

I.O.S.

RRS DISCOVERY
CRUISE 164

19 DECEMBER 1986 – 21 JANUARY 1987

SEASOAR AND CTD SECTIONS IN THE
SOUTHWEST INDIAN AND SOUTHERN OCEANS
FROM 22°S TO 52°S

CRUISE REPORT NO. 191
1987

**INSTITUTE OF
OCEANOGRAPHIC SCIENCES
DEACON LABORATORY**

NATURAL ENVIRONMENT
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SeaSoar and CTD sections in the
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Principal Scientist

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1987

DOCUMENT DATA SHEET

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ABSTRACT	<p>This report summarises RRS "Discovery" Cruise 164, whose objectives were to:</p> <ol style="list-style-type: none"> 1. document the incidence and nature of frontal structures in the Southern Ocean 2. document downstream (zonal) variations in the structure of the Antarctic Circumpolar Current (ACC) 3. estimate the transport of the ACC 4. observe spatial variations in the T/S properties of mode waters and compare the observations with theories of mode water formation 5. explore the potential of the SeaSoar and Acoustic Doppler Profiler to quantify the scales and meridional transport of mesoscale eddies in the Subantarctic Zone. <p>All these objectives can be obtained from the data gathered on two major transects (Fig.1), with 61 full depth CTD casts (Fig.2) and just under 9 days (3000km) of continuous SeaSoaring. In addition, the use of Mauritius for the port calls allowed meridional CTD sections to be made across the South Indian Ocean at 52°-57°E. The latter, along the Madagascar Ridge south of Madagascar, has not been worked before.</p>	
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ANTARCTIC CIRCUMPOLAR CURRENT		
SUBANTARCTIC FRONT		

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The Library, Institute of Oceanographic Sciences, Deacon Laboratory.

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SCIENTIFIC OBJECTIVES

1. To document the incidence and nature of frontal structures in the Southern Ocean. Can the Subantarctic Front be identified on all transects? How do upper ocean properties change across each front? Are the Polar, Subantarctic and Subtropical Fronts the only ones?
2. To document downstream (zonal) variations in the structure of the Antarctic Circumpolar Current (ACC). Is the ACC banded in mid-ocean as it is in the Drake Passage, with geostrophic currents concentrated in frontal zones?
3. To estimate the transport of the ACC.
4. To observe spatial variations in the T/S properties of mode waters and compare the observations with theories of mode water formation.
5. To explore the potential of the SeaSoar and Acoustic Doppler Profiler to quantify the scales and meridional transport of mesoscale eddies in the Subantarctic Zone.

All these objectives can be obtained from the data gathered on two major transects (Fig.1), with 61 full depth CTD casts (Fig.2) and just under 9 days (3000km) of continuous SeaSoaring. In addition, the use of Mauritius for the port calls allowed meridional CTD sections to be made across the South Indian Ocean at 52-57°E and 45-50°E. The latter, along the Madagascar Ridge south of Madagascar, has not been worked before.

NARRATIVE

RRS Discovery was due to sail from Mauritius on Thursday, 18 December 1986, but had to be delayed (a) to await a replacement on the galley staff (b) to await replacement computer tapes. A disk fault had been found in the password directory of the Level C computer, and ALL the backup tapes on board were found to be corrupted, most probably caused by high humidity and excessive temperatures during a passage leg from Gibraltar via the Red Sea to Mauritius during which the computer room air conditioning was switched off. In the event, the tapes arrived at 1545/19/12/86 (GMT), but the seaman did not, and the vessel sailed short handed at 1600Z that evening (2000 local time).

The starboard EM log would not deploy at first, possibly because of ship speed, but it was eventually deployed, so that navigation and echo sounding commenced at 0400/20/12. CTD casts with the shallow (SeaSoar) CTD (11399-11400) were made at 0800 and 1700Z (after dusk) to calibrate the conductivity cell and fluorometer. The latter cast was immediately followed by a deep CTD cast (11401). Problems with level A CTD software (lack of source code) precluded logging to the level C or PDP, and the first ten deep casts had to be logged on Digidata tapes only, and recovered later in the cruise.

After steaming on overnight, a second deep CTD cast was made (11402, 1100/21/12). Plans to calibrate the Acoustic Doppler Profiler (ADP) were deferred because of strong vertical shears apparent in the data. However, steaming at 13kt on three engines with the ASDIC Pod retracted severely reduced ADP data quality once the swell picked up and it was decided to deploy the pod and accept the 10 knot restriction. XBTs were launched at 5 hour (50n.m.) intervals overnight, and the third and last deep CTD cast on the 226° course from Mauritius to the Madagascar Ridge was begun at 0512/22/12 (11403).

The SeaSoar was deployed that afternoon and towed for 7 hours. Conductivity readings soon became useless, and cable noise was apparent, so it was decided to recover that evening rather than run on overnight. Recovery was difficult (p.14), and after a long hour, Discovery steamed on overnight to CTD station 11404 at the northern end of the section down the Madagascar Ridge.

CTD stations 11404-7 were made at 150km intervals from 0500/23/12-1700/24/12 with an XBT midway between casts, and stations 11407-16 were at 100km intervals up to 1700/27/12 with XBTs at 50km intervals in between. The sequence was interrupted

on 24/12 for runs to calibrate the EM log and ADP. Runs at four speeds were made past two drogued transponders (p.20). On Christmas Day at 0115Z (0515 local time) the generator for the port engine caught fire, putting it entirely out of commission. Prompt action by the engineers rapidly extinguished the fire, and no scientific time was lost, though morale was severely dented.

The deep isotherms were beginning to rise at station 11416, so station spacing was reduced to 50km (and even 33km for a short way) up to 11427 (1000/30/12). The Subtropical Front was crossed between 39 and 40°S, stations 11416-19, at around 41°E. After CTD 11417, the 217° course down the Ridge was adjusted to the south west (230°) to cross the Ridge to the western side and head for a point 200n.m. northwest of Marion Island. Spacing was increased to 100km between casts 11427-30 with XBTs in between, but thereafter 50km spacing was maintained until the southernmost station 11450 (0700/6/1/87).

The CTD cable termination had to be re-made prior to 11429 (31/12), and the oxygen sensor failed for cast 11430. After rounding the 200n.m. limit of Marion Island, course was set due south after station 11438 (2/1/87). From that date, passage during darkness was restricted to 5kt because of possible ice hazard. The Polar Front was crossed dramatically between stations 11440 and 41, so Discovery backtracked north to do an extra cast 11442 midway between the two previous casts. Thereafter, a strong southward set became apparent, and consideration was given to terminating the southward run in favour of a few east-west stations. It was preferred to continue south, however, and we were rewarded by recrossing the Polar Front between casts 11448 and 49, indicating a 300km diameter meander in the Polar Front.

