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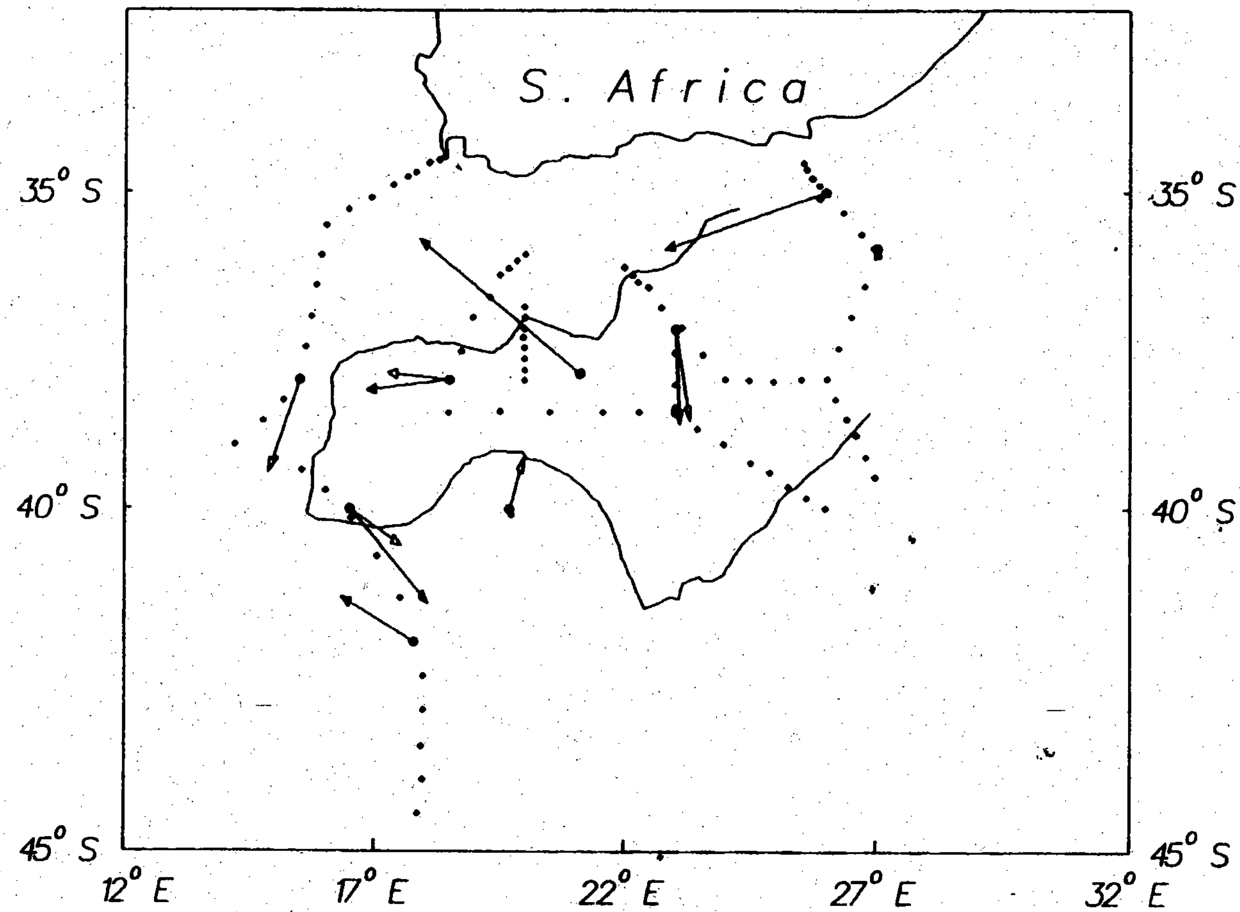
Moored Current Meter, AVHRR, CTD, and Drifter Data From the Agulhas Current and Retroflexion Region (1985-1987) Volume XLII



by

J. Luyten, A. Spencer, S. Tarbell, K. Luetkemeyer, P. Flament, J. Toole, M. Francis and S. Bennett

Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

July 1990

Technical Report

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Approved for Distribution:

James R. Luyten, Chairman
Department of Physical Oceanography

Abstract

Data are presented from an experiment designed to explore the spatial and temporal structure of the Agulhas Current and Retroflexion by direct means. Included are the current meter results from 10 moorings in the Retroflexion region, CTD stations occupied on the deployment cruise in 1985, data from satellite tracked (ARGOS) freely drifting surface buoys and numerous images of the sea surface temperature.

In addition, this report includes a floppy disk on which can be found the one-day average currents, the path of the Agulhas Current, CTD stations in "Live Atlas" format, SST frontal analyses (Chassignet and Olson, personal communication) as well as programs written in QuickBASIC which allow one to access and display these observations. The programs are stored in ASCII and can be run under the Microsoft QuickBasic (Version 4.0 or higher). Instructions for running the programs can be found in a file entitled "read.me" on the disk.

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List of Floppy Disk Directories

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 Volume in drive A is AGULHAS
 Directory of  A:\

READ     ME      18902   3-30-90   9:45a
SST          <DIR>       5-24-90   9:32a
CTD          <DIR>       5-24-90   9:32a
DRIFT        <DIR>       5-24-90   9:32a
MAPS         <DIR>       5-24-90   9:33a
CURRENT      <DIR>       5-24-90   9:34a
PROGRAMS     <DIR>       5-24-90   9:34a
```

```
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 Directory of  A:\SST

.            <DIR>       5-24-90   9:32a
..           <DIR>       5-24-90   9:32a
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AGPATH   RAN     78240   8-21-89  10:11a
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```
 Volume in drive A is AGULHAS
 Directory of  A:\DRIFT

.            <DIR>       5-24-90   9:32a
..           <DIR>       5-24-90   9:32a
DRIFTER  DAT     71992   5-24-90   9:05a
```

```
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 Directory of  A:\CTD

.            <DIR>       5-24-90   9:32a
..           <DIR>       5-24-90   9:32a
AGSTNLL  DAT       552   6-14-88   1:19p
ALLCTD   DAT    235026   5-22-90   1:59p
STATIONS DIR      1288   5-22-90   1:59p
        5 File(s)    111104 bytes free
```

```
 Volume in drive A is AGULHAS
 Directory of  A:\MAPS

.            <DIR>       5-24-90   9:33a
..           <DIR>       5-24-90   9:33a
MERCO    DAT      1065   8-21-89  12:19p
AGULHAS0 DAT       116   8-29-89  10:31a
AGULHAS1 DAT       172   8-29-89  10:31a
AGULHAS2 DAT       204   8-29-89  10:31a
AGULHAS3 DAT       408   8-29-89  10:31a
AGULHAS4 DAT       512   8-29-89  10:31a
```

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 Volume in drive A is AGULHAS
 Directory of  A:\PROGRAMS

.            <DIR>       5-24-90   9:34a
..           <DIR>       5-24-90   9:34a
CTDPLOT  BAS     23713   5-23-90   3:44p
AGULHAS  BAS     31346   6-01-90   1:46p
CMREAD   BAS      9196   8-31-89   3:08p
```

```
 Volume in drive A is AGULHAS
 Directory of  A:\CURRENT

.            <DIR>       5-24-90   9:34a
..           <DIR>       5-24-90   9:34a
AGULCM   RAN    409600   8-13-89   4:28p
CMCONTRL DAT      3410   8-14-89   9:21a
FIFTEEN  RAN       852   8-28-89   1:50p
```

PREFACE

This volume is the 42nd in a series of technical reports presenting moored current meter and associated data collected by the WHOI Buoy Group. Only the volumes covering data gathered since 1978 are listed here. A data directory and bibliography for the years 1963–1978 has been published as WHOI technical report 79-88. A technical memorandum, WHOI-3-88, describes the current-meter data processing system and its use.

Volume Number	WHOI Reference Number	Author	Experiment
XVIII	79-65	Tarbell, S., M. Briscoe & R. Weller	1978 JASIN
XXI	79-85	Mills, C. & P. Rhines	1978 W.B.U.C.
XXIII	80-40	Tarbell, S. & R. Payne	1978 POLYMODE
XXVIII	81-73	Mills, C., S. Tarbell, W. Owens & R. Payne	1978 L.D.E.
XXIX	82-16	Levy, E. *et al.*	1979 INDEX
XXX	82-43	Levy, E., S. Tarbell & N. Fofonoff	1979 GSE/NSOI
XXXI	83-30	Levy, E. & S. Tarbell	1981 WESPAC
XXXII	83-46	Levy, E.	1979 Vema Channel
XXXIII	84-6	Spencer, A., D. Chausse & W. B. Owens	1981 NPBC
XXXIV	84-16	Levy, E. & P. Richardson	1983 SEQUAL I
XXXV	84-36	Tarbell, S., N. Pennington & M. Briscoe	1982–4 LOTUS
XXXVI	84-37	Levy, E. & P. Richardson	1983–4 SEQUAL II
XXXVII	85-7	Levy, E. & P. Richardson	1984 SEQUAL III
XXXVIII	85-39	Tarbell, S., E. Montgomery & M. Briscoe	1983–4 LOTUS
XXXIX	86-14	Levy, E. & S. Tarbell	1983–4 HEBBLE
XL	87-19	Tarbell, S., P. Richardson & J. Price	1984–6 Canary Basin
XLI	87-20	Levy, E. & S. Tarbell	1983–5 Zonal Pacific

Introduction:

This report presents data gathered during the period February, 1985 through February, 1987, in the region of the Agulhas Current and Retroflexion region off southern Africa.

The principal scientific objective of this particular program has been to observe the Agulhas Retroflexion system directly. The Agulhas Current system is the western boundary current for the subtropical gyre of the South Indian Ocean. It is a vigorous narrow current, with typical speeds at the sea surface of 2 m/s or more, extending to the ocean floor. Like other western boundary currents, the Agulhas Current meanders over a wide range. In addition, direct estimates of long term mean flow and its variability provide strong constraints on models of this system.

A two-year moored current meter array spanning the Agulhas Retroflexion was deployed and recovered between 1985 and 1987. The array consisted of 10 moorings, with instruments at four depths, the uppermost instrument at a nominal depth of 200 m. The array spanned the Retroflexion from a region where the Agulhas is closely confined to the continental rise to the far western edge of the circulation. During the deployment cruise, the first detailed survey of the path of the Agulhas Current (as defined by the 15° isotherm at 200-m depth) was made, from the continental rise to the Agulhas Plateau, approximately 1800 km in length. On the recovery cruise, a detailed survey was carried out of the upper ocean density structure in the southwest "corner" of the Retroflexion, using a towed undulating CTD, a Seasoar from the Institute of Oceanographic Sciences Deacon Laboratory, Wormley, U.K.

Data were gathered using four instrumental/measuring systems. In section 1, current meter data from 10 two-year-long moorings are presented. In section 2, sea-surface temperatures obtained from satellite imagery collected at Hartebeeshoek, South Africa are presented. Thirty-three black and white images were selected and three composite color images were computed. In section 3, data from 92 CTD stations with values for salinity, potential temperature, dissolved oxygen and geostrophic velocity, are presented graphically and in tabular form. In section 4, tracks from nine surface drifters are presented graphically.

Deployment Cruise – RV *Thomas Washington*:

The deployment of the moored current meter array was carried out on the RV *Thomas Washington*. The cruise was designated Marathon Legs 11/12 by Scripps Institution of Oceanography. The ship departed Capetown, 20 February, 1985, returning briefly to Capetown on 5 March to load additional equipment for the mooring array. The second leg departed Capetown 7 March and returned at the completion of the work on 28 March, 1985. Charts of the mooring locations and the CTD stations are shown in Figures 1 and 2 of section 1.

The principal scientific activities of the cruise were the deployment of 10 intermediate moorings, occupation of 93 full-depth CTD stations and a detailed survey of the path of the Agulhas Current, as defined by the locus of the 15°C isotherm at 200-m depth. Six ARGOS tracked surface drifters were deployed, one for Robert Chase (WHOI) and the remaining five for Don Olson (RSMAS, University of Miami). Each of these is described briefly in section 4.

Recovery Cruise – RRS *Discovery*:

The mooring recovery operation was carried out on RRS *Discovery*, cruise 165a. After sailing from Port Louis, Mauritius 13 March, 1987 *Discovery* steamed for the first mooring (843) to be recovered. A deep CTD station was made at each mooring location. After recovering the second mooring (842), the Seasoar was launched and was towed approximately parallel to the path of the Agulhas Current, until we approached the next group of moorings. A track chart from Read *et al.* (1987) is shown as Figure 3 (Section 1). Moorings 841, 840, and 839 were recovered. The Seasoar was deployed for a three-day run to the next mooring (837) while making a section across the Agulhas toward the coast and then back out again. Moorings 837, 838, 834, and 835 were recovered and Seasoar sections of 17–19 hours running time were made between them. After recovering the final mooring, 836, the remaining time was spent towing the Seasoar. We planned to survey the Retroflexion region, looking at the structure of the "elbow." As the weather worsened, it was found that progress could not be maintained against the westerly wind and eastward current. The Seasoar was recovered and the ship heaved to. A fire in the main engine room while hove-to terminated the scientific work. The *Discovery* returned to Capetown on 8 April 1987.

