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RRS CHARLES DARWIN
Cruise 32
3 April - 2 May 1988
A joint cruise of Southampton University, Department of Oceanography and the Institute of Oceanographic Sciences, Deacon Laboratory

A study of the upper density and current structure of the western equatorial Pacific[1]

August 1988

[1]This report should be referenced as **Richards, K.J. et al 1988**, RRS Charles Darwin cruise 32, 3 April – 2 May 1988. A study of the upper density and current structure of the western equatorial Pacific. *Southampton: Southampton University, Department of Oceanography. 19pp.*.

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CHARLES DARWIN
CRUISE 32 (1988)

Treat as Cruise Report until we receive one, then file with the Report.

11 May 88

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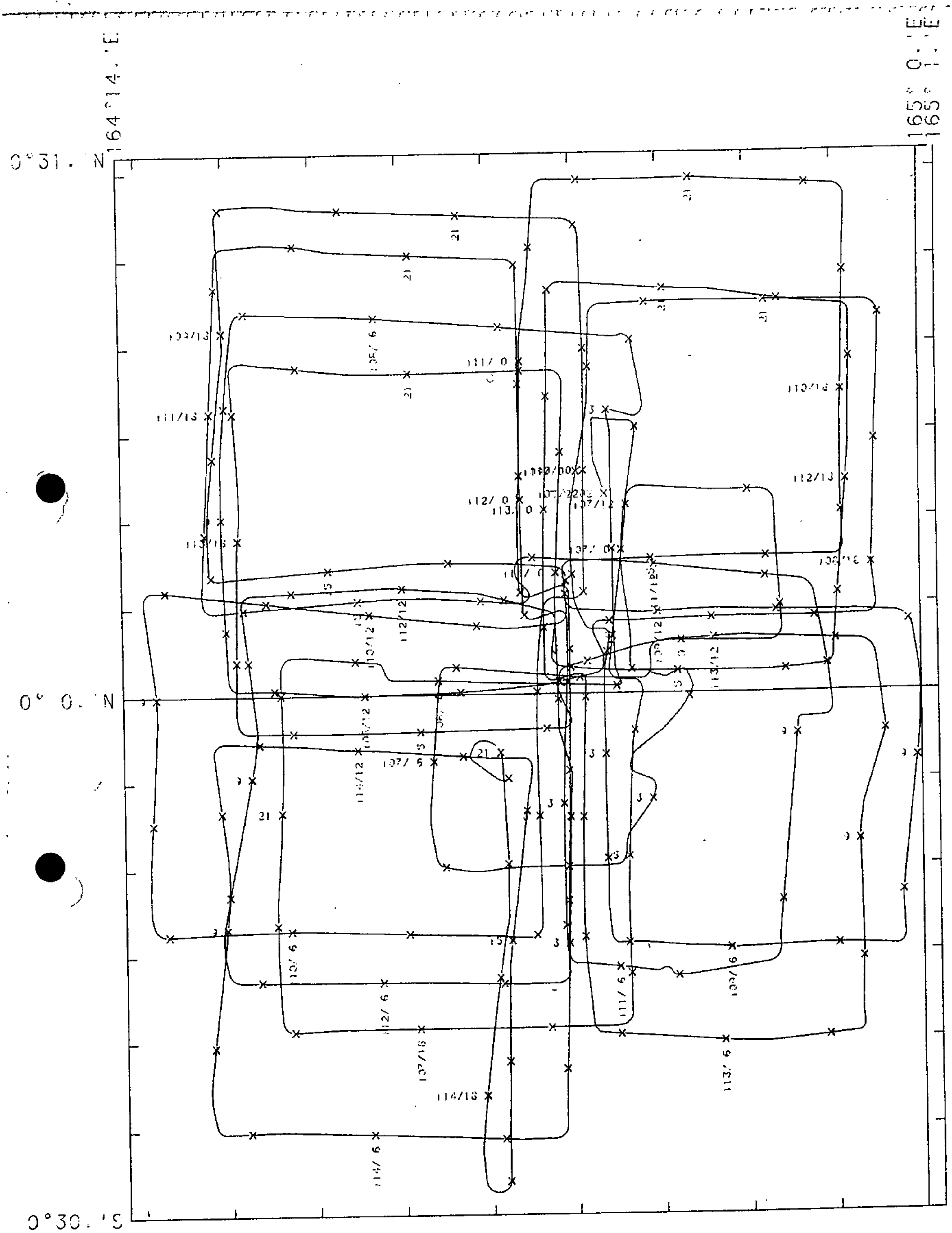

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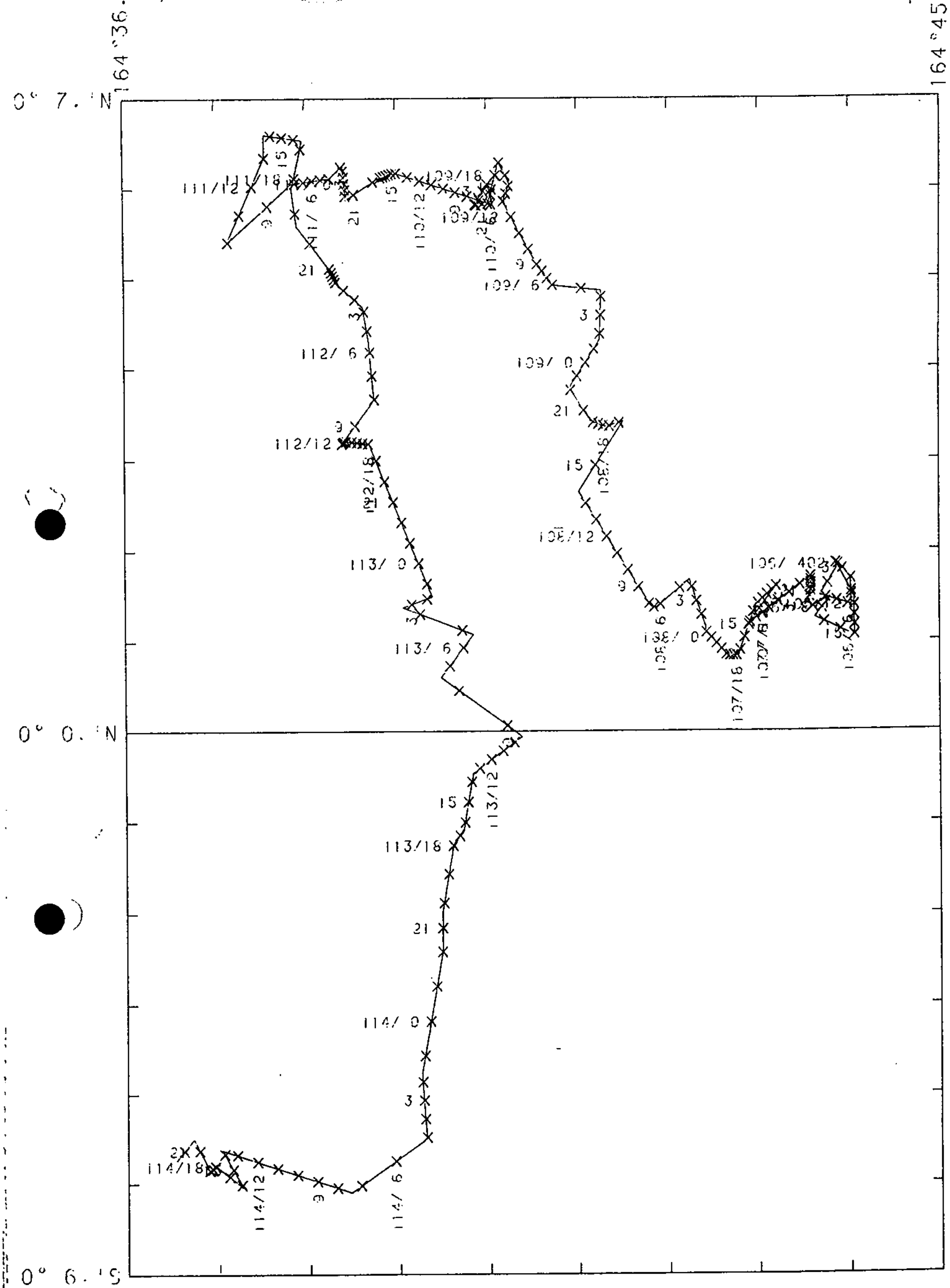
DARWIN CR32