Despite persistent 20-30kt winds (Fig.4), it was only once necessary to heave to, 1800/5/1 to 0200/6/1 prior to cast 11450. Lack of time prevented further southward progress. Instead Discovery ran west on 6/1 while preparing the SeaSoar for deployment, the plan being to tow northwest and then east to cut the eastern edge of the meander and possibly establish whether it was a meander or a detached eddy. However, at 0800, just before the SeaSoar was lifted, a Hiab hydraulic fitting parted under pressure, so during the six hours needed for repair, Discovery steamed northwest.

The SeaSoar was deployed at 1500/6/1, and course was set north for seven hours before turning east at 50°40'S. The signal was noisy whenever the cable was under strain, suggesting that a cable core or termination was going down, but it

was opted to continue, editing out bad data, although speed had to be restricted to 7kt. Sudden loss of signal at 0700/9/1, 2 days 15 hours and 760km later, precipitated recovery. The cable was found to be severely twisted at the cowtail attachment to the bridle, suggesting that the SeaSoar must have flipped.

Discovery steamed on eastward while the cable termination was cut and remade and the cable cores tested to find good conductors.

After redeploying the SeaSoar at 1200/9/1, course was set 010° to pass over the Crozet Plateau between Marion Island and Crozet Island at about $43-45^{\circ}\text{E}$. Course was altered to the east after 890km at $42^{\circ}50'\text{S}$ at 0200/12/1, and again to the north after 600km at 52°E at 1600/13/1. After crossing the Subtropical Front on 14/1, SeaSoar was finally recovered at 1200/15/1 at $37^{\circ}30'\text{S}$, after an unbroken run of 5 days 23 hours.

The final portion of Cruise 164 was devoted to a full-depth CTD section from $37^{\circ}31'\text{S}$ $52^{\circ}17'\text{E}$ towards Mauritius. CTD casts were made every 100n.m. with two XBTs in between each pair of CTD casts. The ASDIC Pod was retracted at the start of the section, to allow passage speed of 11.5-12kt. Station 11452 was at the northern end of a fracture zone in the Southwest Indian Ridge. The CTD wire laid poorly at a wire out of 4600m, so several following casts were done in depths of over 5000m to improve the wire lay.

At 0330/18/1, the Sperry Gyro failed for a few hours, at 0330/19/1 there was a total power failure again resulting in several hours of gyro loss, and shortly after the last CTD cast a second engine failed, delaying arrival in Mauritius until 1300 local time on 21st January 1987.

In short, despite the incredible number of problems which beset the cruise, the co-operation and goodwill of all those on board ensured that Cruise 164 was scientifically highly successful. It was intended as a preliminary SeaSoar survey of the fronts of the Southern Ocean, to enable more detailed surveys to be planned for the future, and in that it fully succeeded.

INDIVIDUAL PROJECT REPORTS

Navigation

Only GPS and transit satellites could provide absolute position fixes in the area of operation. The track plot was therefore computed in the standard way

perfected on Discovery, using the two-component EM log to interpolate between satellite fixes, assuming a constant current between each pair of transit fixes. The EM log had been calibrated on Cruise 162 (Pollard, Swallow and Saunders), and these recent calibrations were used on Cruise 164, namely

misalignment angle

of EM log = 1.7° clockwise from ship's head

$v_{FA}(tru) = 0.1955 + 0.93145 v_{FA}(est)$ (knots)

$v_{Sp}(tru) = 0.015 + 0.962 v_{Sp}(est)$ (knots)

Transit satellite fixes were transferred from the Level C to the PDP11/34 via magnetic tape, eliminated all duplicate and suspect fixes. These were further culled to eliminate all fixes with elevations less than 10° or greater than 70° , with more than 3 or occasionally 4 iterations, and closer together than about one hour. About 400 fixes remained over the 33 day cruise, an average of about one fix every two hours. The currents calculated from these fixes and the EM log DR are shown in Fig.3.

The GPS system provided position fixes for between 3 and 5 hours per day throughout the cruise, typically for periods of one to two hours duration. Once per minute during these periods, fixes were typed on a dedicated printer and time, latitude, longitude and number of space vehicles were logged onto the ship's level A/B/C system.

The GPS user has some control over how the system chooses which space vehicles (SVs) are used to calculate position:

- (1) The minimum angle of elevation of a good SV. This was kept at 10° throughout the cruise.
- (2) The maximum acceptable value of PDOP (Positional Dilution of Precision) for a group of SVs, which is a function of the relative positions of the SVs. The default value for this is 7.0. However, a value of 15 was used for most of the cruise and the fixes obtained when PDOP was greater than 7.0 were not obviously worse than when PDOP was less than 7.0.
- (3) At certain times during the cruise, four or more SVs were visible. If permitted, the system will calculate a horizontal and vertical position

from four SVs. However, the resulting fixes had a high value of PDOP (which may or may not matter). When four SVs were available, the receiver was programmed to calculate a 2-D fix from the best combination of three SVs; the choice of SVs was made by the system.

It is recommended that when a group of SVs comes into view, the system is initialised with a position correct to within half a degree. After initial experimentation, the receiver was left unattended throughout the day and periods of GPS fixes were initialised with the previous GPS fix, which was up to 13 hours earlier and 1.5 degrees distant. This method of operation seems to have been quite adequate.

Accuracy A preliminary analysis of the position fixes shows that even with values of PDOP up to 15, differences between GPS and SATNAV/DR were usually less than 500m, which is the limiting accuracy of the transit fixes themselves.

Note After a mains power failure, the GPS receiver had to be reset to the required mode of operation. Some fixes were lost before it was discovered that the receiver had not recovered to its state before the loss of power.

(Brook, King, Pollard)

CTD

A CTD station list is given in Table 1. All casts except 11399 and 11400 were made with the IOS Neil Brown Instrument Systems "New Deep CTD", and were made to full ocean depth. A transponder attached to the CTD frame was used to make casts to within 20m of the bottom whenever a good bottom echo could be seen.

The earth connection was found to be faulty and the cable termination was remade prior to station 11418. The oxygen sensor failed for station 11430. For all other stations it was found to drift way off calibration, but reasonable oxygen profiles could be recovered using oxygen samples. Only once did a station have to be delayed with the vessel hove to in rough weather, prior to 11450, when winds up to 45kt were recorded.

On station 11452, it was found that the wire on the midships winch did not lay properly at about 4600m, and some time was lost on that and subsequent casts trying to achieve a perfect lay.

The conductivity cell failed after cast 11458 and had to be replaced.

All casts were logged on a Digidata tape deck interfaced to the NBIS deck unit and displayed in real time on a BBC micro computer system. Indeed, for the first ten casts no other data recording was possible, because source code for the CTD Level A computers was not on board (see Narrative) so the CTD data cycle definition could not be modified. This was later patched, and data were averaged to one second values by a Level A micro computer, and transferred to both the Level C and PDP11/34 computers. It proved useful to have all three routes, as two out of three paths failed on a number of occasions, when either the Digidata tape was inadvertently not started, or the logging program to the PDP timed out, or the Level C failed. Consequently, no data were lost.

(Smithers, Hooker, Brook)

SeaSoar

The SeaSoar only had to be deployed and recovered three times (Table 2), for a total of nearly nine days of towing (6 million data cycles, 0.8 million one second samples). The original intention to recover it daily for a deep CTD calibration cast was abandoned to minimise the wear and tear on the system during deployment and recovery.