SECTION 1

Current and Temperature Measurements from Moored Instruments in the Agulhas Retroflexion Region

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In this section, data from current meters set on 10 moorings are presented. Current measurements were obtained from 33 of the 40 instruments set. (See Table 2 for an assessment of data quality and Figures 7–26 for velocity, temperature, and pressure plots.)

Moorings:

The ten moorings were designed and deployed by the WHOI Buoy Group, with four current meters on each mooring. Nine of the ten moorings had a 60-inch syntactic foam sphere as the principal buoyancy element at the top of the mooring to reduce the overall drag in the expected large near-surface current. The local topography was determined prior to launch by using the ship's Seabeam system to complete a detailed survey. The aids to navigation were generally poor, with the transit system being the most reliable. In the presence of the often strong Agulhas Current and inconsistent navigation, it was difficult to position the ship effectively to deploy the mooring "on target." This accounts for some of the variations in the "mean" depth of the current meters from their nominal depths (this is discussed briefly below under Mooring Performance).

This mooring array was the first one in which significant number of moorings (all 10) were deployed for a two-year period. This required modifications to both the current meters and acoustic releases (each discussed below). Given our uncertainty about the navigation and the survival of the acoustic releases for a two-year deployment, we included an acoustic transponder on each mooring, located at approximately 2000 m depth. All ten of the moorings were recovered in 1987 aboard the RRS *Discovery*. One of the ten (mooring 840) had parted in the first shot of the Kevlar near 2250 m depth. A microscopic analysis was performed on the end returned from sea, and it was reported that "a sharp object cut it — perhaps fishbite" (Bryce Prindle, personal communication). The moorings that were in the major part of the Agulhas Current (839, 838, 842) showed considerable wear on the shackles and other hardware close to the attachment of the syntactic foam sphere to the mooring wire.

Mooring Performance:

The performance of the moorings in the strong Agulhas Current was significantly poorer than had been anticipated by the mooring design program. Typically a factor of 2–3 in the ratio between the observed dip of the uppermost instrument and that calculated by the mooring design program NOYFB (Moller, 1976) for the observed current velocities was seen. A study is underway to estimate appropriate drag coefficients by fitting the performance data in a least square sense (Luyten and Tupper, in preparation).

To prepare the releases for a two-year deployment, all circuits were powered by lithium batteries. The capacity of the backup pinger batteries was increased (22 v to 45 v), and the pinger circuit current was closely scrutinized and components changed to obtain the lowest possible current drain in a quiescent state. Likewise, the receiver circuit was tuned so that current drain was minimized and battery life extended. An extended duration test of similar lithium batteries (bottom mooring 832, off Hawaii) showed that they performed after four years in the water.

The transponder placed on each mooring at approximately 2000 m, to act as a back-up for the release transponders, proved worthwhile. On the recovery cruise, two releases failed to transpond, but fired on command after the backup transponder had indicated the mooring was in position. Double anodes were used on the outer case of the releases, to extend corrosion protection.

In September, 1988, the sphere from the parted mooring (840) was reported beached in western Australia, in the Abrolhos Island group (29°S, 114°E, near Geraldton). It was subsequently shipped back to WHOI. Mooring locations are shown in Figure 1 and in Table 1. Mooring 840 was only partially recovered (see above). Details of the moorings are shown in diagrams, located on row G of the fiche, and one is duplicated as Figure 4. The depths of the instruments were computed using program NOYFB (Moller, 1976) and are shown in Tables 2 and 3.

Table 3 gives pressure and depth information for the upper instruments. It should be noted that the depths for all instruments on mooring 835 were adjusted. A discrepancy of approximately 300 m was seen between the pressure record and the computed NOYFB depth. It was determined that a shot of wire had not been put in the mooring line. Apparent discrepancies between "calculated" (NOYFB) and "observed" (most frequent) pressures can be attributed to mean currents tilting the moorings and increasing the mean depth of the instruments.

Current Meters:

The moorings in the array were instrumented with burst sampling (Model 850) and vector averaging (VACM) current meters. They use a Savonius rotor to measure the current speed and are coupled in-line on the moorings. They provide a measure of the speed and direction of the currents and, with calibrated thermistors, water temperature. A crystal-controlled time reference accurate to within one second per day is synchronized with UTC (Universel Temps Coordonne) before launch and the accrued error recorded after recovery.

The only modification for the two-year deployment was the use of lithium batteries. However, with recent information available from a two-year Gulf Stream array, alkaline batteries were found to perform satisfactorily. Magnetic tape length (> 400 feet) and recording interval (30 minutes for VACMs) were chosen so measurements could be recorded for two years. A one-hour recording rate was chosen for model 850 current meters.

The model 850 current meter, originally built by Geodyne, measures in a burst sampling mode described by Webster (1968). These early instruments were extensively modified at WHOI in the mid-1970s to take advantage of newly developed low-power integrated-circuit technology and a new sensor-bearing design. The basic burst sampling technique was not changed. At a pre-selected time interval, which can be set to any binary multiple of 7.5 minutes, the instrument turns on and begins recording a sequence of strobes (either 7, 15, or 23). These data are recorded on magnetic tape. It then turns off until the beginning of the next record. The first strobe contains temperature information, the second contains the time, and the remainder of the strobes are pairs of rotor counts and compass/vane readings. Each strobe of rotor count is accumulated over 5.19 seconds and is paired with instantaneous compass and vane samples. Valdes (1977) included a more detailed discussion of the WHOI COS/MOS 850 current meter. For the Agulhas array, the strobe rate was set to seven and the recording interval to one hour.

By the early 1970's, engineers at WHOI had developed a vector-averaging current meter which is now commonly known as the VACM. Built by AMF Sea-Link Systems (now EG&G Ocean Products), the VACM continuously sums vector increments of water flow sensed by the rotor and vane. At regular intervals, set prior to deployment, it then records on a magnetic tape cassette the accumulated east-west and north-south velocities as a part of the data record. McCullough (1975) discussed calibration of the vector averaging current meter and its recording technique.

Some VACMs average temperature over the entire recording interval to an accuracy of about 0.01°C (Payne *et al.*, 1976). By 1980, a modification had been developed which permitted up to four variables in addition to current data to be recorded in a time-shared or multiplexed (MX) mode. Many of the VACMs measured temperature and pressure in the array, each averaging over one-half of the record interval. The multiplex circuit temperature measurement is accurate to about .006°C. Pressure is measured to about 0.1% or 3 decibars for a standard 3000 decibar transducer. Pressure and temperature sensors are recalibrated between deployments.

Data Processing:

Data from instrument cassettes or cartridges were transferred to VAX disk. Two methods were used; either transfer through an ARI interface or reading to 9-track tape on an LSI-11 computer followed by transfer from tape to VAX disc. The data were then reformatted into BUOY format (Tarbell *et al.*, 1988), the time base checked, and the data converted to scientific units. Then the data quality (Table 2) was determined, bad data points were edited out and the data series were truncated to remove launch and retrieval transients. Gaps in the data were linearly interpolated to create an evenly spaced time series. This series is known as the Best Basic Version (BBV) and is the basis for all further processing. A low-passed version of the data was created by applying a Gaussian filter with a half-width of 24 hours, then subsampling the filtered series once a day.

WHOI Buoy Group data are identified by a mooring number, a sequential instrument position number, a letter to indicate the data version and numbers to indicate the sampling rate. Therefore, 8392B1800, identifies data from the second instrument on mooring 839. The version number is B and the sampling rate is a record every half hour (1800 seconds). 8391B1DG24 is a time series that has had a Gaussian filter applied to the first instrument on mooring 839. The filter has a half width of 24 hours (G24) and is subsampled once a day (1D).

Data quality and other information are shown in Table 2. The duration and dates are for the daily filtered series. Instrument numbers preceded by an M are model 850 current meters. Numbers preceded by a V are VACMs; if a P follows the number, a pressure sensor was used.

Instrumental problems were mostly caused by excessive vibration of the mooring line in the high currents. Data record 8391 was short due to damage to circuit board components. Data records 8371 and 8392 were unavailable due to tape-drive malfunctions. The data for record 8422 is very suspect, and the instrument exhibited a high rotor threshold.

Data Presentation:

Composite plots of 'sticks' (current vectors) and temperature are shown in Figures 7–26. Variables versus time plots, histograms, spectral diagrams statistics and scatterplots are presented on microfiche.

Histograms

The histograms of five variables are plotted as percentage of occurrences. There are 50 cells in the x-axis of East component, North component, Speed and Direction. The x-axis of temperature has 100 cells.

Progressive Vector Plots

Current vectors from the basic data series are placed head-to-tail to show the path a particle would have travelled in a perfectly homogeneous flow. The plot begins with an asterisk followed by annotated triangles at the first of each month.

Scatterplots

East and North components from the Gaussian filtered time series are plotted against each other. The line drawn is the principal axis, the major axis of the ellipse of variance. The values describing the principal axes in the statistical table are not those for the principal axes drawn on the plot, because the table used the basic sampled data and the plot used the Gaussian filtered data. When pressure was measured, plots of temperature vs. pressure and speed vs. pressure are shown.

Spectra

Plots of auto-spectra for the east component of velocity, the north component of velocity, the temperature, and the pressure are shown. Further information about the program used to create these plots may be found in the WHOI program report PROSPECT (Hunt, 1982).

The data is prewhitened and recolored. Program PROSPECT allows averaging in increasingly large groups. Piece lengths are given in Table 5. The frequency-averaging sequence for these data is:

Number of Frequencies	Number of Groups
3	40
6	15
15	6
30	30
60	15
150	6
300	30
600	15
1500	6
3000	30
6000	15
15000	6

Statistics

The statistics for each variable from the basic time series and the daily filtered time series are presented on fiche. The equations used to derive the statistical parameters are described by Tarbell *et al.* (1988). In Table 4, the statistics from the daily series are summarized. The "< >" nomenclature is used to denote time averaging.

Variables vs. Time

All plots of variables versus time are from the Gaussian filtered series. The 'stick' plots, which show individual current vectors along the time scale, are plotted two ways, one with North up and the other rotated so that East is up.

Array Plots

A schematic of frames, with an area representing the location of the array, is set up. For a chosen depth level, vectors are plotted with their base at their instrument location. In Figure 25, the vectors represent the time-averaged velocities over the duration of the experiment (or for as long as the instruments performed). Tick intervals represent 1° of latitude and 1° of longitude. Vector scales are 10 cm/sec at upper levels and 2.5 cm/sec at lower levels. In Figure 26, the vectors are from measurements at 200 m, subsampled every tenth day from a gaussian filtered (five-day half-width) series. Tick intervals represent 2° of latitude and 2° of longitude, and the vector scale is 20 cm/sec.

Acknowledgments:

This research was made possible with funds provided by the Office of Naval Research, contract numbers N00014-84-C-0134, NR083-400, and N00014-85-C-0001, NR083-004. The principal investigator is James R. Luyten.

The current meter moorings were launched from R/V *Thomas Washington* (*Marathon* cruise, # 11, leg 3) and recovered by R/V *Discovery* (cruise # 165A). The observations reported here were obtained through the assistance of many individuals — notably the members of the Woods Hole Buoy Group, the Woods Hole CTD Group, Raymond Pollard and his Seasoar group from IOS Wormley. Their help is gratefully acknowledged. In addition we gratefully acknowledge the officers and crew of the R/V *Thomas Washington* from Scripps and of the RRS *Discovery* from the National Environment Research Council who often went well beyond their specific duties to assist in our program.

References

Hunt, M., 1982. A program for spectral analysis of time series "PROSPECT." WHOI internal document, 188 pp.

McCullough, J. R., 1975. Vector Averaging Current Meter Speed calibration and recording technique. WHOI Technical Report No. 75-44, 49 pp.

Moller, D. A., 1976. A computer program for the design and static analysis of single point susburface mooring systems: NOYFB. WHOI Reference No. 76-59, 106 pp.

Payne, R. E., A. L. Bradshaw, J. P. Dean and K. E. Schleicher, 1976. Accuracy of temperature measurements with the VACM. WHOI Reference No. 76-94, 78 pp.

Read, J. F., R. T. Pollard and J. Smithers, 1987. CTD and Seasoar data from the Agulhas Retroflection Zone. Institute of Oceanographic Sciences Deacon Laboratory Report No. 245, 91 pp.

Tarbell, S., M. Chaffee, A. Williams and R. Payne, 1979. The WHOI Moored Array Project 1963–1978 data directory and bibliography. WHOI Reference No. 79-88, 168 pp.

Tarbell, S., A. Spencer and E. T. Montgomery, 1988. The Buoy Group data processing system. WHOI Technical Memorandum, Reference No. 88-3, 209 pp.

Valdes, J. R., 1977. COS/MOS 850 current meter report. WHOI Technical Report No. 77-30, 89 pp.

Webster, F., 1968. A scheme for sampling deep-sea currents from moored buoys. WHOI Technical Report No. 68-2, 14 pp.