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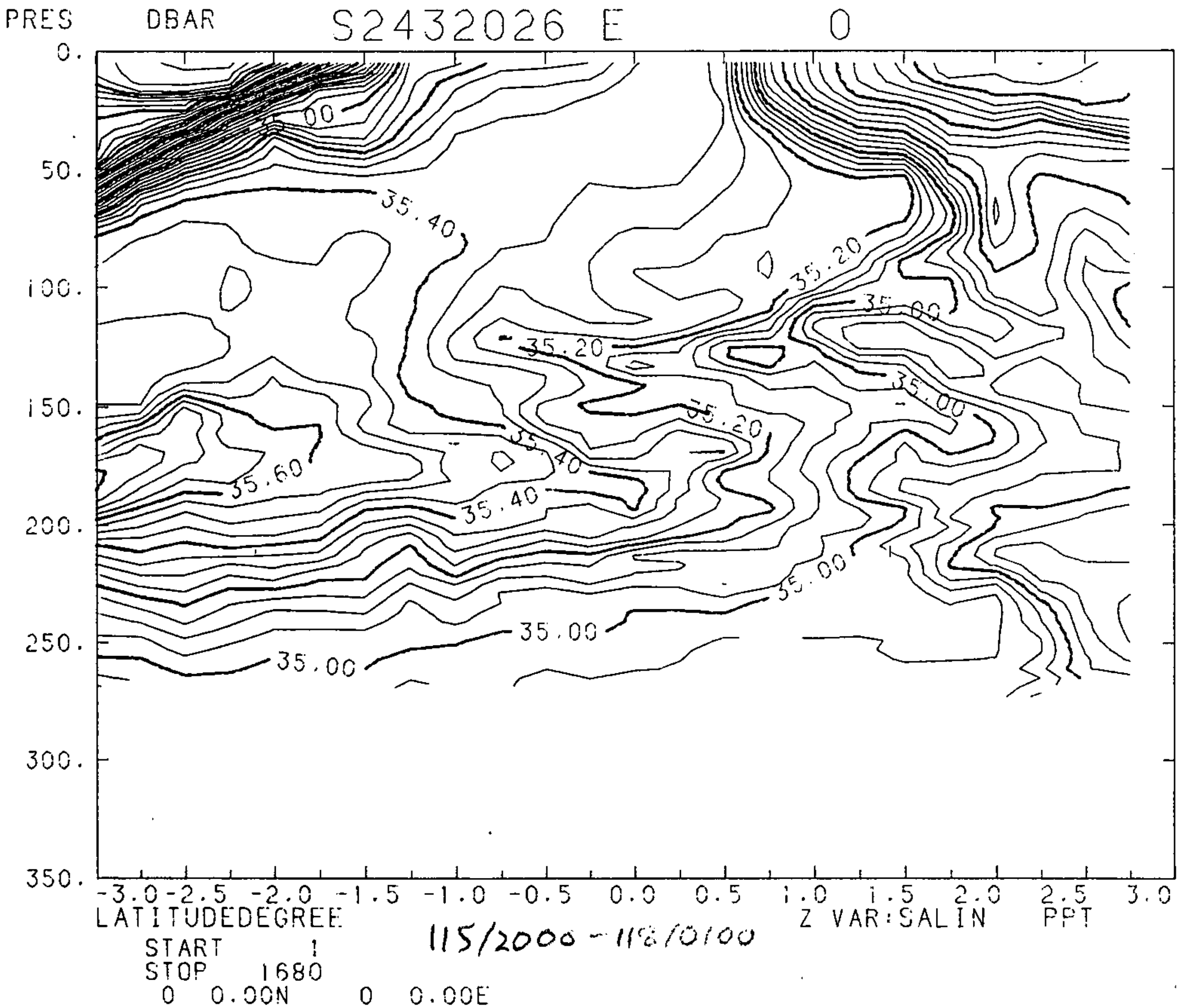
DARWIN CR32

CHARLES DARWIN CR 32



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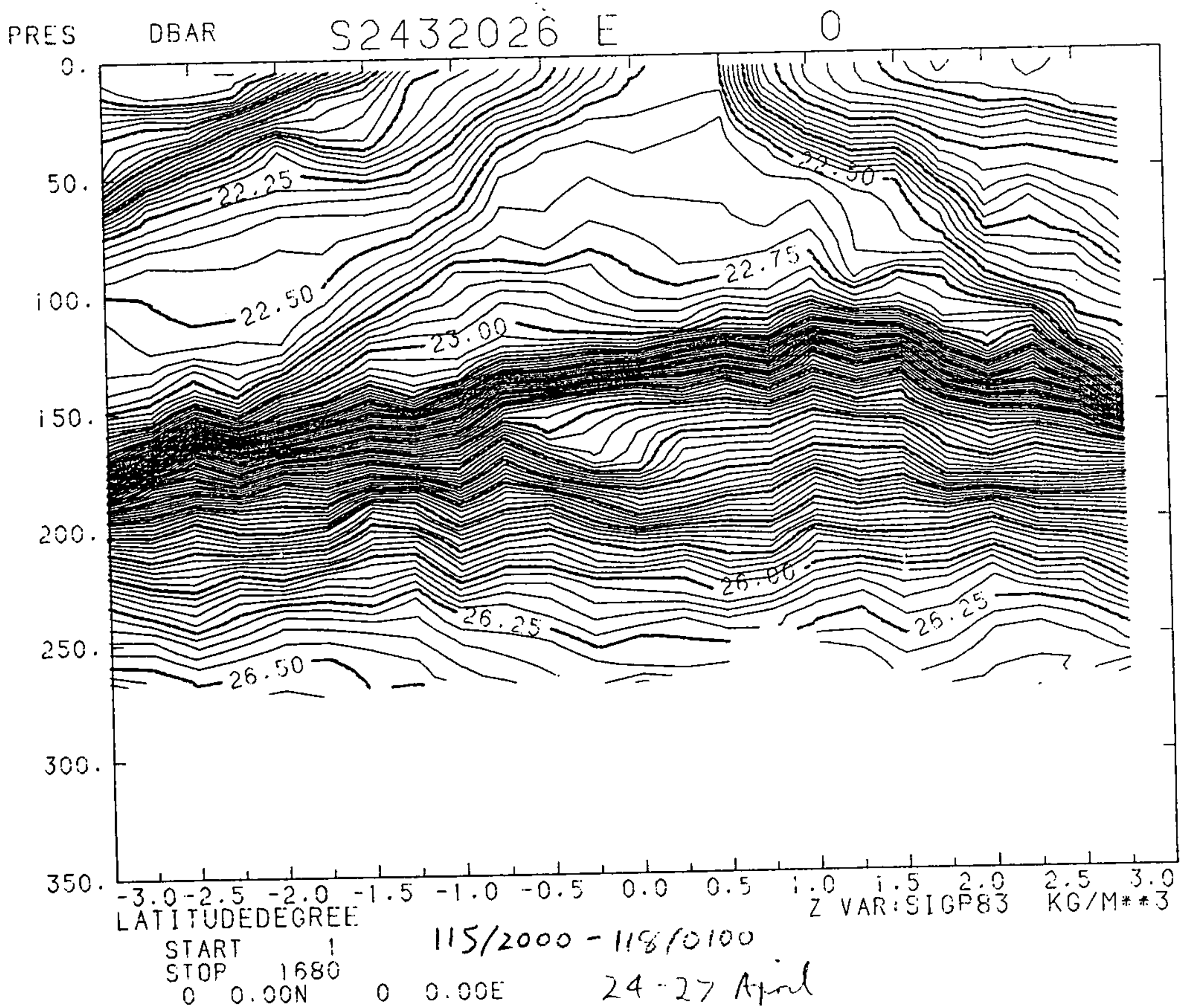