For the first deployment, the block through which the faired cable runs was hung from the Schat davit on a rope led through the wire run to the capstan. This necessitated a seaman to man the capstan, with ropes leading across the deck. On the first recovery it was difficult to transfer the block from the davit to the Hiab.

Several problems (see Narrative) caused early termination of the first deployment, and recovery proved difficult. The wind shot up to 20kt from astern, so recovery head to wind would have been preferable. The cable jammed down the side of the shieve, which had to be partly dismantled to free it. Hiab control was jerky, and it fouled the main Schat davit, weakening a hydraulic pipe connection, which burst just after the SeaSoar was safely on deck, spraying hydraulic fluid on all hands. It was found that the SeaSoar cable must at some stage have taken a turn round a wing, as the wing was damaged and the sensor pod had been knocked loose, and was only held by the electrical leads.

A number of improvements were made for subsequent deployments. The shieve was hung from a strop from an eye near the end of the davit rather than from a rope led through the davit wire run. Side ropes to prevent the shieve swinging were

dispensed with. All future deployments and recoveries were made at 5 knots which significantly reduced the tendency of the SeaSoar cable to drop slack in heavy pitching. The Schat davit was raised out of the way once the block was transferred to the Hiab. Pads were added to the cheeks of the shieve so that the cable could not jump off it and jam down the side. With these improvements, subsequent SeaSoar handling went smoothly.

(Smithers, Grohmann)

CTD and SeaSoar Calibration

The 12 bottle multisampler was used to collect samples for calibration on all CTD casts. On occasion, the multisampler does not trip the sample bottle, but this can be detected by the CTD recovering rather quickly from the firing signal. Thermometer frames were placed on bottles one and four, to keep a check on the NBIS thermometer calibration. The CTD read high by a few millidegrees compared to thermometers throughout the cruise, so was taken to be correct.

Salinities were drawn at 12 levels for the first six deep casts. The CTD calibration appeared to be stable, and about 0.050psu too low at all depths, so salinities were only drawn at three levels thereafter, to keep the number of samples to be analysed to reasonable levels. The Guildline salinometer did not function properly from the start of the cruise. The fault was diagnosed to be a faulty cell, and the Autolab salinometer had to be used for the rest of the cruise. Because it is not as repeatable as the Guildline (when working properly), triplicate samples were drawn at each level. If the duplicate samples proved inconsistent, the triplicate was analysed to decide the matter.

The Beckman oxygen sensor on the NBIS CTD is known to be unstable and hard to calibrate. For this reason, 9 to 12 samples were drawn on casts 11401-15. However, it became apparent that reagents for oxygen titration would run out, as significantly more CTD casts were being made than originally planned. Oxygen samples had therefore to be drawn from a restricted number of levels, namely the bottom, 2500m, oxygen minimum, oxygen maximum, thermocline and near surface, six in all. These proved barely adequate to fit the exponential temperature and pressure coefficients, as the sensor calibration drifted wildly during the course of the cruise. Further details will be given in the CTD data report.

Two shallow casts were made at the start of the cruise to provide an approximate calibration for the conductivity ratio of the shallow CTD to be used in the

SeaSoar. In the absence of daily deep CTD casts during the week long SeaSoar runs, high priority was given to surface salinity samples drawn half hourly from the non-toxic supply. These were entered on the PSTAR computer system and differenced from 6m SeaSoar values after careful correction of the latter for obvious offsets in the T/S relation. It was found that the SeaSoar was within 0.03psu of the samples, with long term drifts (over days) of order 0.01psu, which can be corrected later. The technique is thus a satisfactory way of maintaining the salinity calibration within 0.01psu.

(Moorey, Read, Smithers)

SeaSoar and CTD Data Processing

All data from the shallow (SeaSoar) CTD were transferred from the NBIS deck unit to a Level A micro computer which despiked and averaged the 8hz data over one-second intervals and computed temperature change across the one-second interval. These reduced data were passed both to the Level C and to the PDP. Occasionally the PDP link failed (if the relevant sampling program was not run), in which case the Level C averaged raw data were transferred on magnetic tape to the PDP.

Two hours of data were processed at a time on the PDP, being first converted to PSTAR format, then calibrated, plotted and edited for spikes and salinity fouling or offsets. The two hourly cleaned data were appended every 12 hours into a 14 hour file (allowing for overlap), merged with navigation, then gridded with 4km horizontal averaging (and 8m vertical) and contoured as functions of latitude or longitude and pressure or density. Density was further smoothed over 10km and geostrophic shears relative to 325m calculated and contoured.

Such detailed shipboard processing makes the further analysis of the large data set a manageable task.

CTD casts were also logged mostly through the Level A, then calibrated and plotted. After further calibration to absolute salinities and oxygens, final report plots were generated during the following Cruise 165A.

(Read, Pollard, King)

XBTs

39 Deep Blue XBTs were successfully launched, and recorded using a Bathy Systems XBT controller onto an HP85. In the absence of a computer interface, 6m listings

were entered by hand into the PSTAR system for merging with other data.

(Goy, Diddams)

Routine Underway Observations

The Ocean Data Model 103 thermosalinograph provided by RVS was found to be faulty from the start of the cruise, possibly in the CPU, and was unusable.

Hourly salinity samples were taken from the non-toxic supply increased to half-hourly during SeaSoar runs, and entered manually into the PSTAR system.

The navigating officers logged ship's head and speed, relative wind speed and direction and sea surface temperature (R.A.S.T.U.S.) hourly throughout the cruise, and these too were entered into the PSTAR system, and used to compute wind vectors (Fig.4).

The Precision Echo-Sounder was run throughout the cruise. Depths every 6 minutes were manually entered into the Level C computer, corrected using computerised Carter Tables, and transferred on magnetic tape to the PDP PSTAR system. An uncharted seamount with minimum depth 610m was observed at 47°39'S 43°48.7'E with depths less than 850m on the 010° course between 47°39.8'S 43°48.5'E and 47°37.7'S 43°49.1'E.

(Diddams, Lewis, Brook)

Acoustic Doppler Current Profiler

The RD ADCP was in use throughout the cruise giving current profiles relative to the ship over the upper 150 to 400metres of the ocean. Following the initial trials on Cruise 162 several changes were made whilst at Port Louis. These mainly concerned the interface in the ADCP dealing with the heading and pitch/roll gyros. On Cruise 162 we were unable to lower the Sonar Pod, in which the transducers are mounted, whereas the pod was fully operational on this cruise.

Heading, Pitch and Roll Gyro Interface

A new version of the ADCP firmware (15.79) was installed to handle the stepper heading gyro interface. This system is the first that RD have supplied with a stepper heading interface hence there are still some bugs in both the hardware and firmware.