Table 1: Mooring Information

Mooring S	#	Depth (m)	Latitude (°S)	Longitude (°E)	mv	Deployment Date & Time (1985)	Recovery Date & Time (1987)
8	834	4831	38°01.8′	15°30.9′	25	Feb 23, 0606	Feb 15, 0228
9	835	4847	40°07.96′	16°34.6′	25	Feb 25, 1253	Feb 16, 0545
10	836	4864	41°59.1′	17°50.0′	26	Feb 26, 1137	Feb 17, 0210
7	837	5092	40°06.4′	19°44.8′	26	Mar 01, 0427	Feb 12, 1412
6	838	4705	38°01.5′	18°31.3′	25	Mar 09, 0549	Feb 13, 1529
5	839	4620	37°52.74′	21°08.54′	26	Mar 10, 1003	Feb 09, 1257
4	840	5257	38°34.5′	23°07.7′	26	Mar 11, 0753	Feb 08, 1924
3	841	5318	37°12.2′	23°02.0′	25	Mar 11, 0127	Feb 07, 1535
2	842	4649	35°55.5′	26°59.0′	26	Mar 14, 2326	Feb 06, 0141
1	843	4101	35°03.4′	26°01.8′	25	Mar 15, 1844	Feb 05, 0537

Notes:

- There are two columns of numbers under MOORING. S is the number assigned for scientific use. # is the WHOI mooring number.
- 'mv' is the magnetic variation, in °E, applied to current direction values obtained by the instrument.
- The deployment cruise was leg 3 of the Marathon XI cruise of the R/V *Thomas Washington*. The recovery was made on RRS *Discovery*, cruise #165A.

Table 2: Data Durations, Depth, and Quality

Data Name	Instrument Number	Depth (m)	Number of Days	Start Date	End Date	Quality Notes
8341	V-590P	192	0	—	—	Battery outgassed
8342	V-325P	741	721	02/24/85	02/13/87	Current data only
			449	02/24/85	05/15/86	Early failure of MX data (temp/pressure)
8343	V-375	1493	721	02/24/85	02/13/87	
8344	M-260C	3993	721	02/24/85	02/13/87	
8351	V-181P	408	719	02/27/85	02/14/87	Depth adjusted
8352	V-134P	958	553	02/27/85	02/14/87	See text
8353	V-5115	1709	719	02/27/85	02/14/87	
8354	M-277C	4209	719	02/27/85	02/14/87	
8361	V-177P	145	638	02/28/85	11/26/86	Battery failure
8362	V-115P	697	0	—	—	No tape pulled
8363	V-5105	1446	719	02/28/85	02/15/87	
8364	M-207C	3947	719	02/28/85	02/15/87	
8371	V-109P	291	0	—	—	Tape problem, see text
8372	V-141P	841	713	03/02/85	02/11/87	
8373	V-436	1593	713	03/02/85	02/11/87	
8374	M-261C	4092	713	03/02/85	02/11/87	
8381	V-183P	195	705	03/11/85	02/12/87	
8382	V-366P	745	705	03/11/85	02/12/87	
8383	V-5110	1497	705	03/11/85	02/12/87	
8384	M-238C	3996	705	03/11/85	02/12/87	
8391	V-182P	150	230	03/12/85	10/26/85	Vibration
		150	393	03/12/85	04/07/86	See text
8392	V-163P	699	0	—	—	Tape problem, see text
8393	V-5117	1451	699	03/12/85	02/07/87	
8394	M-256C	3951	176	03/12/85	09/02/85	Velocity data only
			699	03/12/85	02/07/87	Temperature only
8404	M-227C	4055	699	03/12/85	02/07/87	
8411	V-204P	194	613	03/13/85	11/14/86	Battery failure
8412	V-137P	744	697	03/13/85	02/06/87	
8413	V-381	1496	697	03/13/85	02/06/87	
8414	M-250C	3995	697	03/13/85	02/06/87	
8421	V-589P	210	692	03/16/85	02/04/87	
8422	V-164P	760	685	03/16/85	01/28/87	Tape damaged, see text High rotor threshold
8423	V-103	1512	692	03/16/85	02/04/87	
8424	V-681	4011	692	03/16/85	02/04/87	
8431	V-118P	203	355	03/17/85	03/05/86	Battery failure
8432	V-131P	753	0	—	—	Clock board failure
8433	V-113P	1505	690	03/17/85	02/03/87	
8434	V-685	3503	690	03/17/85	02/03/87	

Table 3: Pressure Information

Data Name	Instrument Number	Nominal Depth (m)	NOYFB Depth (m)	Pressure Min	Pressure Max (dbars)	Pressure Range	Most Frequent Pressure (dbars)	Most Frequent Depth (m)
8342	V-325P	700	741	753	1490	737	750	745
8351	V-181P	200	108	412	1105	693	420*	418
8352	V-134P	700	658	966	1653	687	970*	963
8361	V-177P	200	145	167	585	418	170	169
8372	V-141P	700	841	842	1749	907	840	834
8381	V-183P	200	195	205	1148	943	205	204
8382	V-366P	700	745	759	1699	940	770	765
8391	V-182P	200	150	209	982	773	209*	208
8411	V-204P	200	194	205	723	518	210	209
8412	V-137P	700	744	760	1280	520	760	755
8421	V-589P	200	210	159	639	480	225	224
8422	V-164P	700	760	781	1171	390	785	780
8431	V-118P	200	203	208	897	689	400*	398
8433	V-113P	700	1505	1524	2008	484	1650*	1640

* See text.

Table 4: Velocity and Temperature Statistics

DATA NAME	START DATE (1985)	# OF PTS. IN AVG.	DEPTH (m)	LAT. (S)	LONG. (E)	<U>	<V>	$<U>^2$	$<V>^2$	K.m	$<U'^2>$ (c.g.s. units)	$<V'^2>$	K.e	<U'V'>	<T>	$<T'^2>^{\frac{1}{2}}$	<U'T'>	<V'T'>
8342A	02-24	720	741	38°01'	15°30'	-5.8	5.3	33.7	27.9	30.8	371.3	339.7	355.5	30.5				
8342A	02-24	438	741	38°01'	15°30'										4.652	1.3340		
8343B	02-24	720	1493	38°01'	15°30'	-3.7	4.4	13.7	19.2	16.5	152.7	146.1	149.4	-8.3	2.806	0.1441	-0.0873	-0.2834
8344C	02-24	720	3993	38°01'	15°30'	0.0	1.8	0.0	3.3	1.6	177.9	92.2	135.0	-2.8	1.281	0.1479	-0.5038	-0.0147
8351A	02-27	718	409	40°07'	16°34'	7.3	-6.9	53.2	47.7	50.5	912.4	829.4	870.9	4.0	9.527	2.5509	-1.1129	-8.0992
8352D	02-27	718	986	40°07'	16°34'	3.2	-3.6	10.4	12.8	11.6	290.9	261.2	276.1	5.1	4.335	1.4180	-2.6463	-2.7794
8353A	02-27	718	1709	40°07'	16°34'	2.0	-2.1	3.9	4.2	4.0	103.9	90.4	97.1	-9.7	2.766	0.1190	0.0806	-0.2476
8354B	02-27	718	4209	40°07'	16°34'	0.4	1.0	0.1	1.0	0.6	66.6	58.2	62.4	-2.9	1.128	0.1262	0.1023	-0.4076
8361A	02-28	637	145	41°59'	17°50'	9.4	3.8	87.4	14.1	50.8	449.5	365.6	407.5	37.9	10.486	1.4878	-11.5093	-1.3593
8363B	02-28	718	1446	41°59'	17°50'	3.2	0.2	10.2	0.1	5.2	40.1	31.2	35.6	-2.9	2.769	0.0639	-0.0792	-0.0817
8364C	02-28	718	3947	41°59'	17°50'	1.9	-1.3	3.6	1.8	2.7	29.3	18.5	23.9	-7.2	1.147	0.1023	-0.0331	-0.0777
8372A	03-02	712	841	40°06'	19°44'	8.2	5.7	67.2	32.8	50.0	354.3	435.1	394.7	124.8	4.246	1.1735	3.2169	1.4485
8373B	03-02	712	1593	40°06'	19°44'	1.6	5.0	2.5	24.6	13.5	160.4	180.0	170.2	63.4	2.752	0.0974	0.1633	0.1142
8374C	03-02	712	4092	40°06'	19°44'	0.0	3.0	0.0	9.1	4.5	118.3	66.7	92.5	21.5	1.170	0.1104	-0.2321	0.0023
8381B	03-11	704	195	38°01'	18°31'	-14.4	-0.2	206.9	0.0	103.5	1305.3	1387.9	1346.6	31.6	10.326	3.4202	8.9414	3.9019
8382A	03-11	704	745	38°01'	18°31'	-7.9	2.9	62.5	8.3	35.4	448.8	407.8	428.3	-6.6	4.661	1.8664	-4.7828	4.0800
8383A	03-11	704	1497	38°01'	18°31'	-4.3	0.2	18.7	0.1	9.4	226.4	176.1	201.2	-1.3	2.769	0.1505	0.0024	0.2204
8384B	03-11	704	3996	38°01'	18°31'	1.0	1.2	0.9	1.4	1.2	213.2	117.5	165.4	2.4	1.170	0.1203	-0.0287	0.0825
8391C	03-12	229	210	37°52'	21°08'	-49.1	-28.5	2413.0	812.8	1612.9	1026.3	846.4	936.4	87.5	11.813	2.7580	0.6490	27.0470
8391	03-12	392	210	37°52'	21°08'										12.029	2.8931	63.0869	47.0286
8393A	03-12	698	1510	37°52'	21°08'	-6.7	-4.7	44.6	21.9	33.2	182.4	64.3	123.4	-5.1	2.908	0.2521	-1.2886	0.0862
8394B	03-12	175	3951	37°52'	21°08'	7.6	4.5	58.5	20.4	39.4	168.0	61.0	114.5	71.9				
8394TC	03-12	698	3951	37°52'	21°08'										1.251	0.1430		
8404C	03-12	698	4055	38°34'	23°07'	-2.8	4.8	7.6	22.8	15.2	62.1	107.9	85.0	-29.5	1.422	0.1940	-0.0280	-0.5812
8411AC	03-13	612	194	37°12'	23°02'	-15.7	-12.5	247.0	155.3	201.2	503.5	311.6	407.6	82.8	17.357	1.3442	8.1257	5.3881
8412A	03-13	696	744	37°12'	23°02'	-14.2	-10.6	202.0	111.7	156.9	233.3	149.5	191.4	47.1	10.373	1.4504	6.2759	2.9253
8413B	03-13	696	1496	37°12'	23°02'	-7.1	-8.8	50.0	77.0	63.5	70.7	68.5	69.6	4.3	3.730	0.3590	0.6320	-0.0305
8414B	03-13	696	3995	37°12'	23°02'	4.0	1.6	16.1	2.5	9.3	70.3	55.5	62.9	27.8	1.428	0.1310	0.0527	0.0129
8421A	03-16	691	210	35°55'	26°59'	7.6	-1.9	58.3	3.5	30.9	584.2	345.6	464.9	104.9	17.327	1.2480	-16.8060	1.8410
8422QQ	03-16	684	760	35°55'	26°59'	3.7	0.4	13.5	0.1	6.8	165.8	114.5	140.1	38.4	10.498	1.3178	-8.9757	1.5334
8423B	03-16	691	1512	35°55'	26°59'	1.8	0.0	3.3	0.0	1.6	38.8	22.6	30.7	8.1	3.693	0.3614	-0.3036	-0.0564
8424A	03-16	691	4011	35°55'	26°59'	-1.6	-1.1	2.7	1.2	2.0	79.4	56.7	68.0	19.4	1.357	0.0821	0.2103	0.0435
8431B	03-17	354	203	35°03'	26°01'	-65.7	-25.9	4319.3	672.9	2496.1	209.0	423.3	316.2	108.1	14.117	1.9493	-2.3268	18.3787
8433B	03-17	689	1505	35°03'	26°01'	-10.8	-2.2	116.2	4.9	60.6	36.4	20.6	28.5	8.6	3.182	0.2213	-0.1440	0.1321
8434A	03-17	689	3503	35°03'	26°01'	0.4	0.2	0.1	0.0	0.1	32.7	10.8	21.8	4.0	1.753	0.1001	-0.0659	0.0212

Table 5: Spectral Information Table
(number of pieces for all spectral plots = 1)

File Name	Variables	Points Per Piece	Total Data Cycles
8342ATP1800	T	21384	21479
8342A1800	V	34560	34611
8343B1800	V,T	34560	34622
8344C1H	V,T	17280	17305
8351A1800	V,T,P	34496	34515
8352D1800	V,T,P	34496	34514
8353A1800	V,T	34496	34515
8354B1H	V,T	17248	17257
8361A1800	V,T,P	30618	30644
8363B1800	V,T	34496	34514
8364C1H	V,T	17248	17257
8372A1800	V,T,P	34200	34227
8373B1800	V,T	34200	34226
8374C1H	V,T	17100	17113
8381B1800	V,T,P	33800	33846
8382A1800	V,T,P	33800	33843
8383A1800	V,T	33800	33843
8384B1H	V,T	16900	16923
8391C1800	V,T,P	11016	11041
8393A1800	V,T	33534	33555
8394TC1H	T	16758	16777
8394B1H	V	4224	4225
8404C1H	V,T	16758	16777
8411AC1800	V,T,P	29440	29448
8412A1800	V,T,P	33396	33459
8413B1800	V,T	33396	33458
8414B1H	V,T	16698	16729
8421A1800	V,T,P	33212	33219
8422QQ1800	V,T,P	32832	32882
8423B1800	V,T	33212	33218
8424A1800	V,T	33212	33219
8431B1800	V,T,P	17000	17042
8433B1800	V,T,P	33048	33122
8434A1800	V,T	33048	33123

