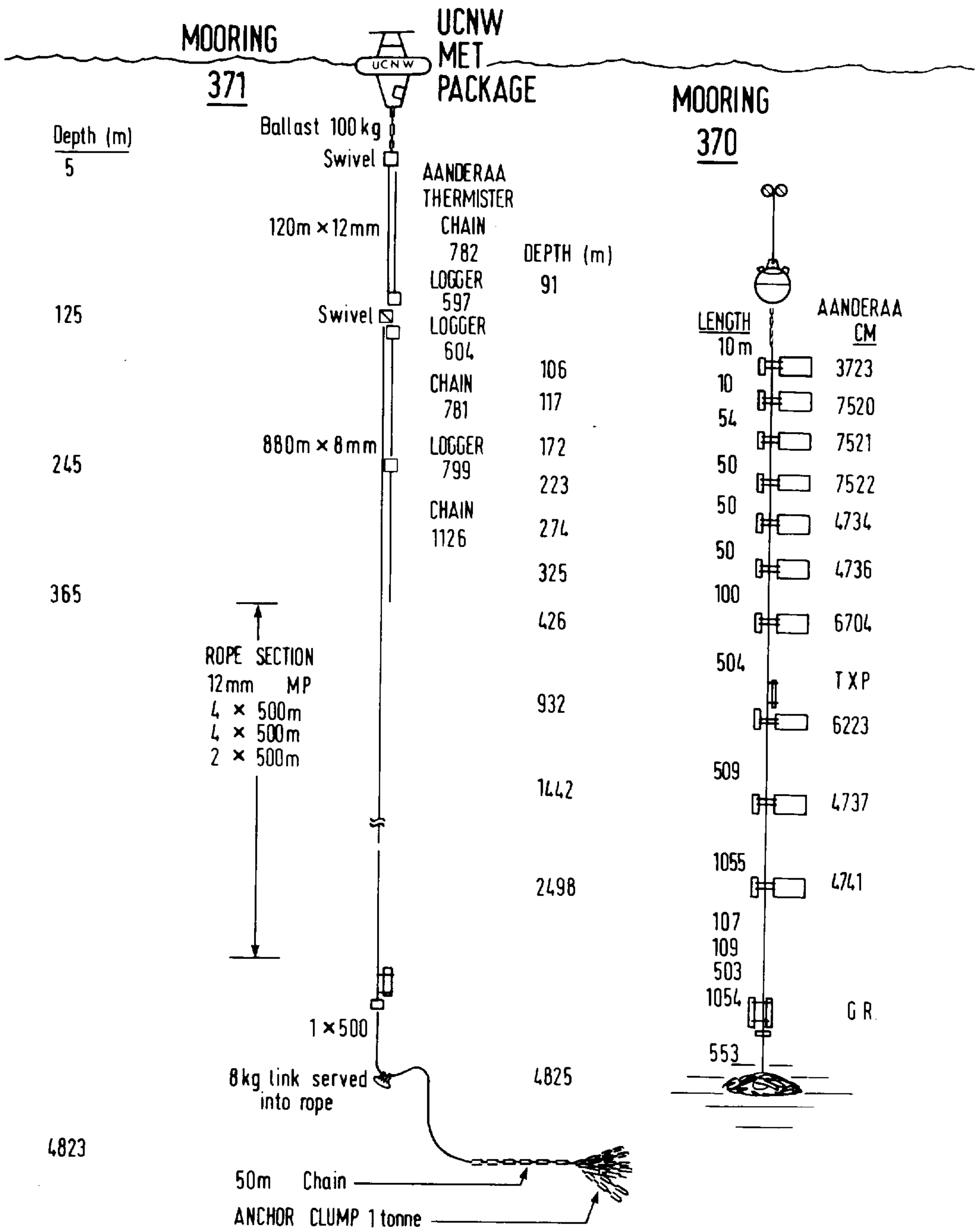

FIG. 4 (b) MOORINGS NORTHERN SITE.