(a) Stepper Heading Gyro

The RD interface should accept the three phase grey-coded stepper signal from the buffer amplifier located in the plot. However, direct connection of the stepper signals to the ADCP failed to change the displayed heading. The cause of the problem was traced to the noise spikes (30 volt, 1ms duration at a 100Hz repetition rate) superimposed on all three gyro phases. A simple RC filter with a 10ms time constant was connected between the buffer amplifier and the ADCP for each phase. This appeared to solve the problem but later experience showed that it was not a complete solution.

To enable the heading display on the ADCP to be set up correctly a multiplexor was added to the slew/test box constructed on Cruise 162.

(b) Pitch and Roll Gyro

The previous version of the firmware (15.77) gave spurious pitch and roll readings with a frequency of about 1 in 5. This problem was apparently cured in the new firmware, but showed up in a different guise later in the cruise. The Colnbrook Instruments Vertical Reference Gyro (located in the gravimeter room) worked perfectly throughout the cruise.

ADCP Temperature

A temperature sensor and digitizing circuit are located within the transducer housing to enable the calculation of sound speed. The data are transferred to the main unit as a serial bit stream. Whilst in port, with a water temperature of about 28°, the ADCP read low by 6.25°. This was initially thought to be a simple offset but later it was shown that the above offset was valid only for temperatures above 26.25°. Below 20° the reading was correct. Upon examination of the data format the above breakpoints were related to the 12th and 10th bits of the data stream. Thus it appears to be a hardware fault in the transducer unit. (The ADCP installed on RRS Charles Darwin also appears to have a problem with the temperature readout.)

Built in Test (BIT) Fail - Low Transmitter Current

The built in test facility showed this error only at sea water temperatures of less than 14°. The frequency of the error increasing with decreasing temperature such that at 2.5° the BIT fail light was continually on. However the profiling range obtained showed that there was little if any loss in transmitter power output. The cause is likely to lie in the transducer unit, either in a change in effective transducer impedance or increasing humidity.

Performance of the Heading Input at Sea

The first indication of trouble with the heading input came about 48 hours into the cruise when the ADCP heading was 6.2° clockwise relative to the bridge. Previously, checks against the bridge repeater had shown differences of only $\pm 0.1^\circ$. This offset was maintained for 17 hours after which the ADCP was taken off-line for disk backup. After the ADCP was put back on line the heading, pitch and roll readings were latched at zero. A re-initialisation commanded from the data acquisition menu failed to unlatch the readings, the ADCP power had to be cycled. This problem recurred several times during the cruise.

Later, loss of synchronism between the ADCP and bridge headings occurred after a rapid 180° turn, at the end of which the ADCP lagged by 12°. The rate of turn varied from 1 to 1.9° per second. Although prolonged turns at such a rate would be rare, small rapid changes of heading could easily occur, for example during heavy pitching. The ability to follow heading changes of several degrees per second is vital. RD Instruments were contacted, and a new interface board is to be delivered together with an updated version of the firmware.

To eliminate the possibility of problems caused by a noisy gyro signal a more sophisticated filter was designed and built. This comprised a second order active low pass filter with a cut-off at 100Hz followed by a Schmidt trigger. This resulted in a very clean signal input to the ADCP interface, yet the slew rate problem with the gyro signal remained. Using the test gyro signal, which changes monotonically, no loss of sync. was seen at rates of up to 4° per second. A detailed discussion with RD is clearly required on this vital aspect of the instrument.

Instrument Performance

(a) Range

North of the sub-tropical convergence the usable profiling range varied from about 150m during daylight to about 250m at night. The increased biological activity south of the convergence gave ranges of 250m to 400m.

(b) Behaviour in heavy weather

The effect of bubbles on the ADCP performance was clearly demonstrated with the sonar pod retracted. In 3m waves of 10s period the ship was pitching $\pm 4.5^\circ$, this resulted in a high minimum signal level coupled with a %good of less than 15% throughout the profiling range.

Later, with the sonar pod deployed, in 3m waves of 6s period and $\pm 5^\circ$ pitch the %good varied from 75% to 95% from 200m to near the surface. This clearly shows the advantage of placing the transducers beneath the bubble layer.

(c) Velocity accuracy

On 24/12/86, two transponders were deployed at 30m depth under cross-shaped drogued floats with minimal windage. The two floats were about 1200m apart. Four runs up and down wind were made past the floats at 4, 6, 8 and 10kts. By observing range and bearing every 2 minutes, the actual speed of the ship relative to drogues could be calculated and compared with the averaged ADCP velocities relative to water, using the range bin centred 30m deep. It was found that the ADCP read low relative to true speed by 0.962 ± 0.01 , 0.949 ± 0.02 , 0.974 and 0.979 ± 0.01 at the four speeds. The ADCP velocities are thus low by about 3.5% on average. From the same data it is estimated that the ADCP is misaligned anticlockwise relative to the ship's head by about $1.3 \pm 1.3^\circ$.

IBM Data Acquisition

The system worked very well with only one minor software problem with over 800 hours constant use. Daily backup of data files from the hard disk to floppy was carried out, and the poor accuracy of the IBM clock required a daily reset.

Sonar Pod

Difficulties were experienced in raising and lowering the sonar pod. It was found that several solenoids were sticky. It was eventually found that judicious tapping of these at the right moment usually enabled smooth operation.

Data Handling

Two minute averaged profiles of ADCP data were transmitted to the PDP11/34, along with statistics and averaged values of heading, temperature, etc. These were converted to PSTAR format and contoured in 12-hourly segments against distance run. Only shear relative to 100m was extracted in this way. Correction to absolute velocities using transit satellite and GPS fixes must await processing ashore.

(Griffiths, Wild)

Biological Sampling

Aspects of micro, nano, and pico plankton biology were investigated and related to changes in the physical characteristics over a large latitude change and with high resolution at the frontal zones. An indication of the potential primary productivity for the surface water was obtained by continually monitoring chlorophyll fluorescence in the non-toxic supply on the Turner Designs fluorometer. Water samples were collected either from the outflow of the Turner Designs fluorometer or from multisampler water bottles from the CTD.

Chlorophyll determinations were carried out for as long as the acetone held out. 10L was not enough. Either size fractionated ($0.2 <> 1.0 <> 5.0 <$) or total ($> 0.2 \mu\text{m}$ diam.) chlorophyll was measured using the Turner 112 fluorometer which was calibrated at Wormley using standard chlorophyll a. On samples where both total and size fractionated chlorophyll a (chl a) was determined there was a difference between the total of the fractions and the total chl a (determined through $0.2 \mu\text{m}$ filter). The two values were shown to have a constant relationship and the difference is probably due to small but consistent errors in volume measurements - either of the volume of seawater extracted or in the volumes of the extract. Chlorophyll was determined for several stations before the Sub Tropical Convergence, all stations through the front, one station between the convergence and the Polar Front, all stations through the Polar Front. Surface chlorophylls

were taken to calibrate the Turner Designs fluorometer until the 13th January when the acetone finally gave up.

Nutrient samples were taken, and stored in the freezer for future analysis at Wormley, for nitrate and phosphate. Ammonia must be assayed immediately for which we had no facility on the cruise. Glass vials were used to store samples so these were useless for silicate analysis. TAKE PLASTIC ONES NEXT TIME.