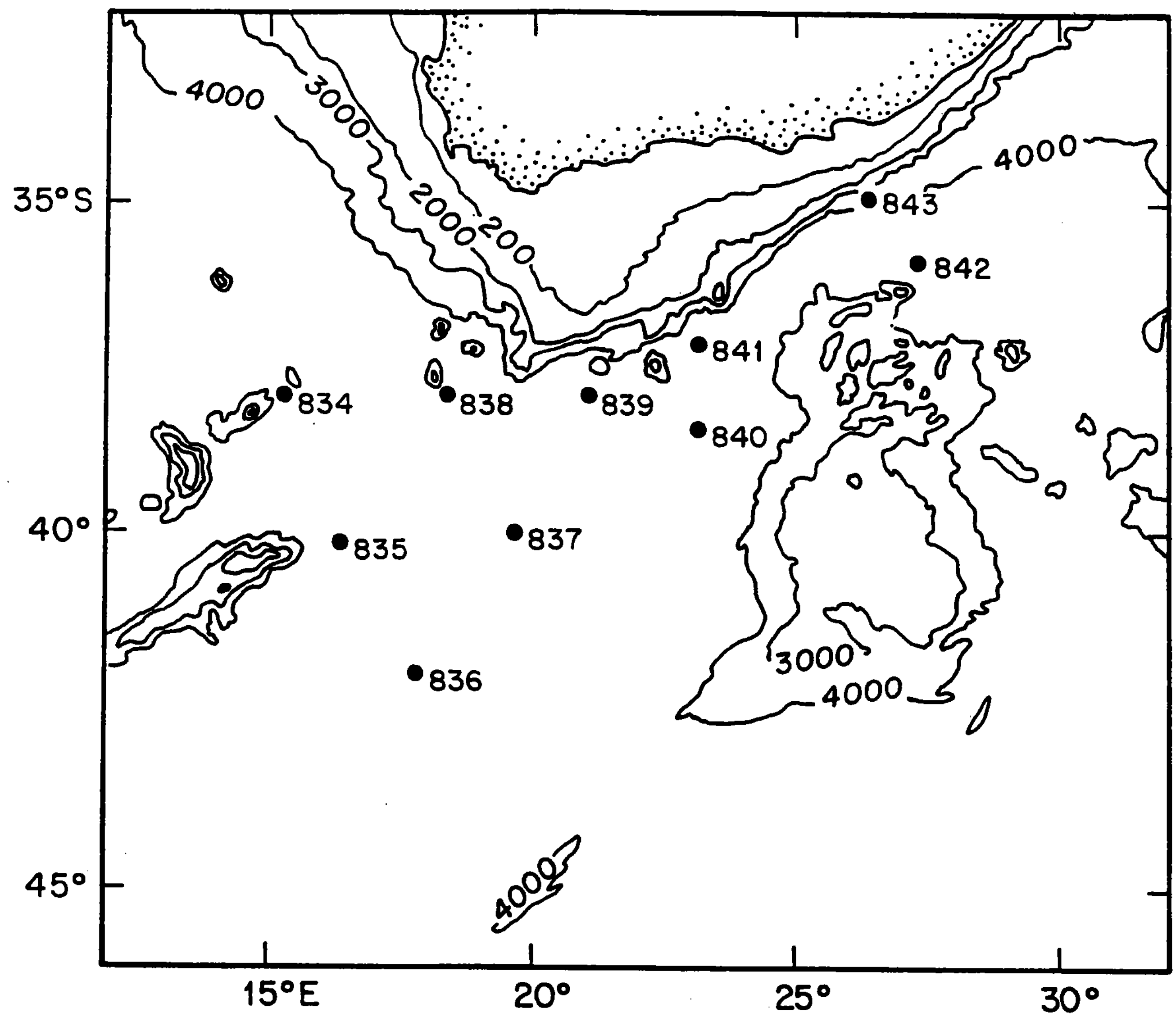


Figure 1
Mooring locations

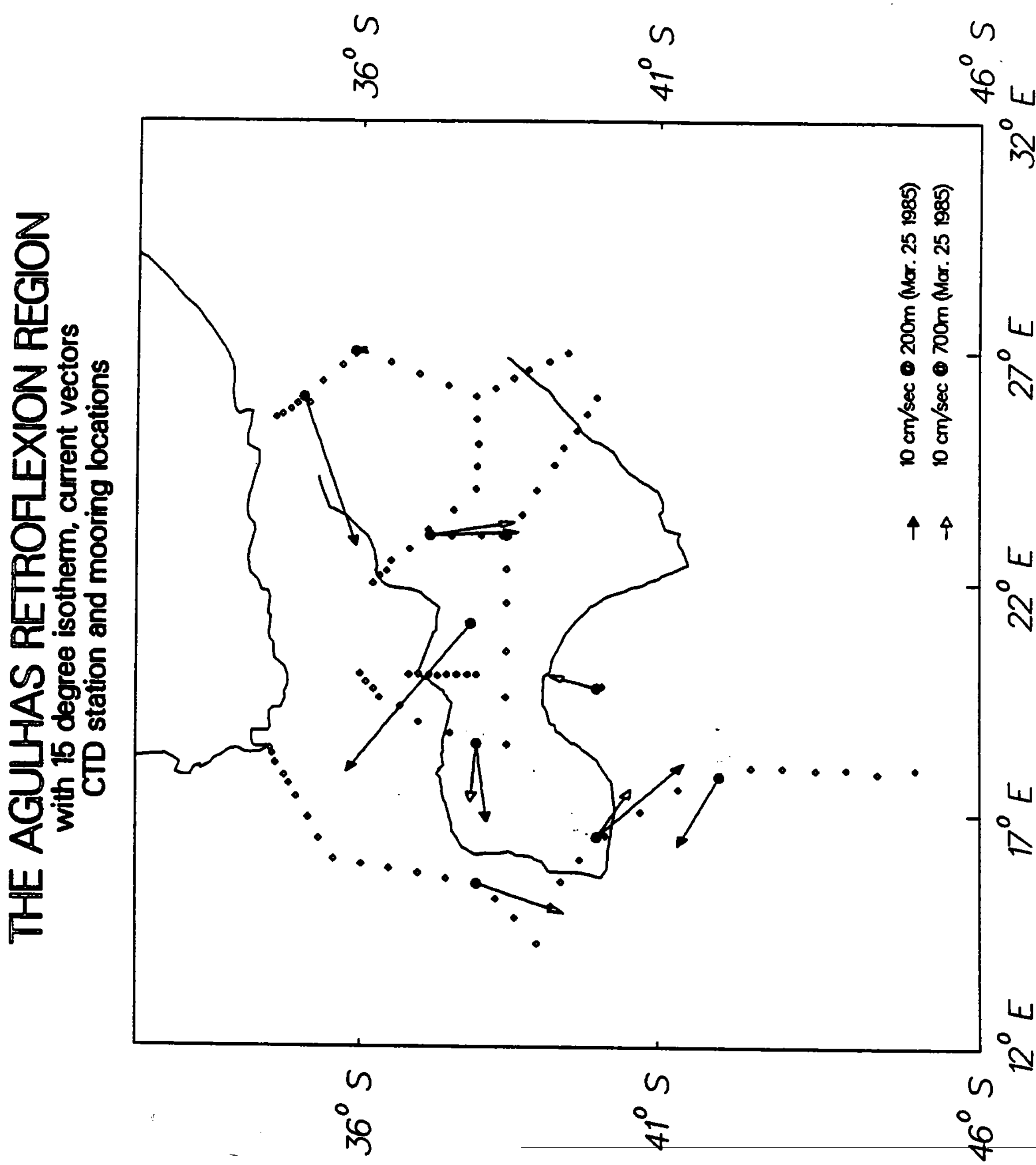

THE AGULHAS RETROFLEXION REGION
with 15 degree isotherm, current vectors
CTD station and mooring locations
10 cm/sec @ 200m (Mar. 25 1985)
10 cm/sec @ 700m (Mar. 25 1985)
36° S
41° S
46° S
12° E
17° E
22° E
27° E
32° E