115/2000 – 118/0100

24-27 April

CHARLES DARWIN CR 32

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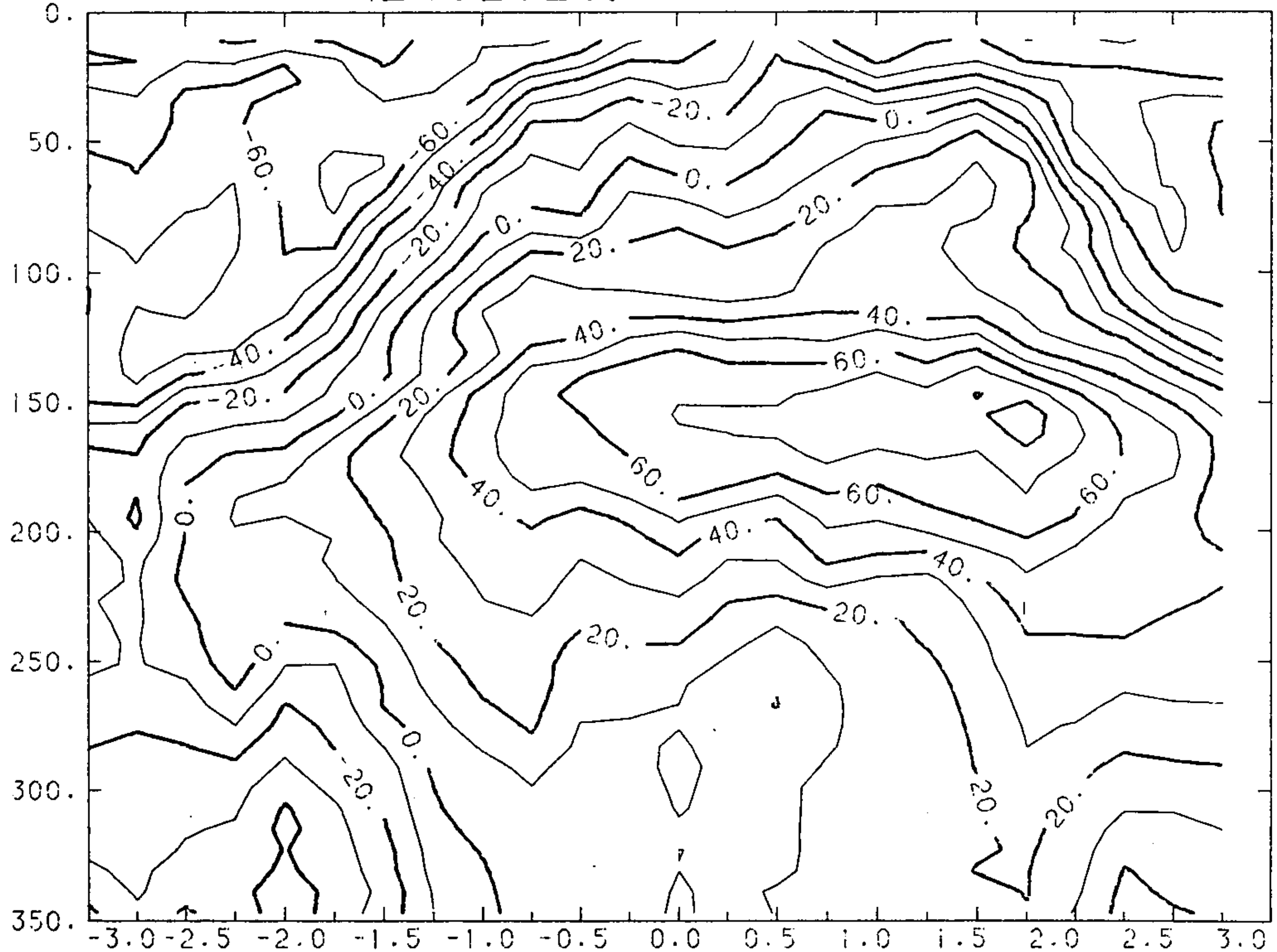

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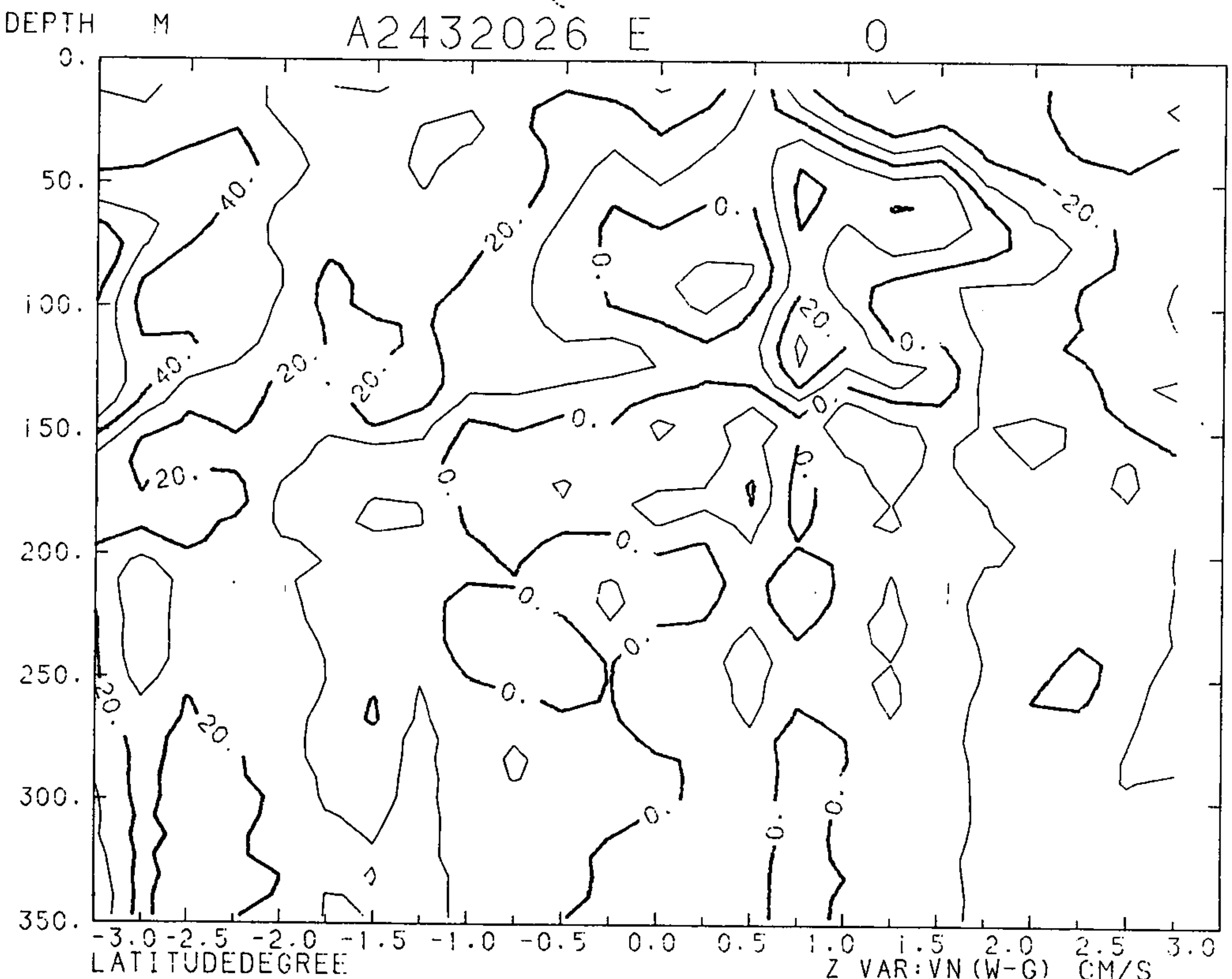
CHARLES DARWIN CR 32



START 1
STOP 1536
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115/2000 - 116/0100

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Acknowledgements

It is a pleasure to acknowledge the willing and capable assistence of the ship's officers and crew in carrying out the work described in this report.

1 Cruise objectives and methodology

The cruise objectives can be divided into three components:

1. Large scale survey of the surface current and density structure.

   This was accomplished using the IOSDL SeaSoar and the ship mounted Acoustic Doppler Current Profiler. The survey consisted of (a) a section from 155^oE to 165^oE along the equator (only partially covered by SeaSoar), (b) a section from3^oN to 3^oS along 165^oE, (c) a CTD section from 3^oN to 3^oS along 165^oE with half degree spacing and (d) a repeat of (b) after the spar buoy deployment (see 2).

2. Determination of the diurnal variation and changes over a nine day period of the temperature and current structure of the the upper 150 metres of the ocean.

   A spar buoy was deployed with a string of five current meters. Attached was a toroid buoy with two thermistor chains and the IOSDL BERTHA. The deployment lasted nine days.

3. Determination of the heat and potential vorticity budgets.

   During the deployment of the spar buoy a SeaSoar and ADCP survey was conducted around the spar buoy in order to determine the horizontal advective effects.

2 Narrative

RRS Charles Darwin sailed from Lae, Papua New Guinea on her thirty second scientific cruise at 2330Z/ 3 April 1988 (year day 093). Course was set for the equator at 155^oE at 11 kts taking us past New Britain and New Ireland (see figure 1 for the cruise track).

The setting up of the PDP11 computer (for SeaSoar and ADCP logging and analysis), was accomplished on the passage leg from Singapore to Lae. Time was also taken on that leg to calibrate the ADCP. In view of the difficulties encountered in making the CTD and SeaSoar systems operational it was fortunate that the passage leg was put to advantage.

At 096/2150Z the ship hove to for a wire test on the midships winch (Station CD32001) to test the spooling after the refit at Singapore. The test had been delayed because the brake on the winch had been found to be seized. The wire was taken out to 3000m and the spooling found to be satisfactory. The PES fish was deployed and the course resumed whilst the CTD was being prepared.