Bacterial activity: 50ml samples of SW were incubated for 2hrs with radioactive thymidine. The incubations were terminated by filtering and washing with cold 3% TCA and the filters returned to UK for analysis in scintillation counter. (TCA was in short supply - use 10ml 3% TCA per sample minimum.)

Microscope Work

No bacterial or flagellate counts were done due to lack of the correct stain.

Samples were filtered on to filters stained with Irgalan black and stored in the fridge for direct counts of autofluorescence (-phytoplankton +cyanobacteria). This proved to be a good short term preservation method. Samples (usually 100ml) were filtered and mounted in glycerin jelly (Geider method). Different classes of phytoplankton and their dominance were recorded. Changes in community structure of the larger size fraction ($>3\mu\text{m}$) were noted and compared to physical parameters.

Samples were preserved in gluteraldehyde for bacterial and flagellate counts and for SEM work on return to Wormley. Samples were preserved in Lugol's solution for further microscope work at Wormley.

Schweppes tonic bottles make excellent sample bottles - all, including plastic tops, can be autoclaved. All equipment worked OK. Flowmeter and thermistor worked fine.

(Stirling, May)

Table 1. CTD and XBT Station List

Station	Start date	Start time	Down time	End time	Latitude (S)	Longitude (E)	Depth (corr m)	Height off bottom (m)
CTD11399	20/12	0800	0835	0906	22° 9.5'	54°46.8'		
CTD11400		1610	1638	1726	23° 7.6'	53°26.1'		
CTD11401		1850	2033	2218	23°17.5'	53°11.9'	4621	50
CTD11402	21/12	1000	1144	1406	25° 7.9'	51°21.9'	5006	30
XBT16401			1900		25°39.8'	50°41.4'		
XBT16402	22/12		0001		26°13.8'	50° 0.0'		
CTD11403		0512	0653	0900	26°50.5'	49°13.0'	4842	120?
XBT16403	23/12		0000		28°14.0'	47°35.5'		
CTD11404		0448	0602	0800	28°41.5'	47° 1.2'	3064	20
XBT16404			1200		29°18.2'	46°37.5'		
CTD11405		1630	1719	1830	29°55.6'	46°23.7'	2116	20
XBT16405	24/12		0012		30°47.9'	46°11.4'		
CTD11606		0246	0324	0442	31° 5.2'	46° 6.7'	2387	40
XBT16406			1229		31°40.7'	45°56.2'		
CTD11407		1531	1610	1712	32° 7.8'	45°48.6'	1891	35
XBT16407			2000		32°33.2'	45°40.8'		
CTD11408		2248	0009	0043	33° 0.7'	45°32.4'	1607	8
XBT16408	25/12		0331		33°26.0'	45°26.1'		
CTD11409		0618	0703	0754	33°52.5'	45°18.3'	1184	20
XBT16409			1021		34°15.4'	45°13.5'		
CTD11410		1335	1411	1515	34°45.0'	45° 3.6'	1660	30
CTD11411		1955	2106	2236	35°29.4'	44°53.3'	3309	10
XBT16410	26/12		0145		35°55.2'	44°30.4'		
CTD11412		0412	0516	0642	36°14.5'	44°13.0'	3120	10
XBT16411			0945		36°35.9'	43°50.6'		
CTD11413		1235	1337	1511	36°56.5'	43°30.8'	3425	15
XBT16412			1810		37°18.6'	43° 9.4'		
CTD11414		2048	2210	2348	37°38.6'	42°50.1'	3881	15
XBT16413	27/12		0246		38° 0.1'	42°28.4'		
CTD11415		0536	0702	0848	38°22.1'	42° 7.2'	3880	90
XBT16414			1142		38°44.5'	41°46.7'		
CTD11416		1430	1541	1724	39° 4.8'	41°27.0'	3775	40
CTD11417		2036	2207	2336	39°27.3'	41° 5.6'	3613	18
XBT16415	28/12		0114		39°39.9'	40°55.4'		
CTD11418		0258	0412	0542	39°48.2'	40°42.1'	3575	25
CTD11419		0800	0916	1048	40° 1.1'	40°27.3'	3740	15
CTD11420		1313	1424	1554	40°16.2'	40°12.5'	3944	15
CTD11421		1800	1923	2054	40°29.6'	39°57.0'	3618	20
CTD11422		2330	0044	0210	40°50.3'	39°35.6'	3643	35
CTD11423	29/12	0530	0650	0824	41° 7.3'	39° 6.7'	3865	15
CTD11424		1112	1223	1337	41°24.3'	38°40.4'	3182	25
CTD11425		1700	1816	1924	41°42.9'	38°13.7'	3748	30
CTD11426		2236	0012	0146	42° 1.7'	37°47.0'	3813	80
CTD11427	30/12	0712	0828	1000	42°19.5'	37°19.2'	3606	100
XBT16416			1352		42°37.3'	36°52.2'		
CTD11428		1730	1855	2054	42°55.3'	36°24.1'	4118	50?
XBT16417	31/12		0032		43°13.5'	35°56.5'		
XBT16418			0354		43°31.7'	35°29.2'		