Figure 2

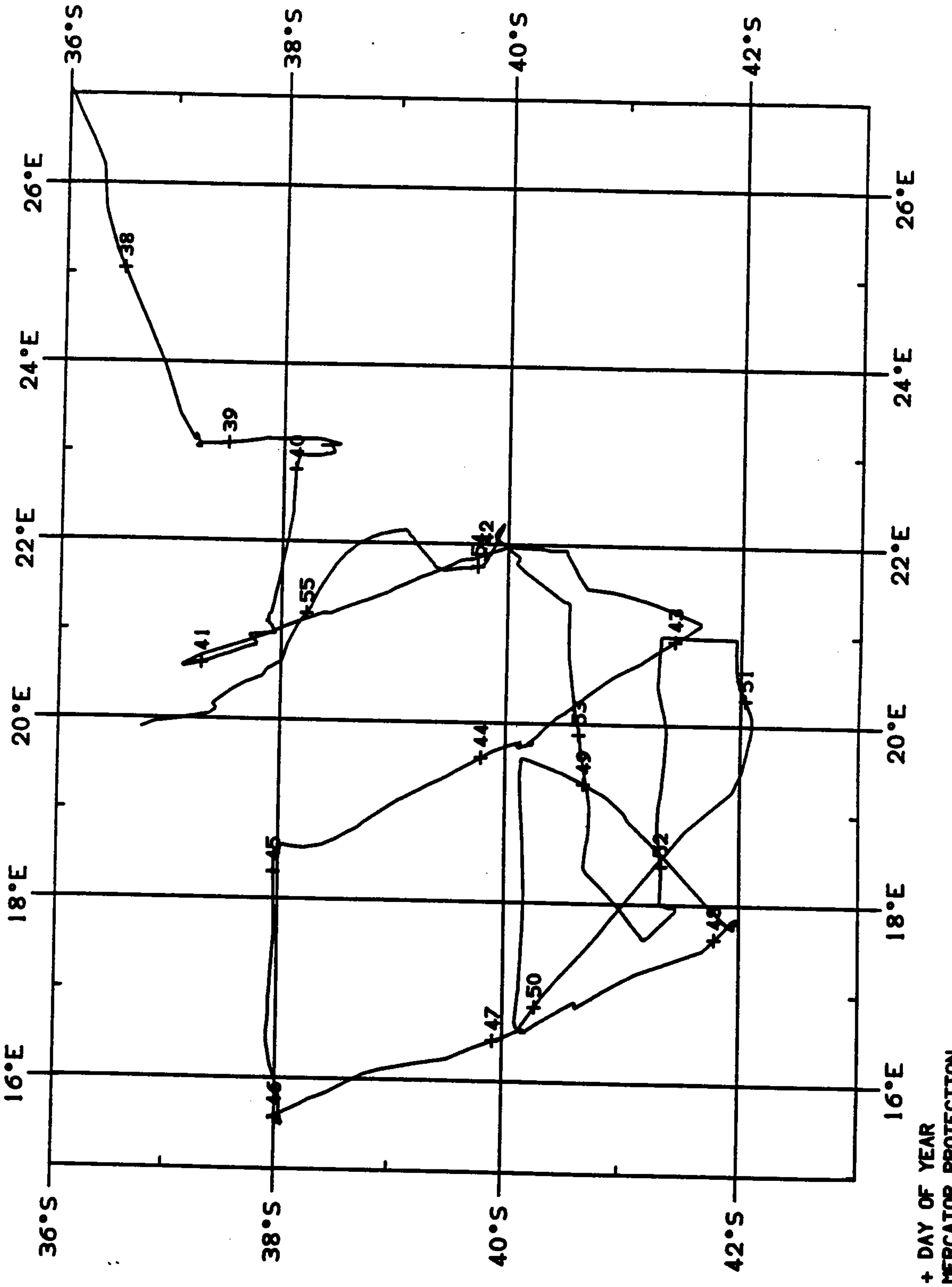


Figure 3
Track of Seasoar deployment

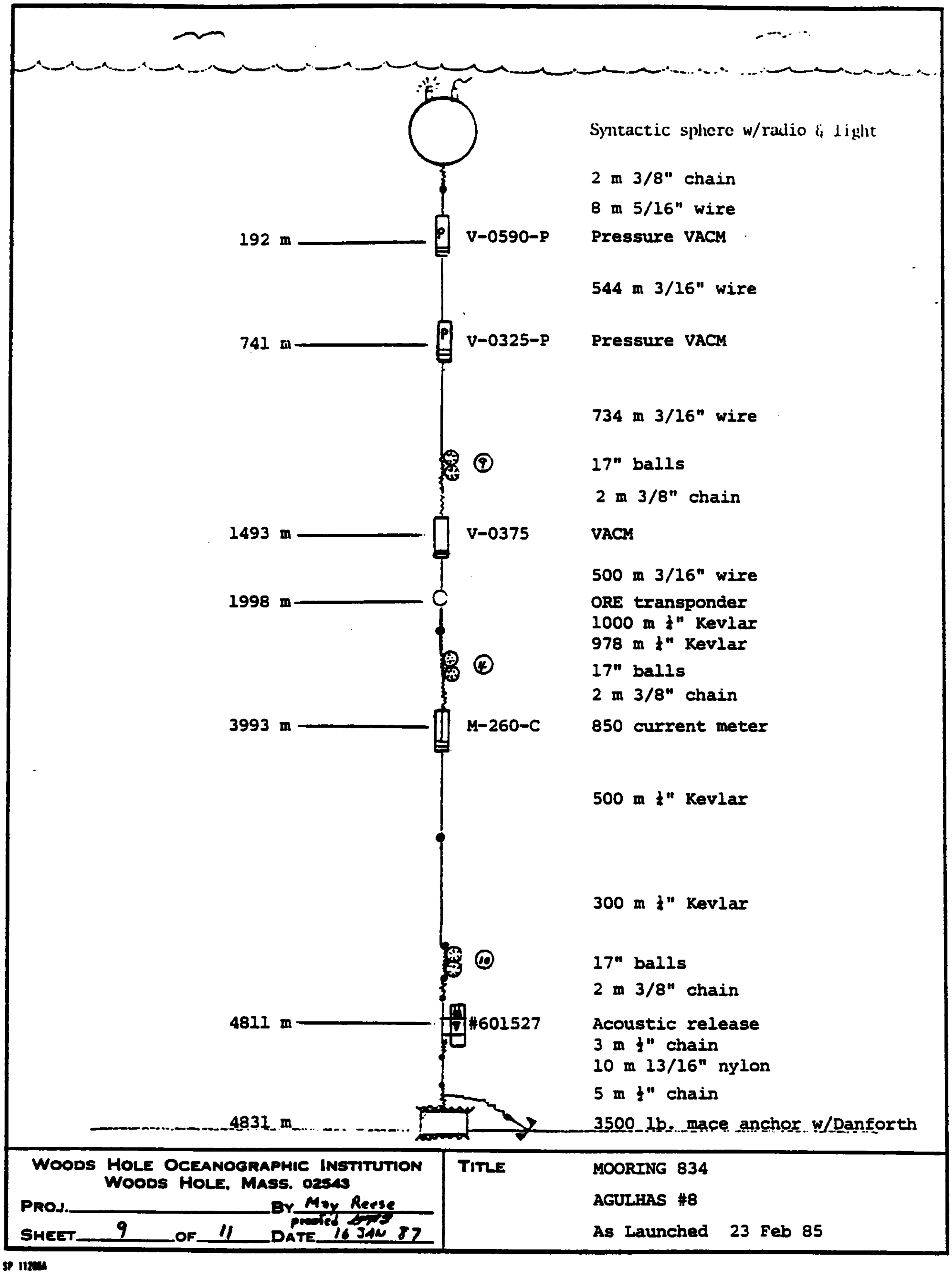


Figure 4
Diagram of typical mooring

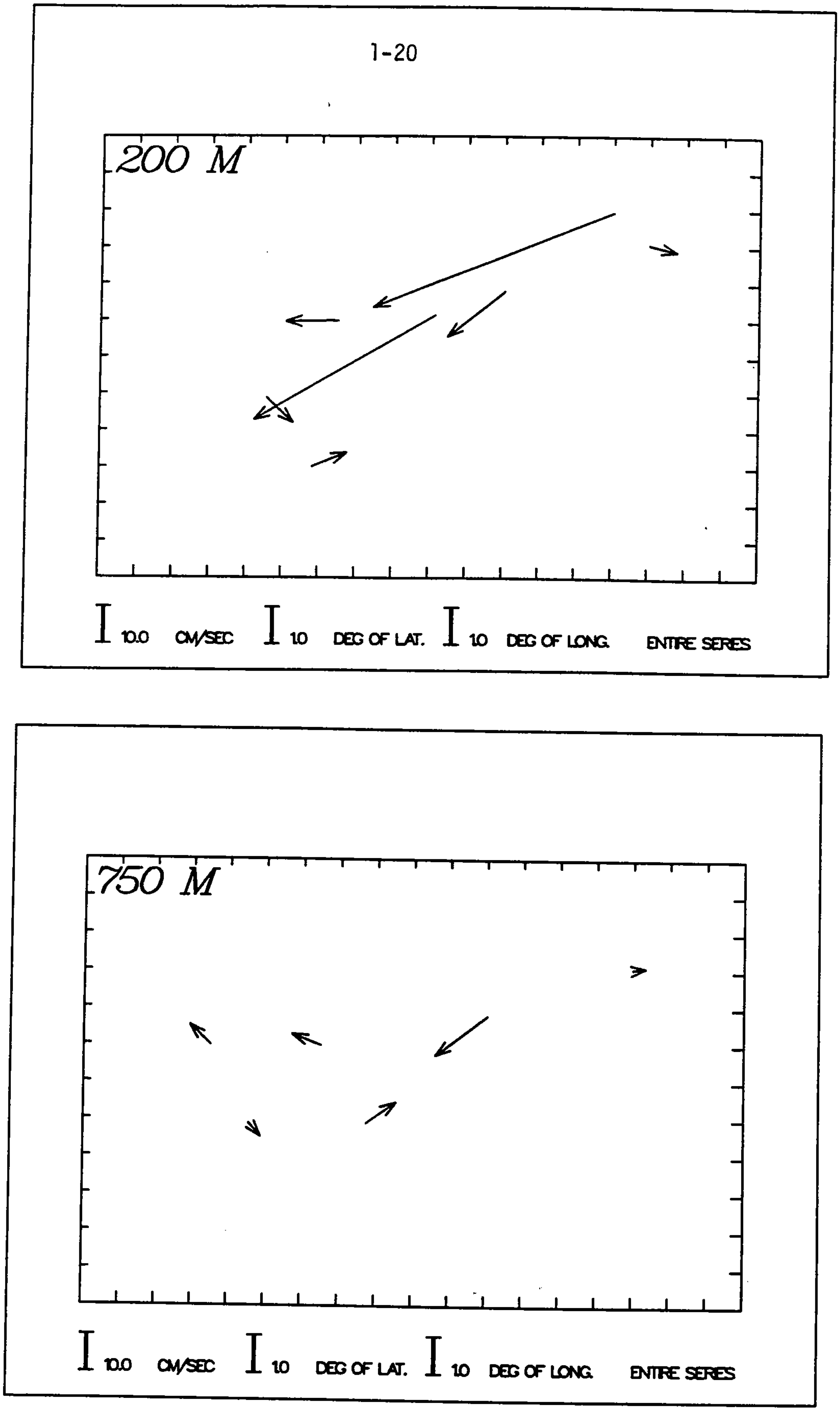
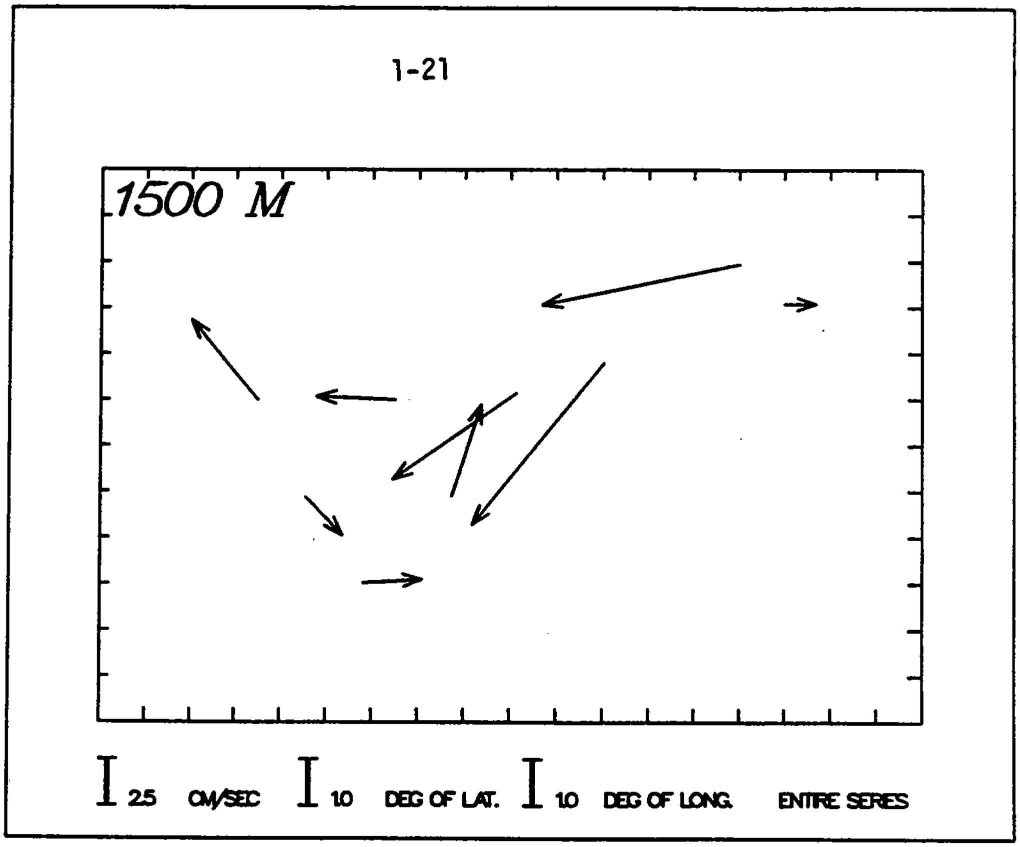


Figure 5
Mean current vectors at
each depth



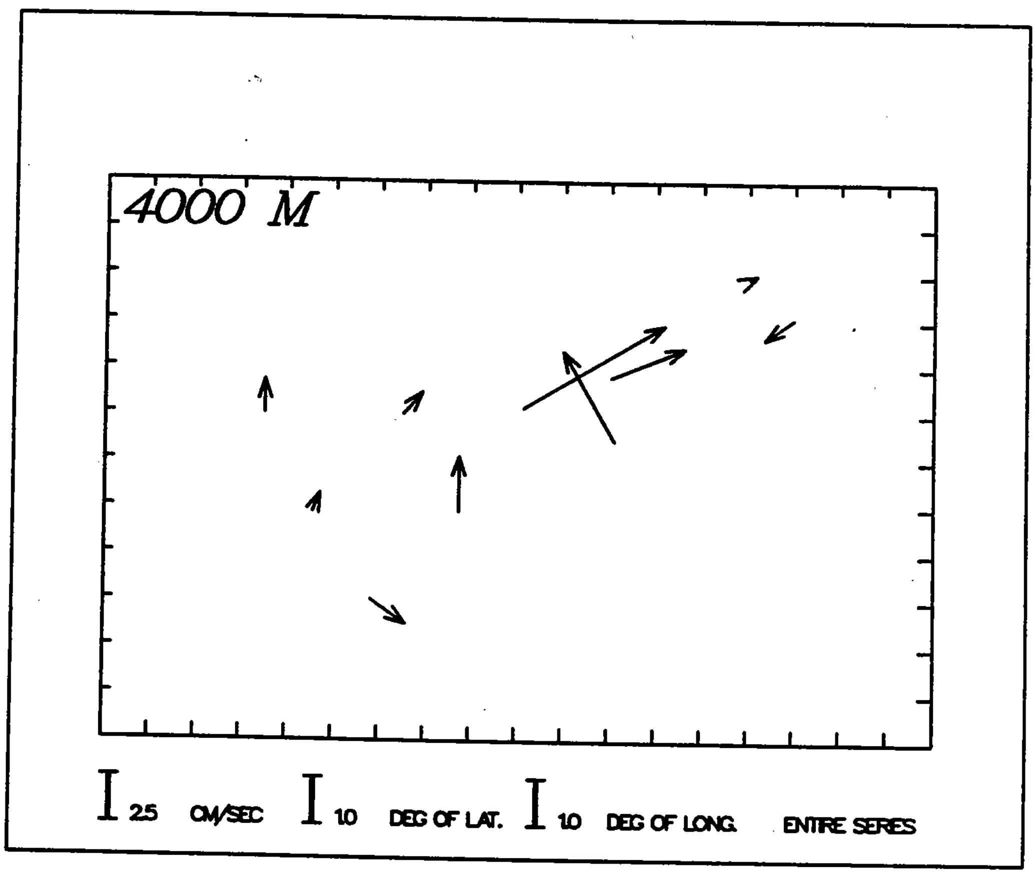


Figure 5 (cont.)