The logging of the ADCP and thermosalinograph data started. The ADCP performed well throughout the cruise and provided invaluable real time information on the current structure down to 400m. Navigation is greatly aided by GPS. GPS was available approximately 8 hours per day and required to provide accurate absolute velocities from the ADCP. The first CTD station (CD32002) was performed at 096/0248. This was to test the system. A large number of bad data values were produced. The sea unit failed when at 500m. The fault was traced to the cable termination. The course was again resumed for the equator.

The equator was crossed at 096/1620. The ADCP profiles had been showing a large vertical shear between the westward surface current and the eastward undercurrent since $3^{o}S$. The intension was to cross the undercurrent on a zigzag course between $155^{o}E$ and $165^{o}E$. The deep eastward flow was, however, much broader than expected. It was decided to steam further north, first on a heading of 010° and then 045° until the edge of the undercurrent was encountered.

The deployment of the SeaSoar had been delayed due to a large number of mechanical and electrical problems. The first trial deployment was eventually done at 096/2100 (deployment 001). This was the first time that SeaSoar had been deployed from Drawin. The cable was fed through a block suspended from the aft A frame. Side strops on the block were used to control the sideways movement. Both the deployment and recovery procedures were found to be satisfactory. The cable itself, however, was not. After 2 and a half minutes data transmission ceased and SeaSoar was recovered. The fault was traced to the slip ring assembly in the winch which had seized.

The course was resumed and at 096/2147 a second test of the CTD system (CD32003) was done at $0^{o}50'N$ $155^{o}16'E$. After a few false starts the unit was taken down to 1000m. Bottle samples were taken on the up cast. It had been found that the reversing thermometers expected to be supplied by IOSDL were not on the ship. We therefore had to rely on the RVS laboratory tempertaure calibration of the CTD. Oxygen samples were drawn. It was subsequently found that the sulphuric acid supplied at Singapore was too weak and so no tritrations could be performed onboard.

By 097/0845 we had reached $1^{o}59.5'N$ $156^{o}23.6'E$. There had been no clear end to the deep eastward flow although the vertical shear had reduced in strength. Altered course to 135° to recross the equator.

The ship's speed was reduced at 097/2308 for a SeaSoar deployment (deployment 002a). The data transmission failed when the fish was at 100m depth and SeaSoar was recovered.

A second attempt at deploying SeaSoar was made in the afternoon (deployment 002b, 098/0236). The vehicle immediately dived to depth and had difficulty in rising through the undercurrent. This rectified itself after a few ups and downs (*Sic*). The data logging was good. The signal was lost after 8 hours. Upon recovery the wire was found to be at fault and was reterminated.

At 099/0047 the SeaSoar was again deployed (deployment 003). The vehicle failed to respond to signals to come up (again it went deep on launch). SeaSoar was recovered and course resumed at full speed on 135°. Fault traced to a control wire for the hydrulics shorting. The cable was reterminated again leaving only four wires in the cable (a bare minimum) functional. There was concern as to whether the cable would last the cruise. Morale was getting low.

Deployment 004 of the SeaSoar was started at 099/0753. This proved to be the first reasonable run of the SeaSoar which lasted 20 hrs (see tables 2 and 4 for timings and positions of each deployment). A workable towing speed was found to be around 7.5 kts which gave acceptable strain on the cable.

By 099/0930 we had reached $3°10'S$ $161°36'E$. No dramatic change in the vertical shear had been found as was expected from the previous northward ADCP run. It was decided to change course to 047° for the equator at $165°E$.

The SeaSoar continued until a hydraulic failure. The vechicle was recovered at 100/0415. The recovered unit showed water had got into the hydraulics. The spare hydraulic unit was fitted, which lasted to the end of the cruise.

The next SeaSoar deployment (005) was started at 100/0723. The vehicle responded well to begin with. The system failed at 100/1800 and the vehicle recovered. It was found to be yet another cable problem. This time one of the connections in the unit had failed. The course was resumed for the equator. Because of the numerous problems with the SeaSoar and in particular the cable the planned sections from $155°E$ to $165°E$ were only very partially completed

At 100/2225 the surface buoy of the PMEL mooring was sighted. Its position was fixed at $0°02.68'S$ $164°56.4'E$. In order to give adequate clearance to this mooring and the thermistor chain moorings at $2°N$ and $2°S$ the line of the $3^0N/3°S$ section was taken along $164°52'E$.

The first of the CTD stations (CD32004) on the section was started at 100/2256 on the equator. Water samples were taken on all stations. Also at this position the first deployment of the SUDO irradiance meter was undertaken (CD32005). The meter was attached to the CTD frame so as to have depth information and the wire lowered to 100m. The instrument was found to be badly adjusted which was rectified for subsequent deployments.

Then followed a series of CTD stations (CD32006-011) at half degree spacing to $3°N$, completing at 112/0737. Most stations were completed without incident except the $2°30'N$ station when the deck unit failed when the CTD was 200m from the surface on the up cast and the $3°N$ station when shortly after the beginning of the down cast the signal was lost requiring a cable retermination before redeployment.

The SeaSoar was then deployed (006) and the course set at 180°. The run continued until 103/0644 when the SeaSoar was recovered with suspected hydraulic problems because of bad flying. The fault was traced to the cable and a retermination took place. Steamed 7 miles north to regain lost ground and redeployed the SeaSoar at 103/0900 (007). The section was resumed.

At 104/1736 the SeaSoar was recovered at the end of the section, this time when planned.

The remainder of the CTD section from $3°S$ to $0°30'S$ was then completed (CD32012-017) with no problems finishing at 105/1945. The opportunity of calibrating BERTHA was taken at $3°N$. The sensors were bundled together and placed in a hessian bag to ensure the water around each sensor was of the same temperature. The unit was deployed off the stern using the A frame. This was subsequently changed to over the side using the crane at the request of the bridge so as to allow free use of the stern propellor. Upon recovery it was found that one of the connections on a sensor had come apart. The unit was redeployed on the $2°30'$ station. Also on that station the irrradiance meter was deployed (no station number) this time giving good results.

After the completion of the CTD stations the rest of the morning was spent in preparing the spar buoy and its instrumentation. Steamed westward so as to be 10 miles west of the PMEL mooring. It was expected that the buoy would drift westwards with the surface current. The mooring configuration is shown in figure 2. The toroid buoy and associated BERTHA and thermistor chains were deployed first over the stern using the A frame and then allowed to drift away from the ship. The current meter string was deployed from the midship winch and the spar buoy from the crane. The toroid and spar were then connected with polos and released at 106/0230.

Shortly after deployment it was noticed that the Argos beacon, which had been attached to the spar, had fallen off. This was retrieved and subsequently attached to the toroid buoy using the ship's boat.

Initial attempts at fixing the buoy proved to be only partially successful. It was later learnt that the transponder fitted to the mooring was not designed for this purpose. Its signal was quickly lost, although later experience showed that a signal was received up to 2 km distance from the buoy when abeam of the ship. The radio direction finder was found to be effective out to a range of 5-7 miles although it sometimes gave unreliable results. The ship's radar picked up the buoy at a distance varying from 3 to 5 miles. After some experience it was found that a combination of all three provided a reliable method of fixing the buoy. Whilst awaiting an Argos fix we steamed off to redo the equatorial CTD station (CD32019).

After completion of the CTD station the ship returned to remain hove to close to the buoy for the rest of the night. No Argos fixes had been received and we were loath to leave the buoy until there was confirmation that it could be returned to should we fail to find it during the survey. This also brought a welcome rest to the overworked technical support people.

The morning brought the first Argos fix. The next 8 days (106/2231 to 114/2128) were spent surveying around the spar with SeaSoar and the ADCP (SeaSoar deployments 008 to 011). The number of recoveries of the SeaSoar required to complete the survey was pleasingly small after the problems at the beginning of the cruise.

The survey pattern was chosen to be two figures of eight taking two days to complete each circuit (figure 3). This would allow the determination of both the heat and potential vorticity budgets. Since GPS was only useful for 8 hours a day the timing of the survey track was chosen so that the north/south legs coincided with GPS. The spar was fixed at 12 hourly intervals.

The track of the spar during its deployment (figure 4) showed that it did not drift with the strong westward surface current. Because of this the ship was navigated with respect to the earth rather than the surface water as on previous spar deployments.

The SeaSoar had problems flying on the east/west legs because of the large vertical shear in the current. Several speed changes and some manual intervention of the flying was required on these legs.

The spar buoy was grappled at 144/2222 and recovery completed by 115/1142.It was noted that the cable to one of the sensors of BERTHA was broken and the connection to the logger had been pulled out. Because the Sea Data reader onboard proved to be not working the length of the recorded dataset could not be ascertained. (It was later discovered that BERTHA had failed on deployment).

Set course at full speed for $3^{\circ}N164^{\circ}52'E$ for the start of the second SeaSoar north/south section.