Station	Start date	Start time	Down time	End time	Latitude (S)	Longitude (E)	Depth (corr m)	Height off bottom (m)
CTD11429		0726	0842	1018	43°33.2'	35°28.0'	4216	15
XBT16419			1410		43°49.6'	35° 1.4'		
CTD11430		1500	1627	1800	43°53.8'	34°54.2'	3957	25
CTD11431		2156	2306	0048	44°13.4'	34°25.5'	3952	160?
CTD11432	1/1/87	0330	0443	0606	44°34.4'	34° 5.0'	3730	65
CTD11433		0912	1048	1227	44°56.3'	33°41.9'	4630	22
CTD11434		1516	1640	1818	45°20.3'	33°23.1'	4145	45
CTD11435		2100	2239	0018	45°44.3'	33° 9.0'	4791	10?
CTD11436	2/1	0322	0440	0618	46° 9.5'	32°53.3'	4424	20
CTD11437		0900	1012	1130	46°35.5'	32°45.8'	3229	15
CTD11438		1418	1510	1600	47° 2.5'	32°43.4'	2428	35
CTD11439		1906	2002	2058	47°29.7'	32°43.4'	2333	20
CTD11440	3/1	0137	0238	0347	47°56.2'	32°44.0'	3114	40
CTD11441		0636	0817	1012	48°24.2'	32°46.7'	4782	10
CTD11442		1200	1309	1420	48°10.7'	32°46.0'	3135	20
CTD11443		1900	2029	2218	48°49.8'	32°42.4'	4297	10
CTD11444	4/1	0232	0354	0612	49°17.9'	32°43.8'	4130	25
CTD11445		0848	1039	1248	49°46.3'	32°42.5'	5500	20
CTD11446		1512	1652	1924	50°14.1'	32°42.5'	5410	?
CTD11447		2218	2345	0127	50°38.7'	32°43.3'	4030	20
CTD11448	5/1	0400	0542	0736	51° 4.6'	32°41.8'	4531	?
CTD11449		1048	1229	1438	51°30.8'	32°38.4'	5245	?
CTD11450	6/1	0200	0409	0700	52° 0.1'	32°45.4'	5118	?
CTD11451	15/1	1240	1417	1636	37°31.5'	52°16.8'	4224	12
XBT16420			1940		36°58.1'	52°19.8'		
XBT16421			2226		36°20.8'	52°20.4'		
CTD11452	16/1	0121	0246	0448	35°51.0'	52°21.2'	4635	30
XBT16422			0800		35°15.7'	52°25.4'		
XBT16423			1036		34°44.7'	52°27.2'		
CTD11453		1330	1442	1600	34°11.7'	52°29.3'	3282	20
XBT16424			1855		33°38.3'	52°30.1'		
XBT16425			2133		33° 8.2'	52°32.3'		
CTD11454	17/1	0012	0205	0430	32°40.3'	52°33.8'	5309	145
XBT16426			0800		32° 5.0'	52°47.8'		
XBT16427			1036		31°38.0'	52°58.4'		
CTD11455		1324	1431	1600	31° 8.3'	53° 8.8'	4031	20
XBT16428			1845		30°39.3'	53°21.3'		
XBT16429			2118		30°11.3'	53°30.0'		
CTD11456	18/1	0006	0138	0400	29°43.5'	53°41.7'	4765	15
XBT16430			0651		29°14.6'	53°54.7'		
XBT16431			0922		28°46.6'	54° 7.0'		
CTD11457		1200	1331	1512	28°14.7'	54°16.8'	5102	?
XBT16432			1918		27°28.5'	54°33.9'		
CTD11458		2236	0028	0224	26°52.1'	54°50.1'	5273	25
XBT16433	19/1		0528		26°25.9'	55° 4.7'		
XBT16434			0819		25°59.5'	55°19.0'		
XBT16435			1130		25°31.9'	55°28.6'		
CTD11459		1300	1429	1612	25°19.6'	55°36.4'	4873	20
XBT16436	19/1		1841		24°56.9'	55°48.5'		
XBT16437			2146		24°25.3'	56° 5.3'		

Station	Start date	Start time	Down time	End time	Latitude (S)	Longitude (E)	Depth (corr m)	Height off bottom (m)
	20/1							
XBT16438			0729		23°18.3'	56°44.5'		
XBT16439			1044		22°45.1'	57° 2.1'		

Table 2. SeaSoar Deployments

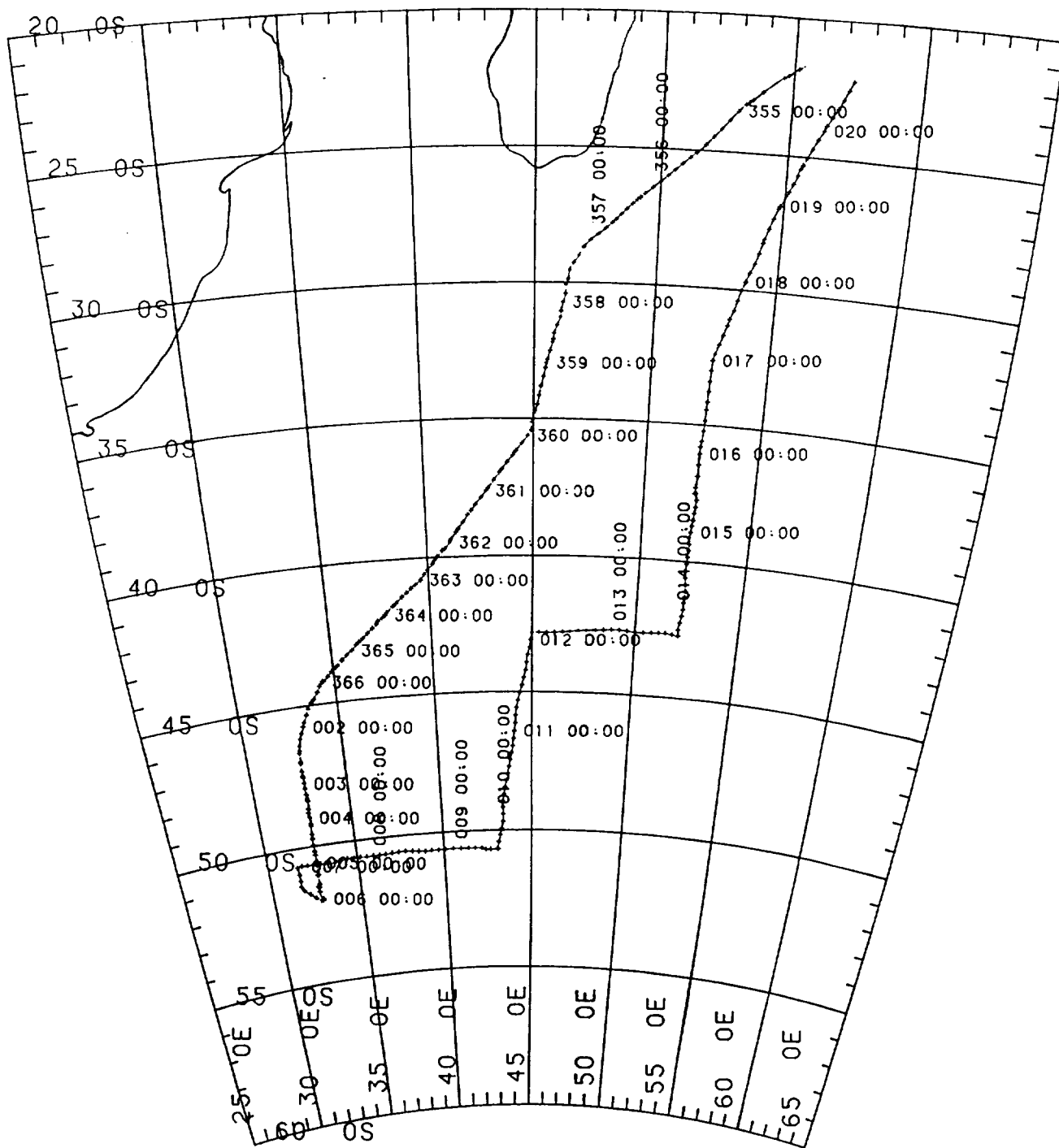
Run	Date	Time	Latitude (S)	Longitude (E)	Duration	Distance Run (Km)	Event	Course	Comments																																						
1	22/12	1045	26°58'	49° 3'	0d 6h 55m	108	Start End	226°	Cable noise, no conductivity																																						
		1740	27°39'	48°17'						2	6/1	1529	51°27'	31°39'	0d 6h 56m 2d 8h 35m	90 754	Start a/c End	354° 090°	Run N at 31°38'E Run E at 50°40'S Loss of signal, cable twisted	2225	50°40'	31°37'	0700	50°41'	42°21'	3	9/1	1300	50°47'	43° 2'	2d 13h 0m 1d 14h 0m 1d 19h 42m	897 580 582	Start a/c a/c End	009° 087° 003°	Run N at 44° Run E at 42°46'S Run N at 52°10'E End of run	12/1	42°51'	44°58'	1600	42°46'	52° 4'	1142	37°32'	52°23'	Totals:		
2	6/1	1529	51°27'	31°39'	0d 6h 56m 2d 8h 35m	90 754	Start a/c End	354° 090°	Run N at 31°38'E Run E at 50°40'S Loss of signal, cable twisted																																						
		2225	50°40'	31°37'																																											
		0700	50°41'	42°21'																																											
3	9/1	1300	50°47'	43° 2'	2d 13h 0m 1d 14h 0m 1d 19h 42m	897 580 582	Start a/c a/c End	009° 087° 003°	Run N at 44° Run E at 42°46'S Run N at 52°10'E End of run																																						
		12/1	42°51'	44°58'																																											
		1600	42°46'	52° 4'																																											
		1142	37°32'	52°23'																																											
Totals:					8d 21h	3011km																																									