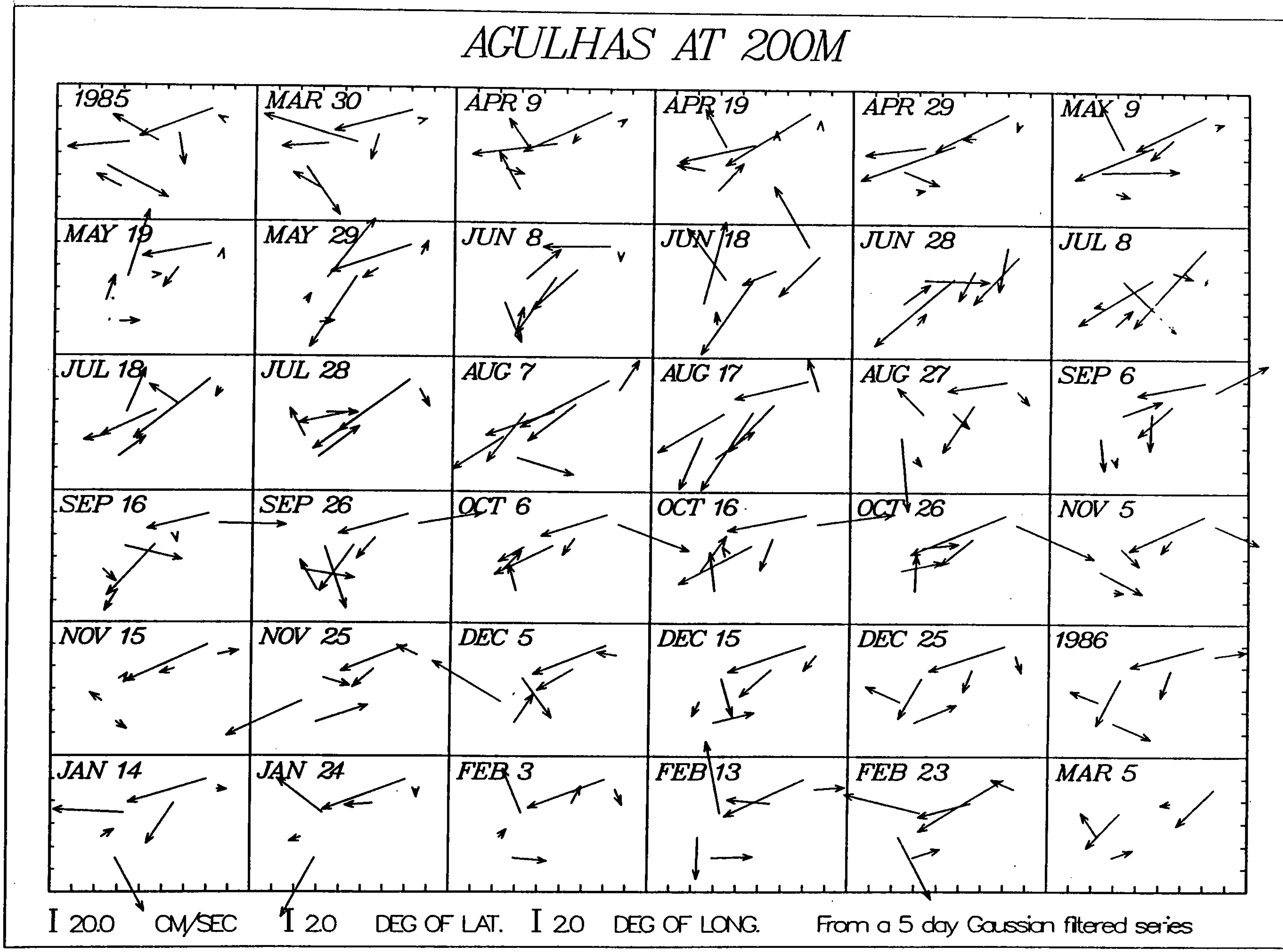


Figure 6
Mean 10-day current vectors
at 200 m

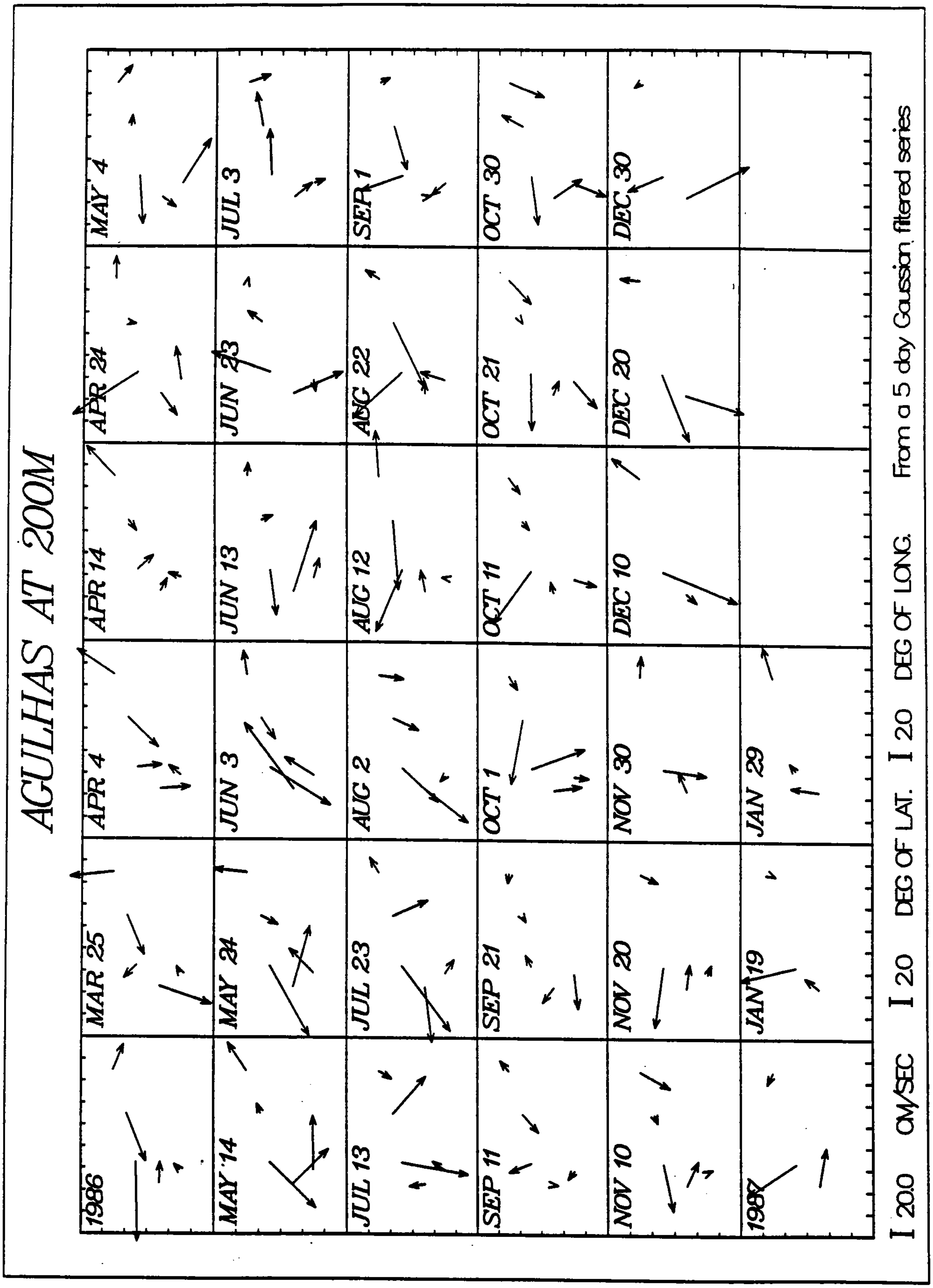


Figure 6 (cont.)

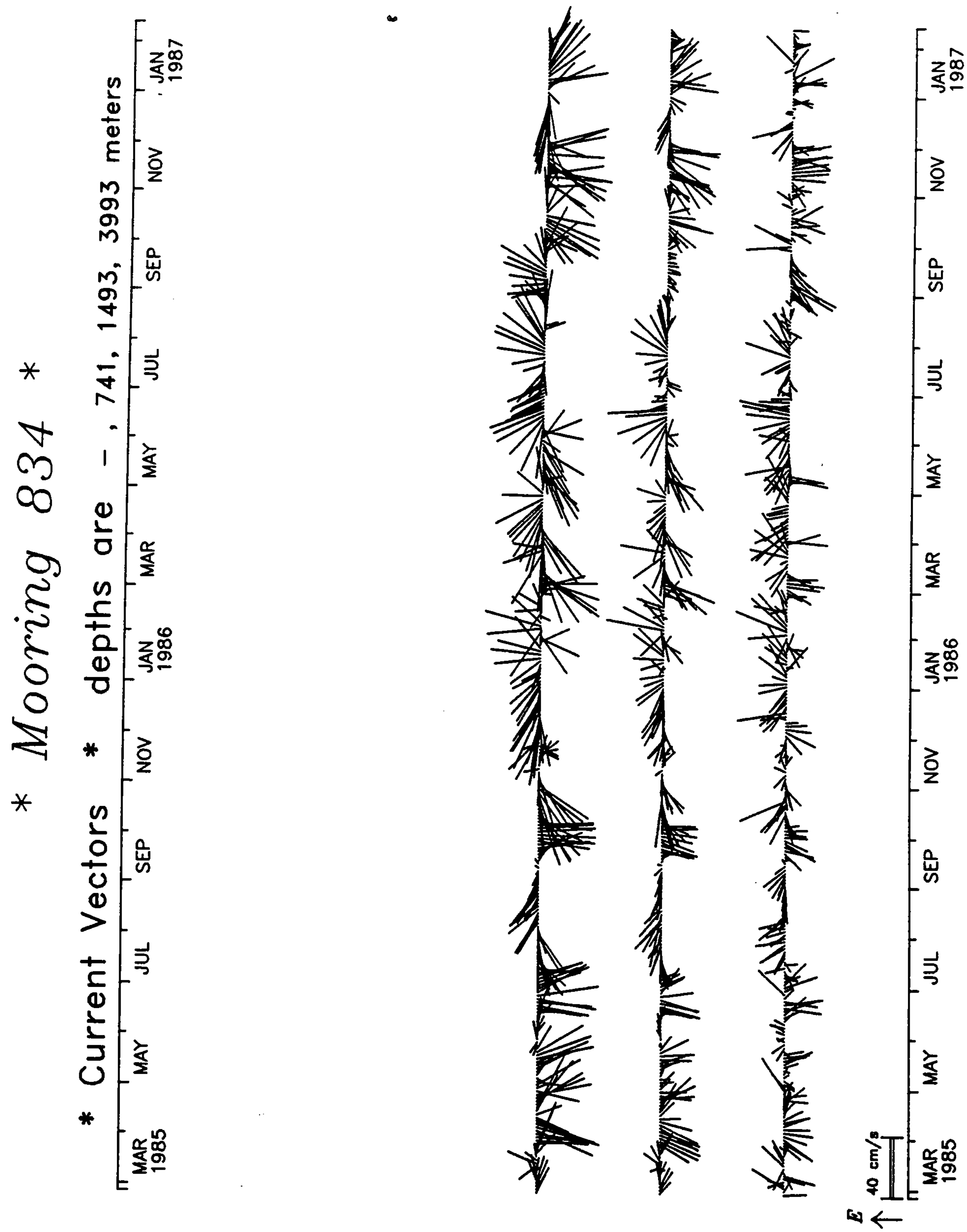

* Mooring 834 *
* Current Vectors * depths are - , 741, 1493, 3993 meters
MAR 1985
MAY
JUL
SEP
NOV
JAN 1986
MAR
MAY
JUL
SEP
NOV
JAN 1987
40 cm/s
E

Figure 7

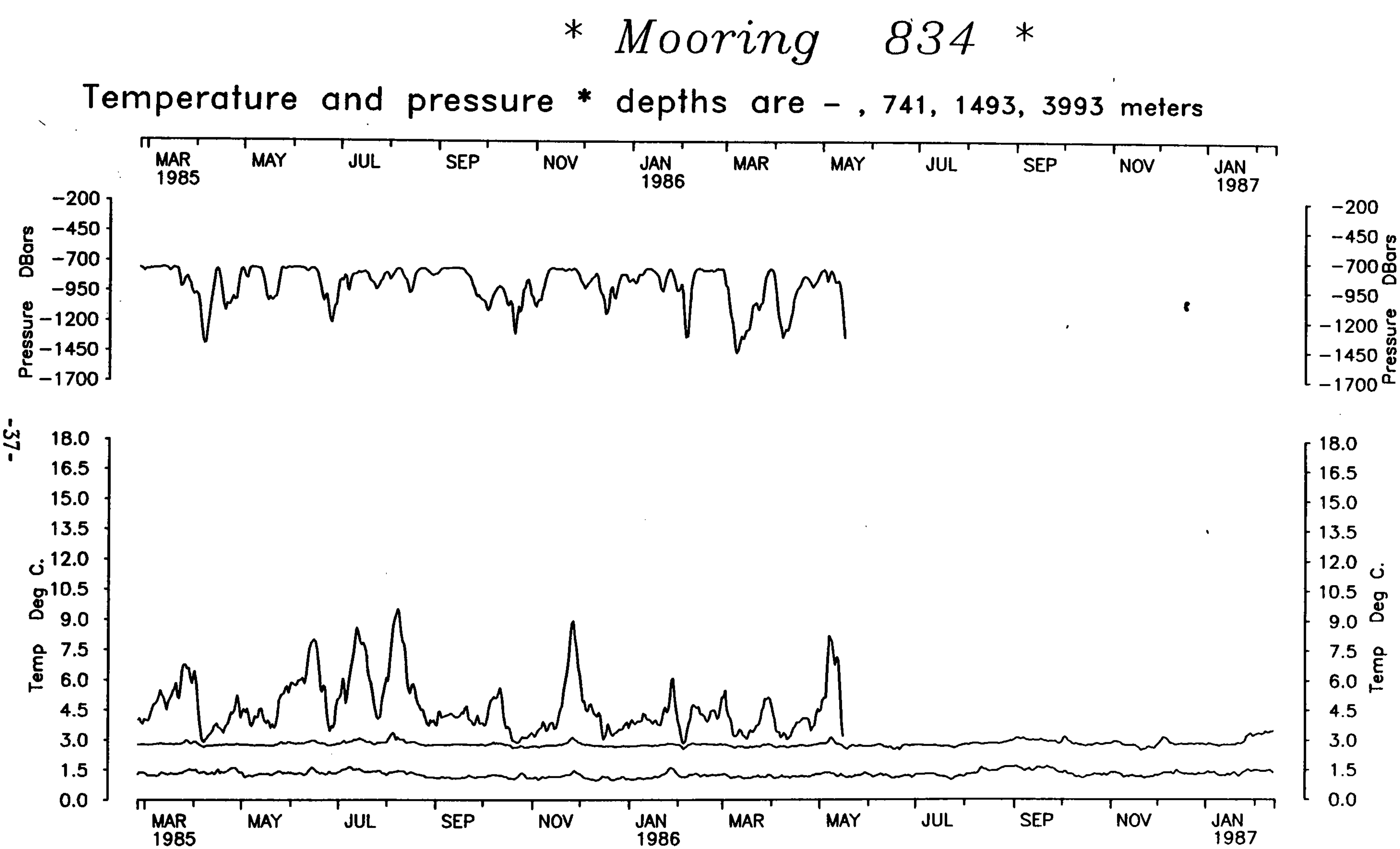

* Mooring 834 *
Temperature and pressure * depths are - , 741, 1493, 3993 meters
MAR 1985
MAY
JUL
SEP
NOV
JAN 1986
MAR
MAY
JUL
SEP
NOV
JAN 1987
Pressure DBars
-200
-450
-700
-950
-1200
-1450
-1700
Temp Deg C.
18.0
16.5
15.0
13.5
12.0
10.5
9.0
7.5
6.0
4.5
3.0
1.5
0.0