During the deployment of the SeaSoar at $3°N$ (012, 115/1819) concern was expressed over the signal and the vehicle was recovered. The concern proved to be groundless and the SeaSoar was redeployed (014, 115/1946). The SeaSoar behaved well and was kept in the water until the end of the section at $3°21'S$ with recovery at 118/0100.

The recovery of the SeaSoar marked the end of the scientific programme and all data logging ceased. The PES fish was recovered and course set at full speed for Suva. Data processing continued until Sunday 1 May when the PDP11 was dismantled.

3 Individual project reports

3.1 SeaSoar (Gwilliam, Birch, Goy, Davies, Griffiths)

After initial problems with the SeaSoar control electronics and the winch slip ring assembly, the system was first deployed on Day 098. Approximately 311 hours of data were collected and processed by the PDP11 computer as well as being archived on 40 Digi Data magnetic tapes. The times for each deployment are given in table 4. The main problem throughout the cruise was cable failure due to its very poor condition from the start of the cruise. A total of ten reterminations had to be made, reducing the cable length by 50 metres. The condition of the cable at the end of the cruise is such that of the 7 cores, two are shorted to screen, two shorted to each other and the remaining cores as individuals. This cable is not recommended for further use.

3.2 Spar buoy (Goy, Birch)

The configuration of the instrumentation is shown in figure 2.

Prior to deployment all instrumentation below the toriod was preconnected on the afterdeck. The BERTHA cable and thermistor chains were supported on Kevlar rope by plastic clips at 1m intervals.

The toroid was deployed through the stern A frame and allowed to drift astern, controlled by a recovery line leading over the starboard quarter. The instrumentation was paid out over the stern by hand. Finally the ballast was cut away and the toroid secured approximately 100m off the starboard quarter.

Because of its length the spar was deployed over the starboard side. The string was lowered anchor first off the starboard A frame, stopping off to insert the instrumentation. Ths spar was hoisted on the sea crane and clipped into the top of the string taking the strain through the spar. While the spar was lowered into the water, the toriod was hauled alongside on the aft capstan. Surface rigging and flotation was connected between the spar and the toriod and the whole allowed to drift away. The spar was observed to float approximately 1m up the surface piercing spar.

The spar was tracked using Argos, a radio direction finder and acoustic transponder. Shortly after deployment the Argos beacon was seen to float away from the spar. This was subsequently attached to the toriod with the aid of the ship's boat. Both buoyancy units were lit at night by O.A.R. flashing lights.

Both the spar and toroid were recovered from the starboard side using the sea crane and starboard A frame. During recovery it was noted that the top 4 meters of the BERTHA cable had become detached from the Kevlar and the cable between sensors 7 and 8 had pulled adrift. VAECM No. 2 sustained damage to the EM head when it fouled the wire.

Both deployment and recovery were carried out under almost ideal conditions and no major problems were encountered.

3.3 CTD stations (Richards, Pollard, Phillips)

Sixteen stations were worked, all from the midships winch and to a maximum depth of 2000m (see table 1). The instrument package consisted of a Neil Brown deep CTD probe, a multisampler rosette, a vertically mounted flourimeter and a horizontally mounted 25cm transmissometer.

Before stations commenced 50m of CTD cable had to be cut off before the condition of it was suitable for terminating.

The data were recorded on the level B ship's computer, on the PDP11 and backed up on audio tape. It was impossible to use the IOSDL deck unit and hence the DigiData unit because of incompatibility of signal rate.

Problems encountered included on station CD32008 the PDP11 started to receive noisy data. This was traced to the electronics of the deck unit and not the signal from the CTD. Still the exact source was not tracked down and stayed the same throughout the cruise.

On the following cast CD32009 the signal was lost during the upward profile. This was rectified by reterminating the cable.

During cast CD32011 the transmissometer started to give a false profile. This could have been due to pressure effects or the temperature compensation. It was not possible to rectify this fault on board.

A number of the sample bottles proved upon recovery to be leaking from their seals. Leaking bottles were replaced by spare IOSDL bottles that were being carried.

3.4 Thermosalinograph calibration (Taylor)

The salinity of the the upper 4m of the water column was monitored continually by means of a thermosalinograph plumbed into the ship's non toxic supply. Calibration of this instrument was achieved by drawing for salinity determination using the Guildline Autosal.

The thermosalinograph was shown to yield a good linear response although a slight offset was observed. Midway through the cruise a problem developed in the conductivity cell. The response of the cell changed and a second calibration was necessary.

The calibrations obtained were as follows:

094/0000 to 107/0600

$$\text{Truesal} = 1.10144\ \text{Tsgsal} - 0.5794$$

110/2130 to 118/0132

$$\text{Truesal} = 0.9829\ \text{Tsgsal} + 0.3723$$

3.5 SeaSoar data processing (Pollard, Read, Taylor, Barkmann)

CTD and SeaSoar CTD data were passed in ship message protocol (SMP) ASCII format to the PDP11/34, where they were processed 2-hourly, edited, plotted and relatively calibrated to fit a smoothly varying T/S relation. Every 12 hours, the 2 hourly raw files were appended to form files named SS0320nn, where nn is the Run Number (tables 2 and 4). These were merged with the navigation, gridded and contoured against pressure and distance run.

Salinity samples were drawn hourly and later halfhourly off the non-toxic supply, analysed and merged with the relatively calibrated, gridded SeaSoar data using the 3-7m vertical average and 4km horizontal average values. It was found that useful calibration values could only be extracted when the horizontal gradient (difference between adjacent 4km averages) was less than 0.020 psu/4km. On several calm sunny days a strong diurnal vertical gradient also formed (salinity and temperature decreasing downwards) and these periods were also useless for calibration.

The number of samples taken and number usable are shown in table 4. The SeaSoar salinities were low by an amount that reduced from 0.078 tp 0.029 psu with time. Standard deviations were around 0.010 psu with worst possible errors estimated to be 0.030 psu on one or two occasions when severe fouling made recovery of relative calibration difficult. These can be more accurately calibrated by later recomparison of the T/S curves from repeated circuits of the drifting spar.

After absolute calibration using the values shown in table 4, the two sections from 3N to 3S were regridded to 0.25 degree of latitude averages and recontoured.

3.6 ADCP calibration and processing (Pollard, Read and Jia)

An RDI acoustic doppler current profiler (ADCP) transducer was fitted at Singapore prior to this cruise. On the passage leg from Singapore to Lae, six calibration runs were done, during which the ship changed course by 90 degrees every 20 minutes, using GPS to give the velocity of the ship relative to ground, and deriving misalignment angle and scaling factor for the doppler velocities of the water relative to the ship by assuming that the current was unchanged before and after each turn. The misalignment angle ϕ is the clockwise offset of the ADCP foreaft beam from the ship's head. The scaling factor A is the ratio *true speed/adcp speed* by which the ADCP must be scaled up.

It was found that:

1. A is different for bottom track and water track mode.

A (bottom) ranged from	1.0044 ± 0.0005
to	1.0019 ± 0.0008
A (water) ranged from	1.025 ± 0.0028 (11 knots)
	1.016 ± 0.0077 (8 knots)

to 1.004 ± 0.0028 (6 knots)

2. ϕ was similar for bottom and water track modes.

Values ranged from	3.4 ± 0.014^o
to	4.2 ± 0.013^o

The ADCP velocities were therefore all corrected by using the 8 knot values

$$\phi = 3.7^o$$
$$A = 1.016$$

throughout the cruise, as 8 knots was the desirable SeaSoar tow speed. At over 8 knots bubbles diminish the ADCP data greatly. Up to that speed usable returns were received down to 500m.

150 second ADCP average profiles with 64 bins from 11m to 515m were recorded on an IBM PC and passed to the PDP11/34 throughout the cruise. The IBM PC was reinitialised daily to reset the clock and backup the data. The 150s profiles were plotted as relative velocity profiles every 2 hours, then appended, averaged over 4 km, contoured every 12 hours and archived as files AD0320nn (table 3).

Despite the passage leg calibrations, the absolute velocity contours show sudden shifts at all depths a few times in every 12 hour contour plot. These appear to be caused by a lack of EM log calibration, acceptance of satellite fixes too close together, changes in ship speed or direction, large heading changes during an averaging interval, etc. Careful postcruise analysis will be necessary.

3.7 Navigation (Pollard, Read, Brook)

In order to grid and contour SeaSoar and ADCP data against distance run the *best* possible navigation must be determined every 12 hours. GPS fixes were available with *PDOP* less than 7 daily from about 2000Z to 0400Z. For the rest of the time transit satellite fixes were combined with the ship's 2-component EM log to derive the track assuming a constant current between good satellites to adjust the DR. The same technique was used to merge the first good GPS fix with an earlier good satellite fix and similarly the last good GPS fix with a following good satellite fix.