Figure 1 - Track plot of RRS Discovery Cruise 164, December 1986 - January 1987.

Figure 2 - Positions of CTD casts on RRS Discovery Cruise 164.

Figure 3 - Surface current vectors derived from the difference between dead reckoning using a two component EM log and transit satellite fixes. Fixes have been culled to good fixes one to four hours apart, to give a worst case noise level of 5-20 cm/s. The arrow underneath the figure is a northward velocity of 1 knot (50 cm/s).

Figure 4 - Hourly surface wind vectors, derived from logged values of relative wind velocity and ship's velocity. The arrow underneath the figure is a northward velocity of 10 knots.



U.T.M. PROJECTION

SCALE 1 TO 22500000 (.9996 NATURAL SCALE AT C.M.)

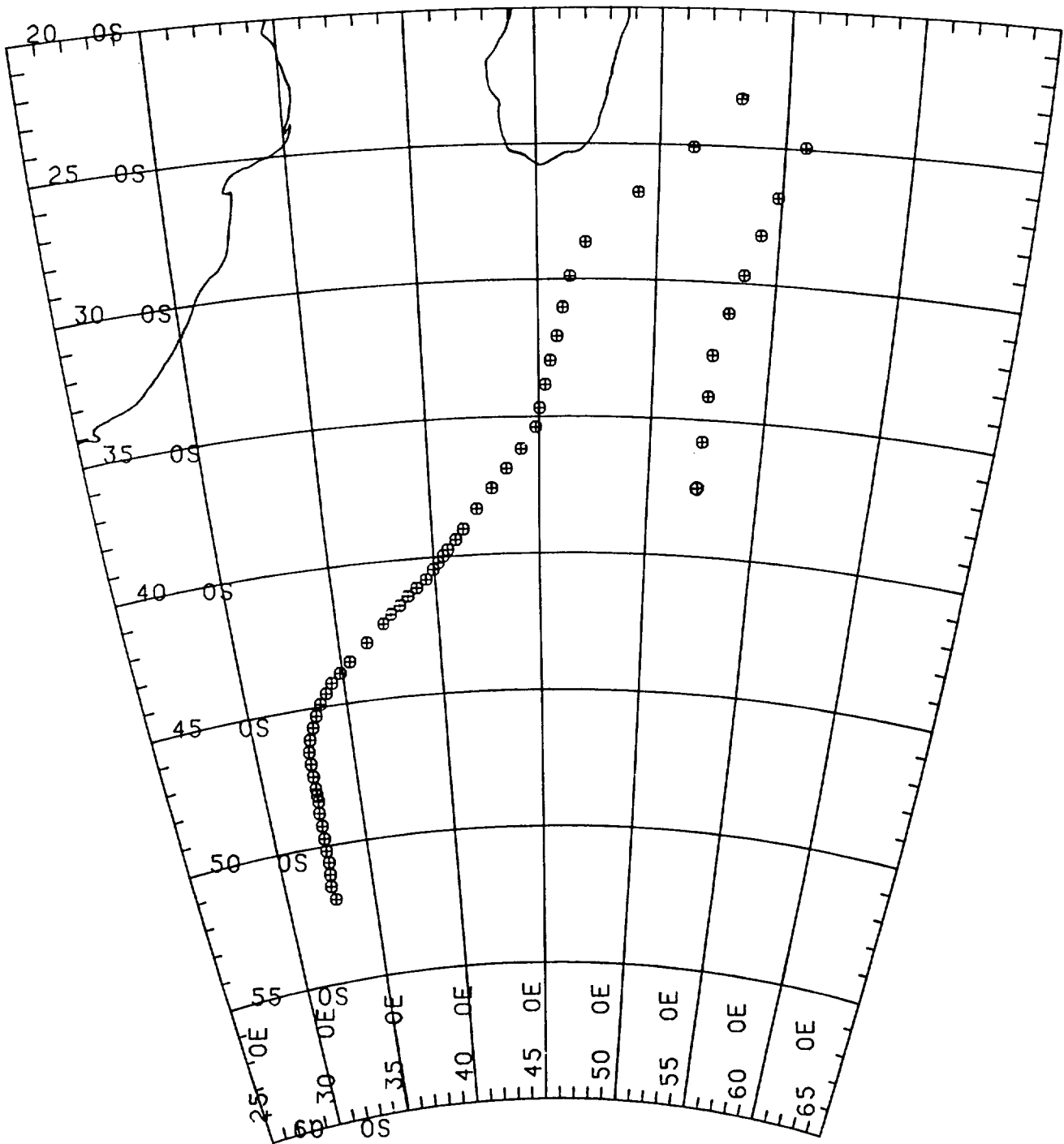
C.M. 45E International Spheroid

U.T.M. Zone 38

R.R.S. Discovery Cruise 164 R.T.Pollard 1986/87

GRID NO. 1
TRACK NO. 1

Fig.1



U.T.M. PROJECTION

GRID NO. 1

SCALE 1 TO 22500000 (.9996 NATURAL SCALE AT C.M.)