Figure 8

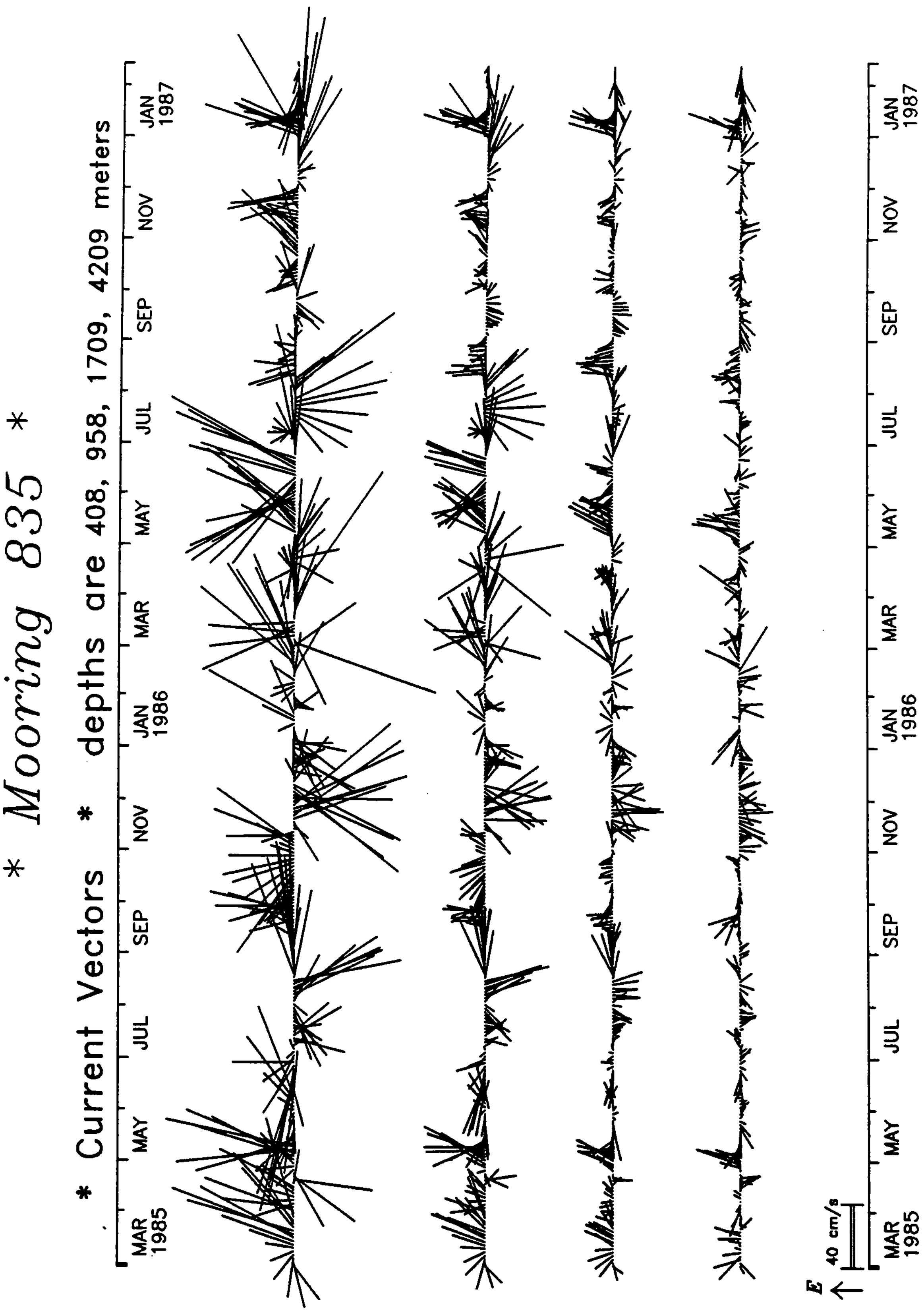

* Mooring 835 *
* Current Vectors * depths are 408, 958, 1709, 4209 meters
MAR 1985
MAY
JUL
SEP
NOV
JAN 1986
MAR
MAY
JUL
SEP
NOV
JAN 1987
40 cm/s
E

Figure 9

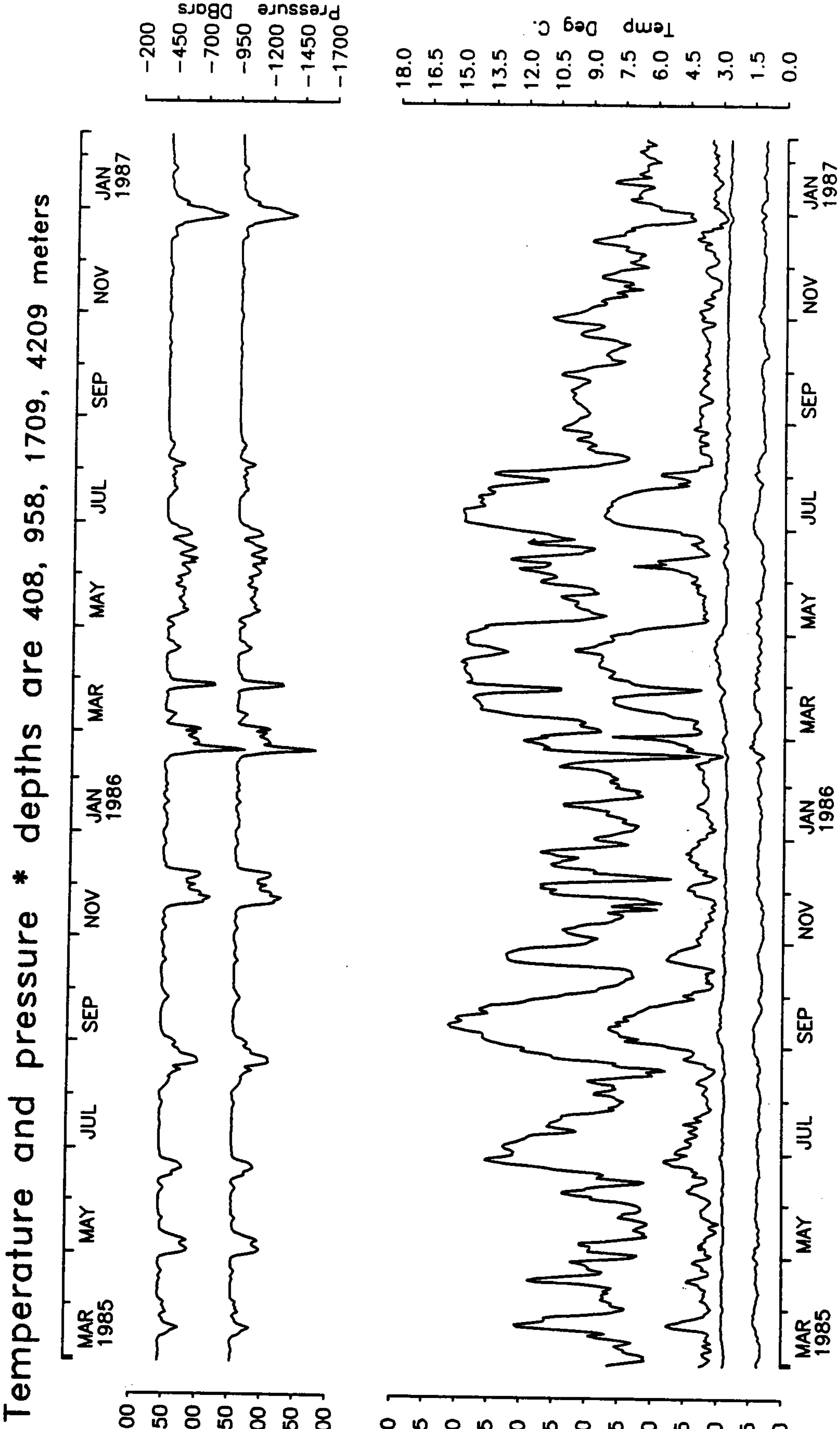

* Mooring 835 *
Temperature and pressure * depths are 408, 958, 1709, 4209 meters
MAR 1985
MAY
JUL
SEP
NOV
JAN 1986
MAR
MAY
JUL
SEP
NOV
JAN 1987
Pressure DBars
-200
-450
-700
-950
-1200
-1450
-1700
Temp Deg C.
18.0
16.5
15.0
13.5
12.0
10.5
9.0
7.5
6.0
4.5
3.0
1.5
0.0

Figure 10

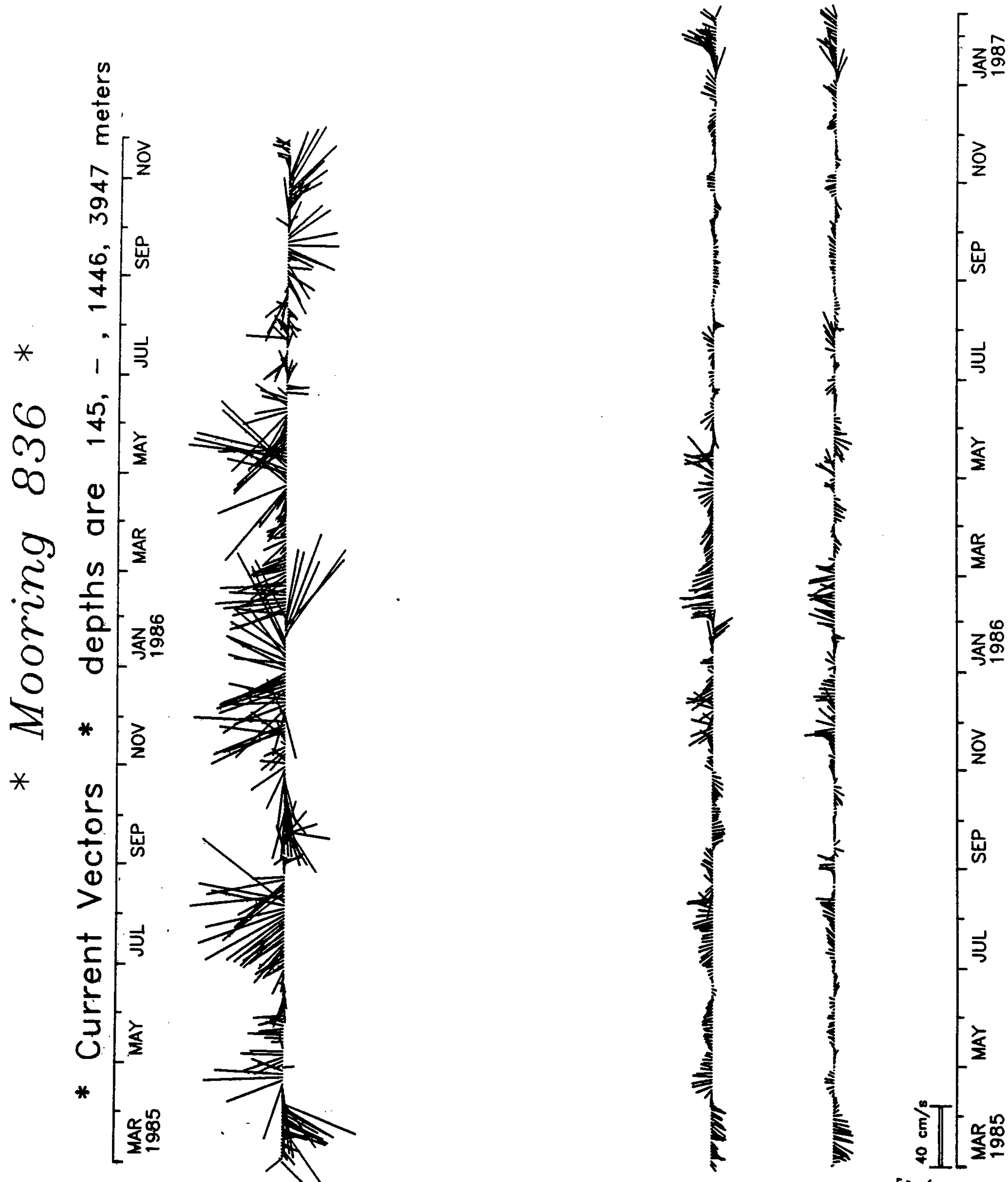

* Mooring 836 *
* Current Vectors * depths are 145, – , 1446, 3947 meters
MAR 1985
MAY
JUL
SEP
NOV
JAN 1986
MAR
MAY
JUL
SEP
NOV
JAN 1987
40 cm/s
E