This procedure was done manually using interactive programs on the PDP11/34 for most of the cruise. Comparisons with the *bestnav* output from the Plessey Level C, in which the above procedure is automated, showed excellent agreement, with some provisos, with the manual method. The *bestnav* output was used for the last week of the cruise.

Provisos are:

- *Bestnav* uses all GPS fixes passed to it, assuming that they have been filtered already. The navigation officer accepts fixes with *PDOP* less than 40 which he finds to be navigationally useful. However, on the passage leg from Singapore to Lae the ADCP was calibrated in bottom track mode against GPS. With *PDOPs* less than 10 the ratio of *GPS ship speed/ADCP ship speed* $= 1.0044 \pm 0.0006$, i.e. the ADCP underreads by 0.44 ± 0.06. With *PDOPs* between 10 and 40 this ratio varied from 0.94 to 1.02. Thus GPS estimates ship speed with an error as large as 6% for 10-40 *PDOPs*. While this is navigationally useful it is inadequate for deriving speed to a few cm/s for accurate current estimation. A filter was therefore inserted to pass only GPS fixes with *PDOP* less than 7 (the handbook recommended value) to the ***bestnav*** program.

- Both manual and automated culling of satellite fixes removes all those elevations less than 10^o or higher than 75^o and with more than 4 iterations. However, automated culling does not remove fixes close together in time to satisfy these croteria. It was found that fixes only 15 minutes apart were used by ***bestnav*** causing step changes in currents of 30-40 cm/s. This is because two fixes with, say, 500m error in each cause an estimated current error over 15 minutes of 0.8 m/s. For ADCP velocity calculations therefore ***bestnav*** should in future only run after manual culling of transit fixes to accept fixes approximately an hour or more apart and as evenly spaced in time as possible.

- Because of problems with the EM log on the passage leg (failure to deploy, attempts to remove a port bias), it had not been calibrated. It was believed that errors in the log calibration would be extracted in a spurious current by forcing the DR to transit satellites. Examination late in the cruise showed that this is not the case. While a miscalibrated log results in only minor errors in the cruise track (and hence distance run), it can cause serious (0.1-0.5 m/s) errors in the estimated velocity of the ship relative to ground, changing suddenly at each transit fix. These are reflected in step changes in ADCP calculated currents. The navigation for Cruise 32 will therefore have to be reworked, and in future the EM log must be calibrated at the start of a cruise.

3.8 Meteorological measurements (Birch, Wells, Barkmann, Whitcombe, Jia)

MultiMet sensors were deployed during the passage leg from Singapore to Lae. The forward mast was instrumented with sensors measuring wind speed, wind direction, dry and wet bulb temperatures with an aspirated Psychrometer and two radiometers measuring downward short and long wave solar radiation. On the wheelhouse top starboard side a second suite of wind and air temperature sensors, identical to the forward mast were deployed. The two sensor sites were chosen to ensure that at least one sensor suite was always in air uncontaminated by the ship's superstructure for all relative wind directions.

Recording of the data was commenced on day 095 at 2345Z and was terminated on day 118 at 2100Z. The data were recorded to Sea Data cassette and using MetMan software to computer discs. Throughout this period a hard copy time series plot was generated. Hardware problems with MultiMet resulted in some data loss. The fault could not be isolated but the implimentation of a Watchdog circuit, which automatically rebooted the system after a ten second delay, minimised the system downtime. This fault highlights the problem of supporting MultiMet hardware without adequate spares and sufficient test equipment.

The wind, air temperature and radiometer sensors worked throughout the cruise. The sea temperature sensor was replaced on day 113 after leaking and losing calibration. The monitoring of the ship's gyro via a Level A interface was not possible until day 107 as the software initially provided did not function correctly. Measurement of the ship's speed was not possible as the EM log is not calibrated and has a permanant offset to starboard.

In addition to MultiMet, WMO observations were taken at 3 hourly intervals throughout the cruise. Hand held aspirated psychrometers were used whilst all other measurements (wind direction and speed, ship's heading and speed and sea surface temperature) were taken from the ship's bridge. *Champagne* rainfall gauges were located on the forward mast and on the wheelhouse top with measurements taken at 3 hourly intervals. 24 hour rainfall samples were also taken from two plastic gauges mounted on the port and starboard side of the wheelhouse top for Dr Tranter, SUDO.

An all sky camera was positioned on the wheelhouse top and exposures on Ilford Pan F135 film were taken at 30 minute intervals for ten hours each day of the cruise.

3.9 Weather report (Wells)

The weather throughout the cruise was typical of conditions to be expected in the western equatorial Pacific at the end of the austral monsoon. The dominant wind flow was from E-NE with fluctuations from between NW and SE. The northerly winds were predominant in the first few days of the cruise whilst easterly winds were most frequent in the remainder of the period. Mean wind speeds were generally below 10 knots throughout the period. However, gusts of between 20 and 30 knots were reported in showers on days 096 and 101. In all there were 10 days of measurable rain with the majority of the rain occuring in heavy showers associated with cumulonimbus developments. Line squalls were observed on two occasions (days 099 and 102) and lightning seen on four occasions.

The sea surface temperature ranged from $27.7°C$ at the equator on day 114 to $29.9°C$ on day 119. The wind waves were between 0.5 and 1.5m high, whilst swell ranged between 1.0 and 2.5m high.

3.10 Irradiance meter (Wells, McEwan)

The irradiance meter was lowered on two occasions on the CTD frame. Adjustments to the gain of the amplifer were required to avoid saturation under high irradiance conditions (the solar irradiance at the sea surface reached 1100 Wm^{-2}). On the last occasion the instrument was lowered to a depth of 80m (day 105) and the output voltage V ranged from 10 mV (saturation at 10m) to 0.25 mV at 80m. By plotting $\ln V$ with depth for both downward and upward casts, and comparison with the Jerlov optical water types, it was found that the water type was between Ia and Ib. Further casts were not made.

3.11 Radiometer (Barkmann, McEwan, Taylor)

The SUDO infrared radiometer was used to determine the skin temperature of the sea surface. The instrument measures the intensity of infrared radiation with wavelengths in the range 7 to 15 micrometres. The instrument was installed on the port side of the bridge deck at an angle of 45° to the vertical. This allows the radiometer to view the undisturbed sea surface. The instrument was controlled, and data logged, by a BBC microcomputer.

Test measurements were made in order to study the behaviour of the instrument in tropical conditions. The sampling interval was set to five minutes. The original resolution of the detector output was found to be not sufficient. Adjustments to the signal amplifer improved the situation. Data was collected on days 116 to 117. The quality of the data was still poor, however. A dependency of the observed sea surface temperature on the temperatures of the calibration bodies was identified. A further investigation of this problem is necessary.