C.M. 45E International Spheroid

U.T.M. Zone 38

R.R.S. Discovery Cruise 164 R.T.Pollard 1986/87

Fig.2

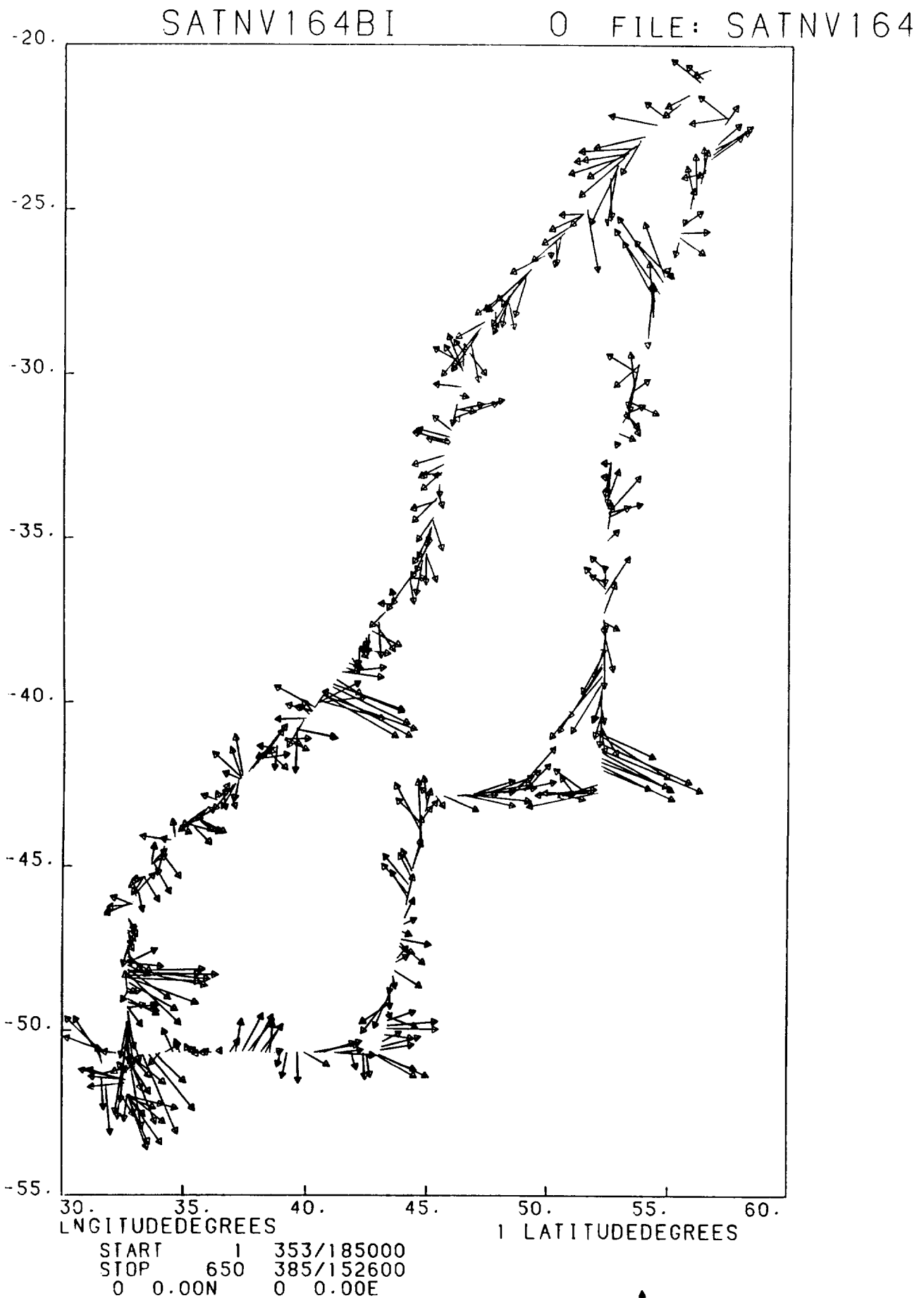
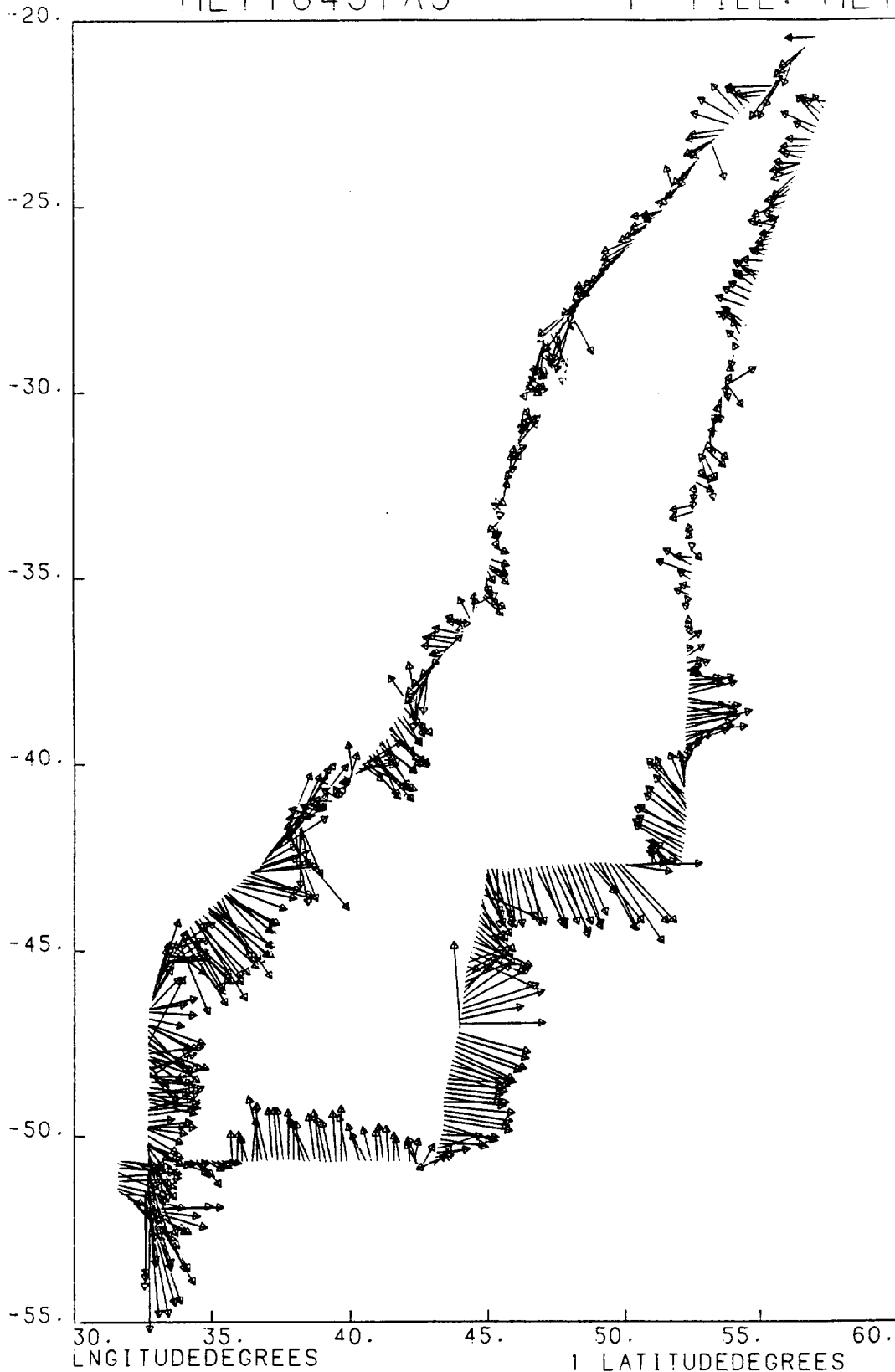


Fig.3

MET1640IAJ

1 FILE: MET1640



START 1 353/200000
STOP 746 385/150000
0 0.00N 0 0.00E



Fig.4