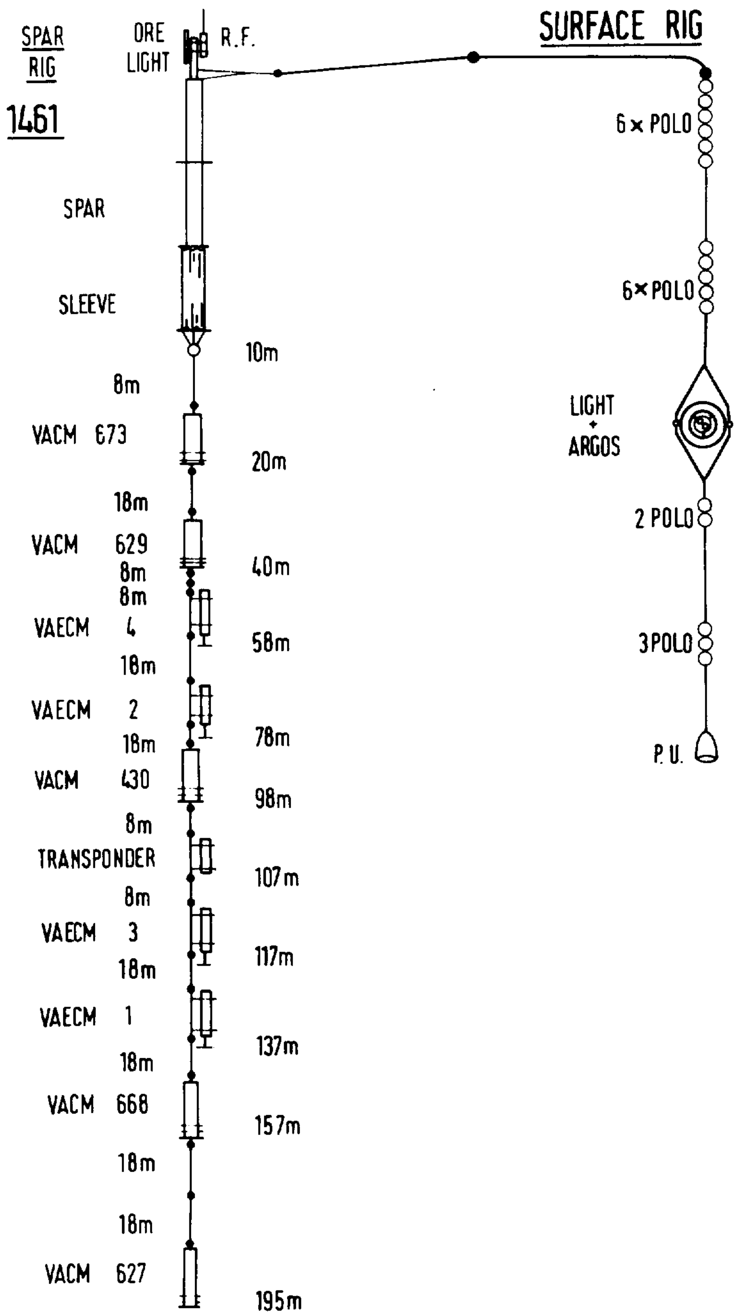

Fig.5 Example of Drifting Spar Rig

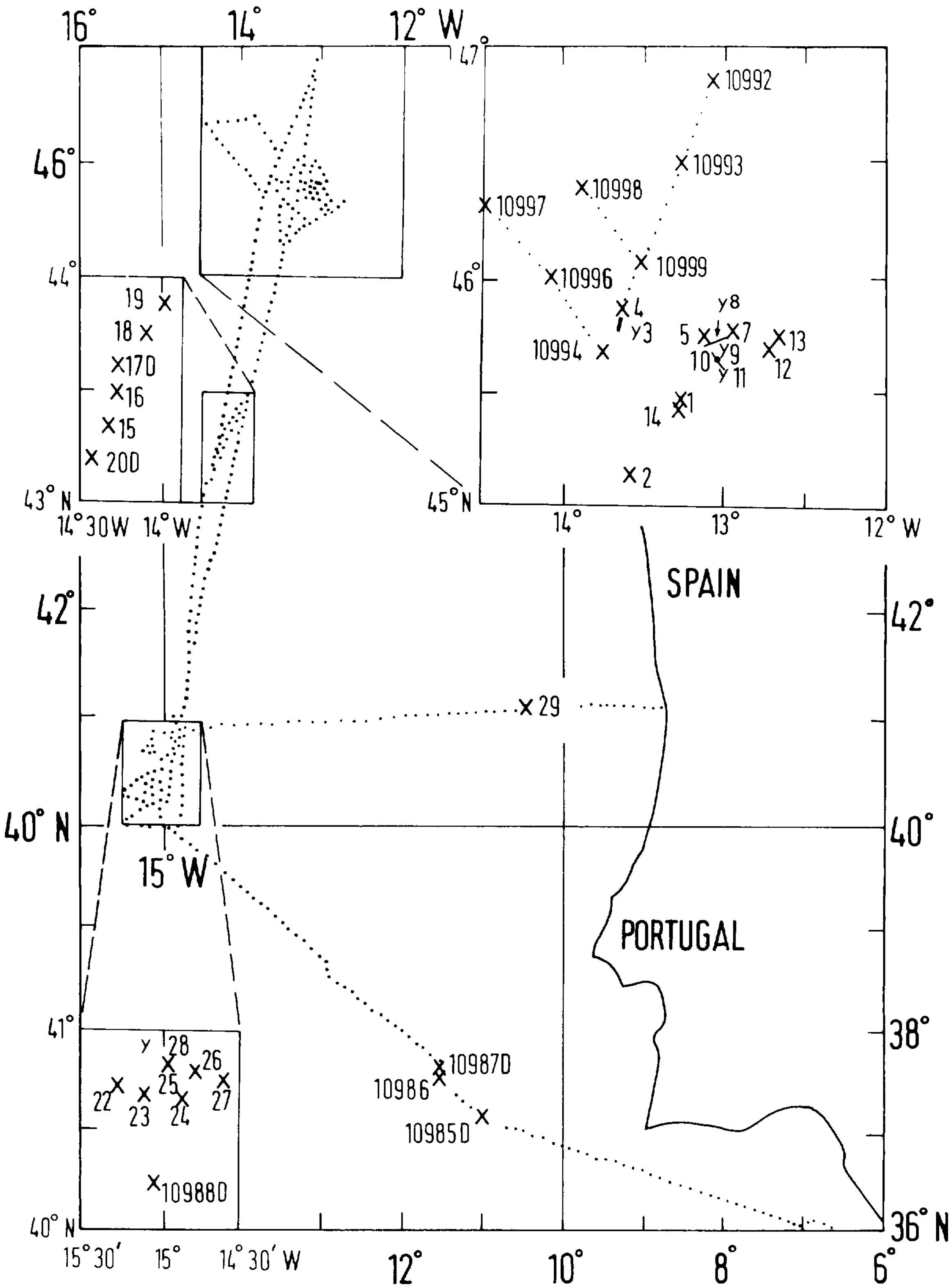

Fig.6 CTD stations on Cr 145. Stations labelled 1 to 