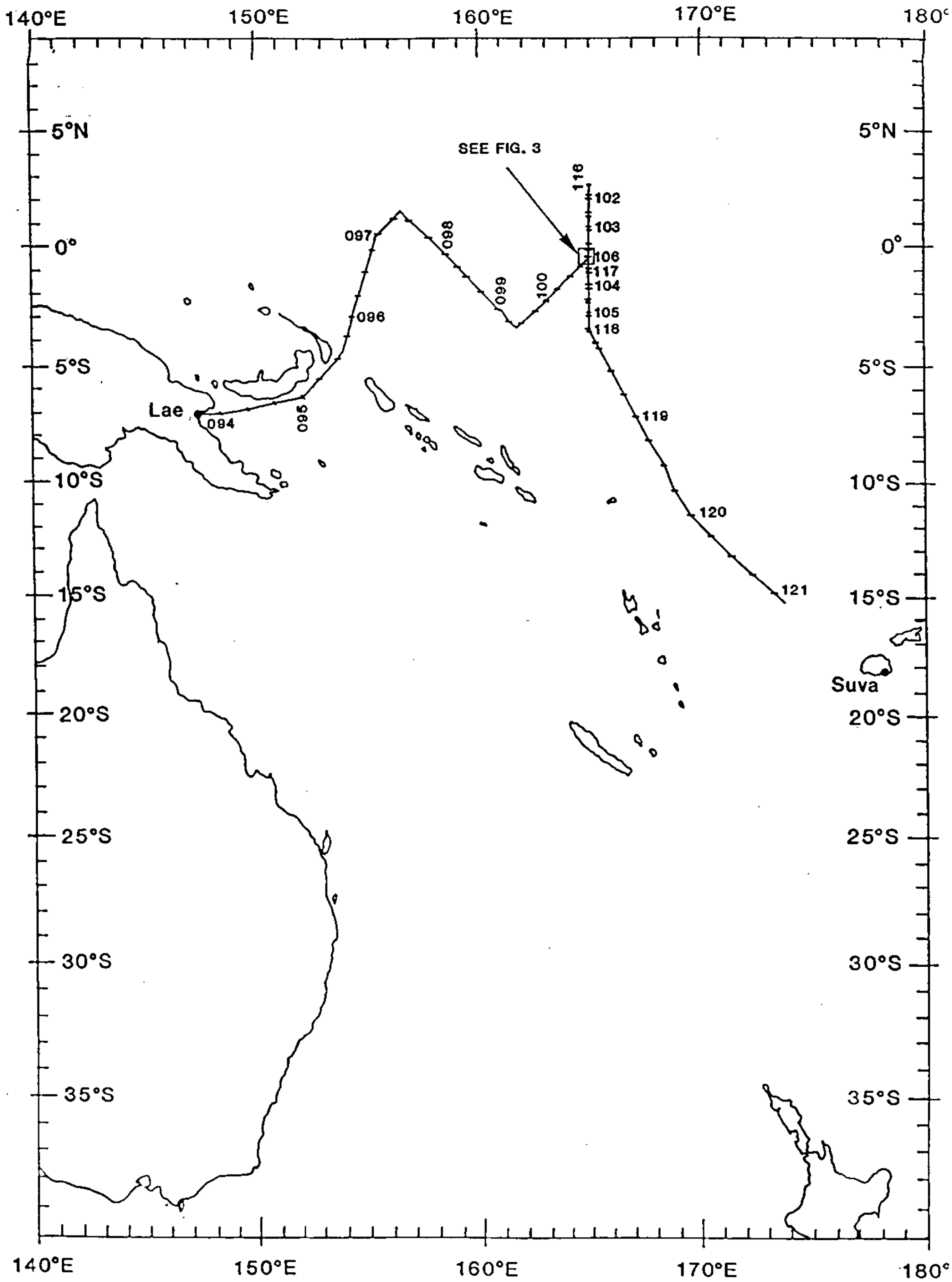

Figure 1: Charles Darwin 32 cruise track

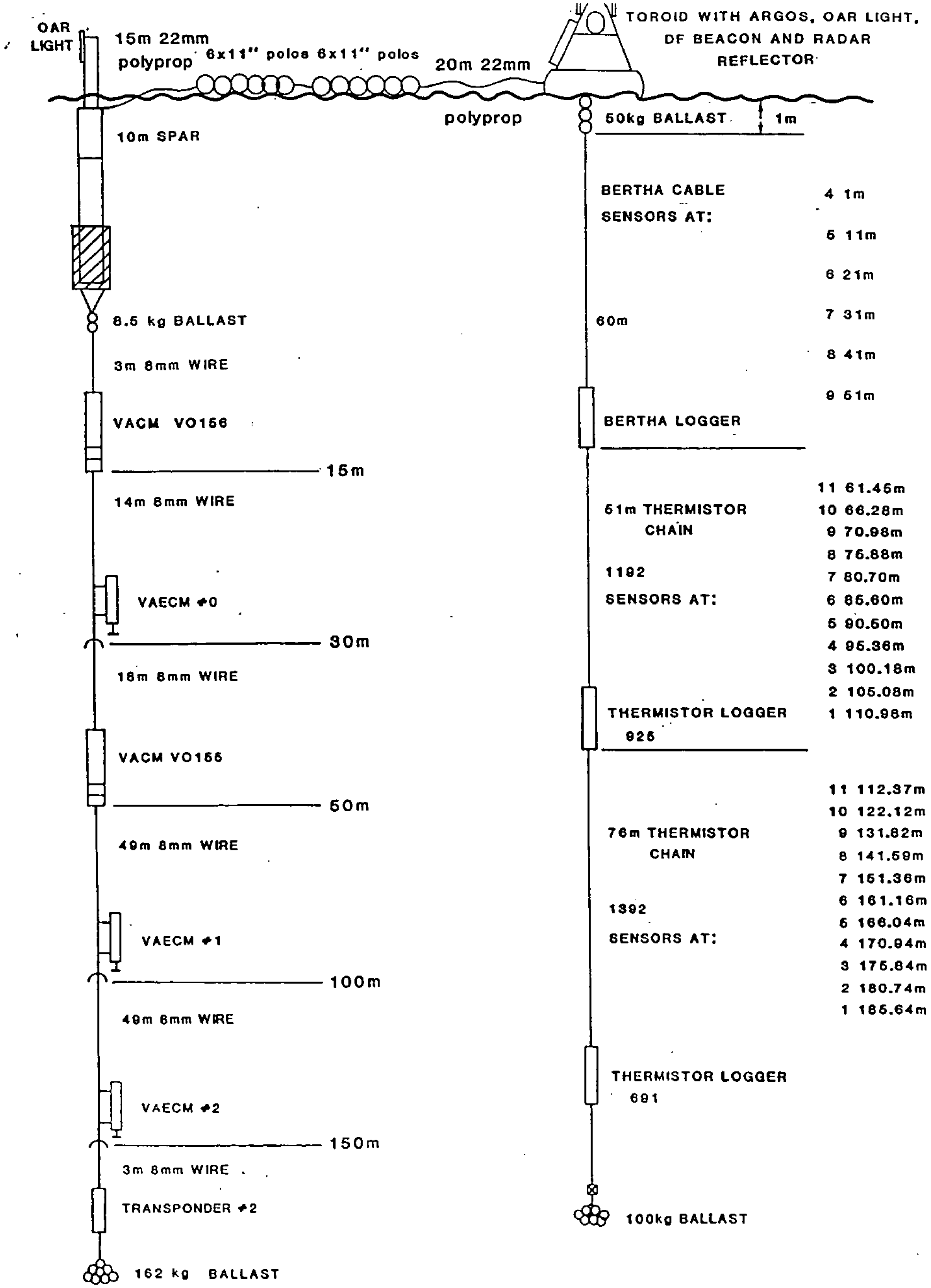

Figure 2: Spar buoy and toriod buoy configuration

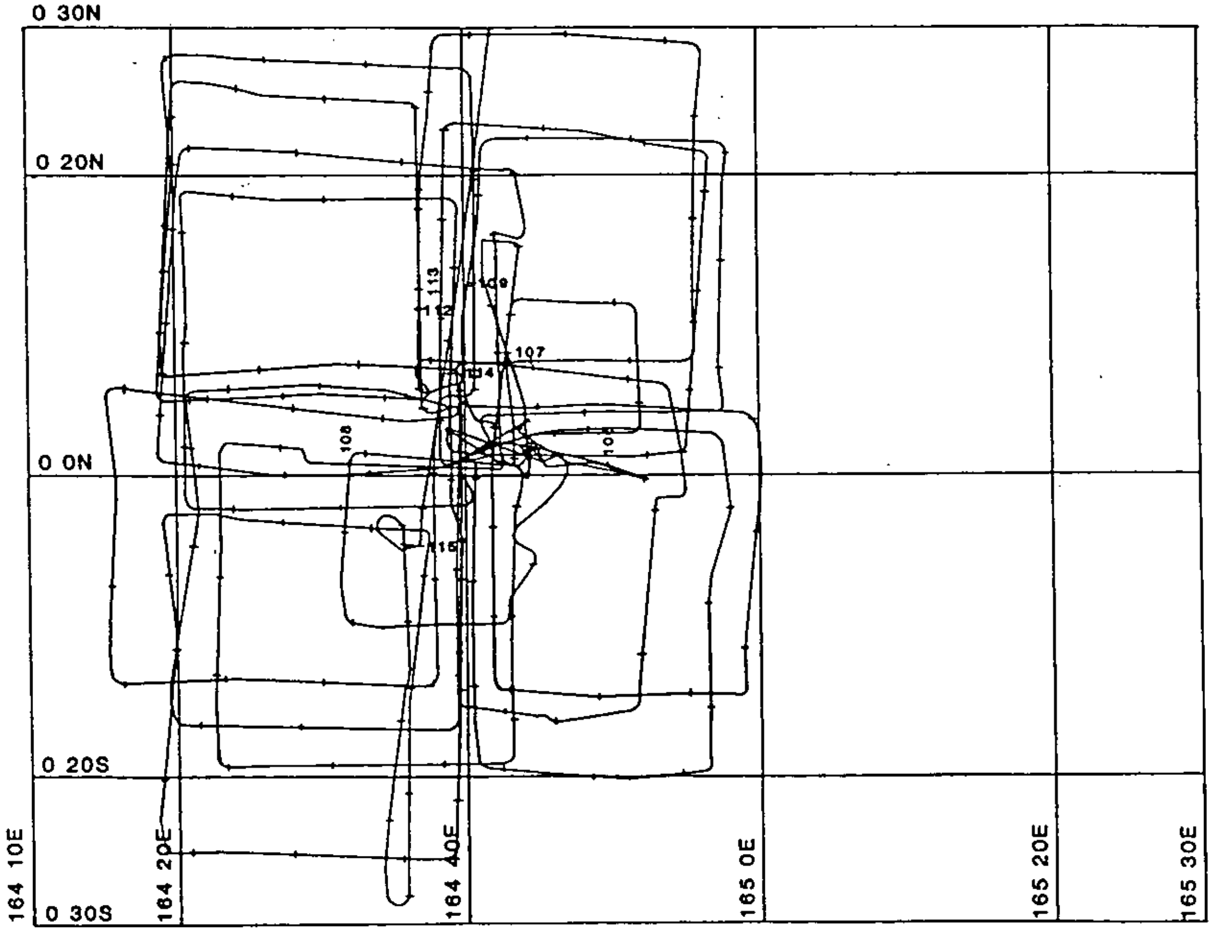

Figure 3: Survey track around the spar buoy

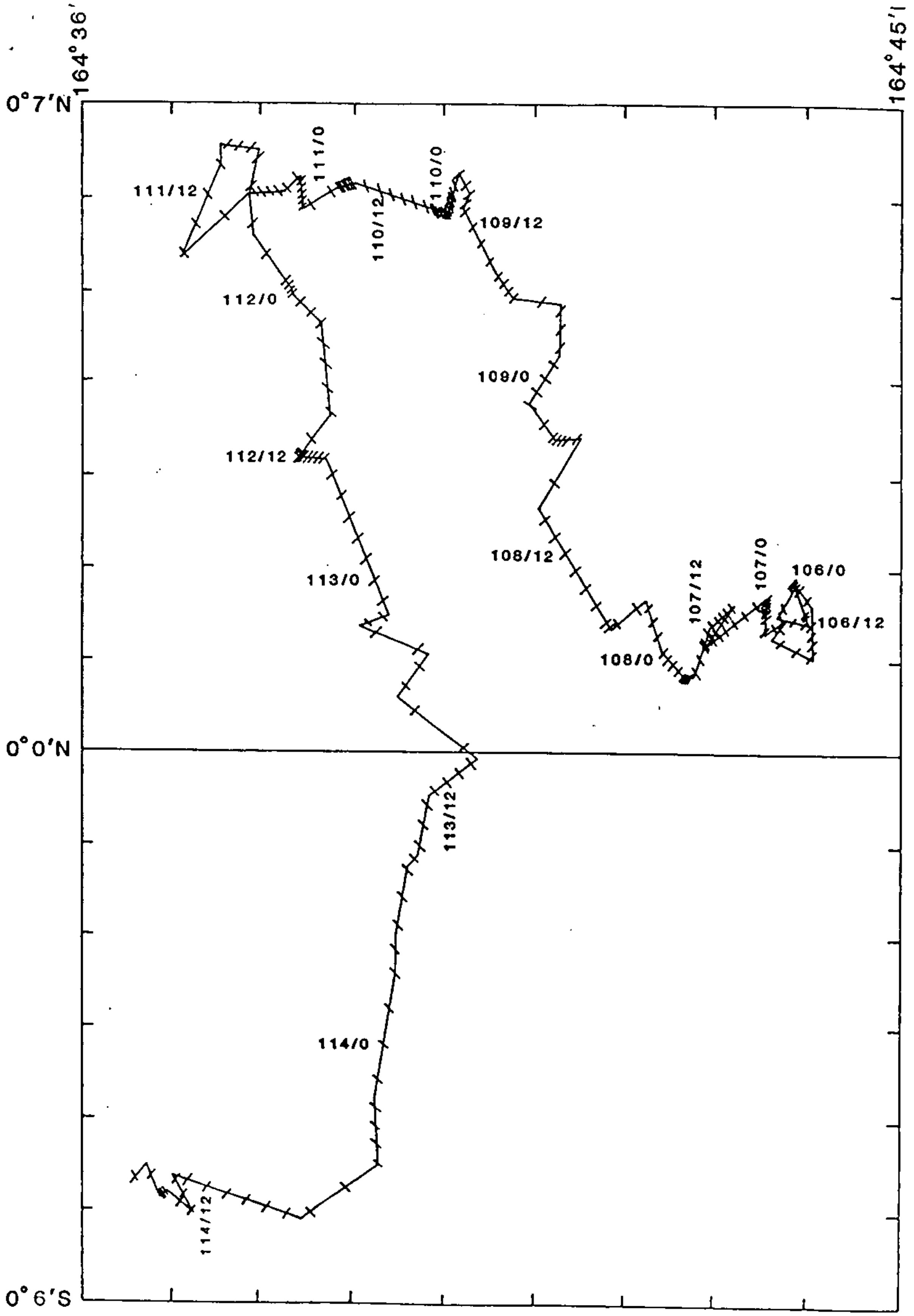

Figure 4: Track of the spar buoy

cast	start	down	latitude	longitude	depth (m)
2	96/0254	96/0308	-2.2085	154.3230	500
3	96/2201	96/2220	0.8225	155.2530	1000
4	100/2312	100/2343	-0.0072	164.8591	2000
6	101/0435	101/0511	0.5035	164.8680	2000
7	101/0911	101/0942	0.9849	164.8715	2000
8	101/1443	101/1519	1.5220	164.8760	2000
9	101/1902	101/1934	2.0215	164.8357	2000
10	101/2332	102/0016	2.5037	164.8733	2000
11	102/0611	102/0644	3.0294	164.8332	2000
12	104/1811	104/1850	-3.1915	164.8653	2000
13	104/2329	105/0019	-2.4857	164.8621	2000
14	105/0530	105/0603	-2.0177	164.8266	2000
15	105/0956	105/1029	-1.5040	164.8916	2000
16	105/1426	105/1501	-0.9972	164.8734	2000
17	105/1828	105/1903	-0.5135	164.8740	2000
19	106/1236	106/1308	-0.0028	164.8685	2000

Table 1: Hydrographic station list

run	start time	stop time	deployment	area
02	99/0800	99/2100	4	on passage
03	99/1900	100/0500		
04	100/0720	100/1900	5	on passage
05	102/0812	102/2100	6	3N - 3S
06	102/1900	103/0700		
07	103/0909	103/2100	7	
08	103/1900	104/0900		
09	104/0700	104/1738		
10	106/2231	107/0700	8	round spar
	107/0300		9	
11	107/0500	107/1900		
12	107/1700	108/0700		
	108/0314		10	
13	108/0500	108/1900		
14	108/1700	109/0900		
15	109/0700	109/1900		
16	109/1700	110/0900		
17	110/0700	110/1900		
18	110/1700	111/0500		
19	111/0300	111/1900		
	111/0915		11	