29 are abbreviations for 11001 to 11029. D = full depth cast.
Y = yoyo

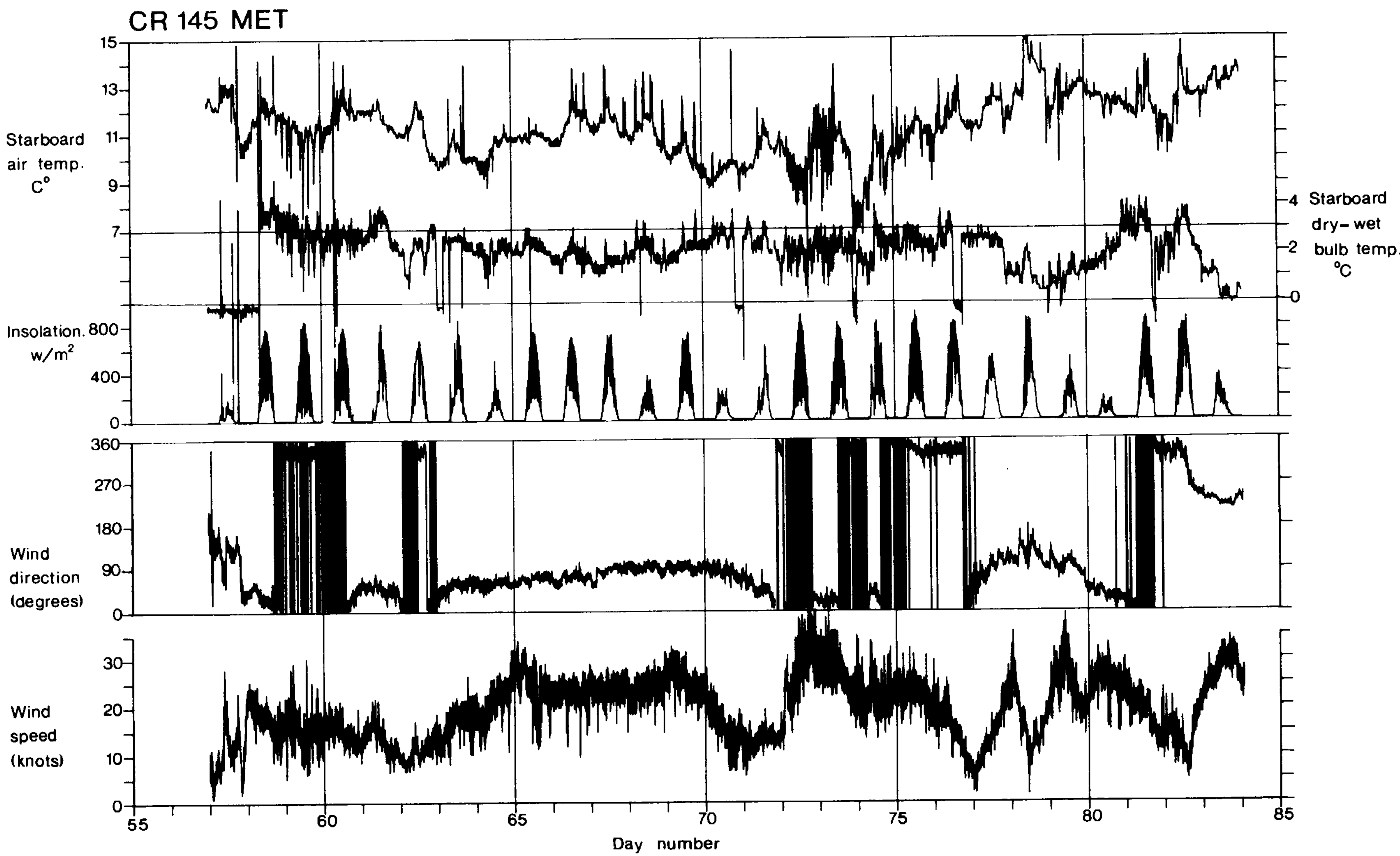

Fig. 7 1-minute time series of uncorrected surface met. obs.