20	111/1700	112/0900		
21	112/0700	112/1500		
22	112/1300	113/0700		
23	113/0500	113/1900		
24	113/1700	114/0700		
25	114/0500	114/2128		
26	115/2000	116/1100	14	3N - 3S
27	116/0900	116/2100		
28	116/1900	117/1100		
29	117/0900	118/0100		

Table 2: SeaSoar computer run numbers

run	start time	run	start time
01	93/2300	25	105/2300
02	94/1100	26	106/1100
03	94/2300	27	106/2300
04	95/1100	28	107/1100
05	95/2300	29	107/2300
06	96/1100	30	108/1100
07	96/2300	31	108/2300
08	97/1100	32	109/1100
09	97/2300	33	109/2300
10	98/1100	34	110/1100
11	98/2300	35	110/2300
12	99/1100	36	111/1100
13	99/2300	37	111/2300
14	100/1100	38	112/1100
15	100/2300	39	112/2300
16	101/1100	40	113/1100
17	101/2300	41	113/2300
18	102/1100	42	114/1100
19	102/2300	43	114/2300
20	103/1100	44	115/1100
21	103/2300	45	115/2300
22	104/1100	46	115/1100
23	104/2300	47	115/2300
24	105/1100	48	116/1100

Table 3: ADCP computer run numbers

deploy -ment	run	raw files	time	calibration statistics			
				no. of samples taken	no. of samples used	true sal – SS sal (psu)	stand. dev. (psu)
2	1	1–7	98/0236–98/1100	7	4	0.078	0.009
3		11	99/0047–99/0327	0	0		
4	2–3	12–24	99/0753–100/0418	20	6	0.073	0.004
5	4	25–34	100/0723–100/1839	12	9	0.068	0.007
6	5–6	35–51	102/0812–103/0644	32	6	0.062	0.010
7	7–9	52–72	103/0910–104/1738	45	19	0.044	0.011
8	10	74–76	106/2231–107/0130	185	104	0.039	0.006
9	10–12	100–112	107/0300–107/2300				
10	12–19	114–163	108/0314–111/0653				
11	19–24	164–230	111/0915–114/2128				
11	25	231–240		12	12	0.031	0.003
14	26–29	244–277	115/1946–118/0100	93	28	0.029	0.009

Table 4: SeaSoar salinity corrections to initial calibration