Figure 11

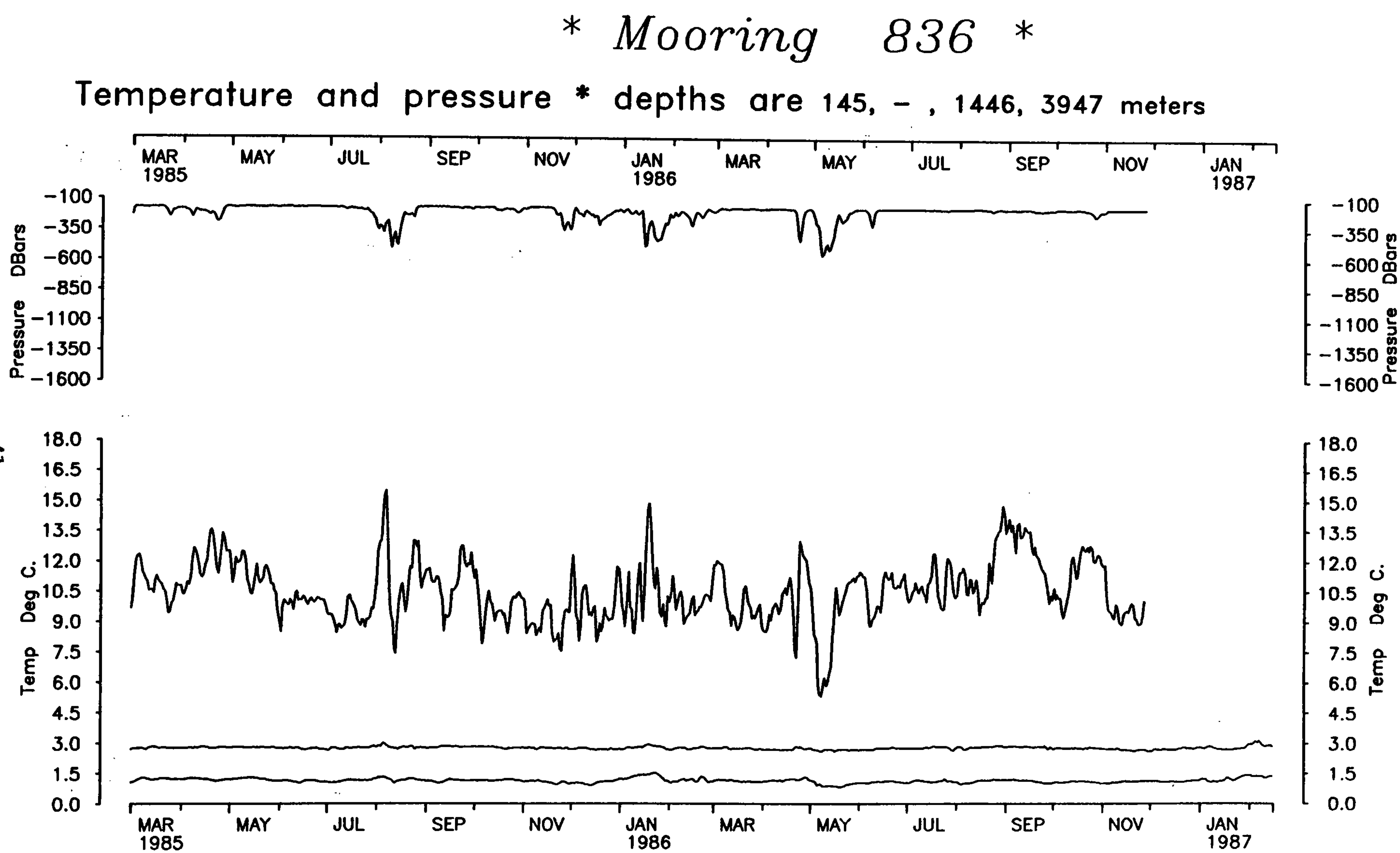

* Mooring 836 *
Temperature and pressure * depths are 145, - , 1446, 3947 meters
MAR 1985
MAY
JUL
SEP
NOV
JAN 1986
MAR
MAY
JUL
SEP
NOV
JAN 1987
Pressure DBars
-100
-350
-600
-850
-1100
-1350
-1600
Temp Deg C.
18.0
16.5
15.0
13.5
12.0
10.5
9.0
7.5
6.0
4.5
3.0
1.5
0.0

Figure 12

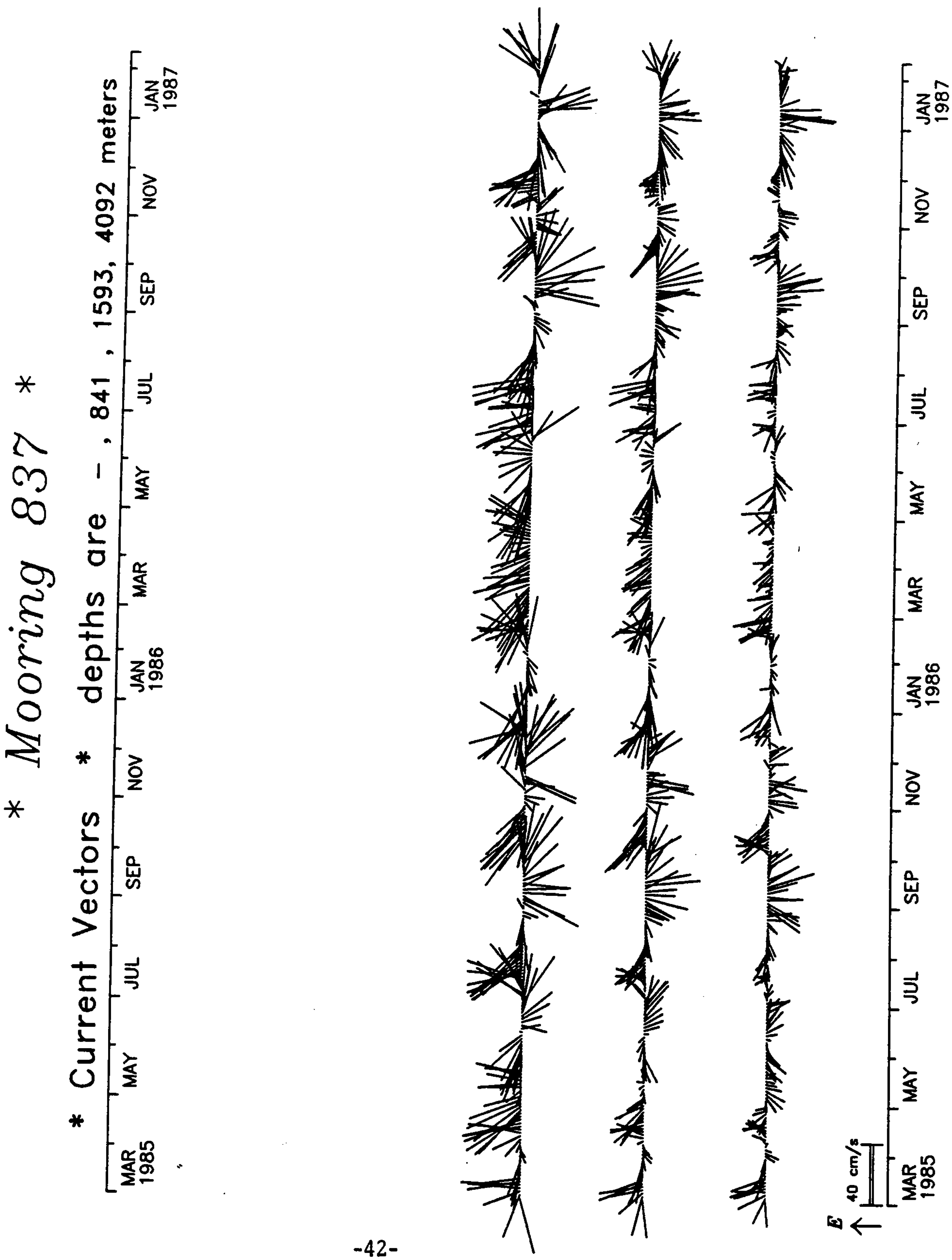

* Mooring 837 *
* Current Vectors * depths are - , 841 , 1593, 4092 meters
MAR 1985
MAY
JUL
SEP
NOV
JAN 1986
MAR
MAY
JUL
SEP
NOV
JAN 1987
E
40 cm/s

Figure 13

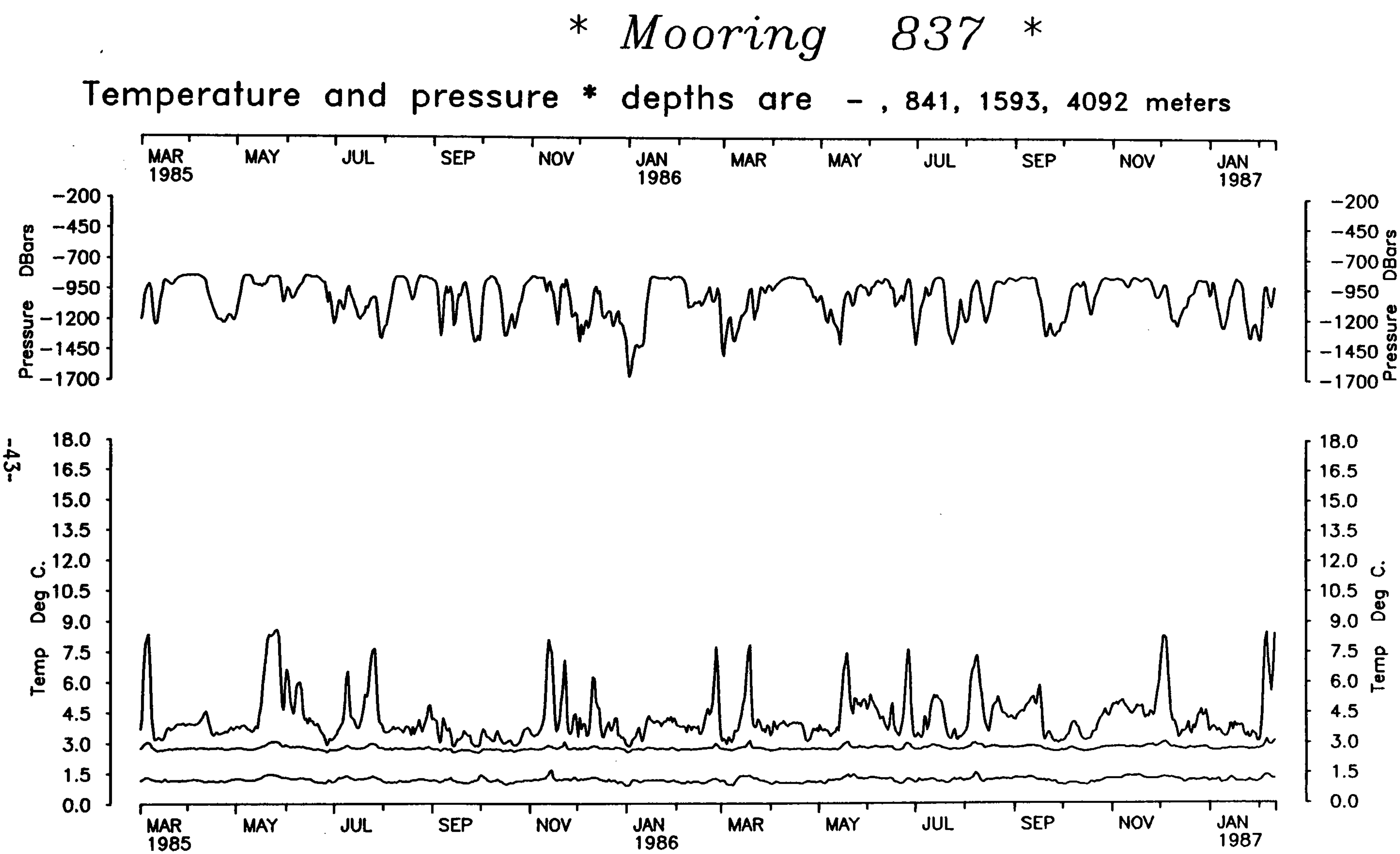

* Mooring 837 *
Temperature and pressure * depths are - , 841, 1593, 4092 meters
MAR 1985
MAY
JUL
SEP
NOV
JAN 1986
MAR
MAY
JUL
SEP
NOV
JAN 1987
Pressure DBars
-200
-450
-700
-950
-1200
-1450
-1700
Temp Deg C.
18.0
16.5
15.0
13.5
12.0
10.5
9.0
7.5
6.0
4.5
3.0
1.5
0.0

Figure 14

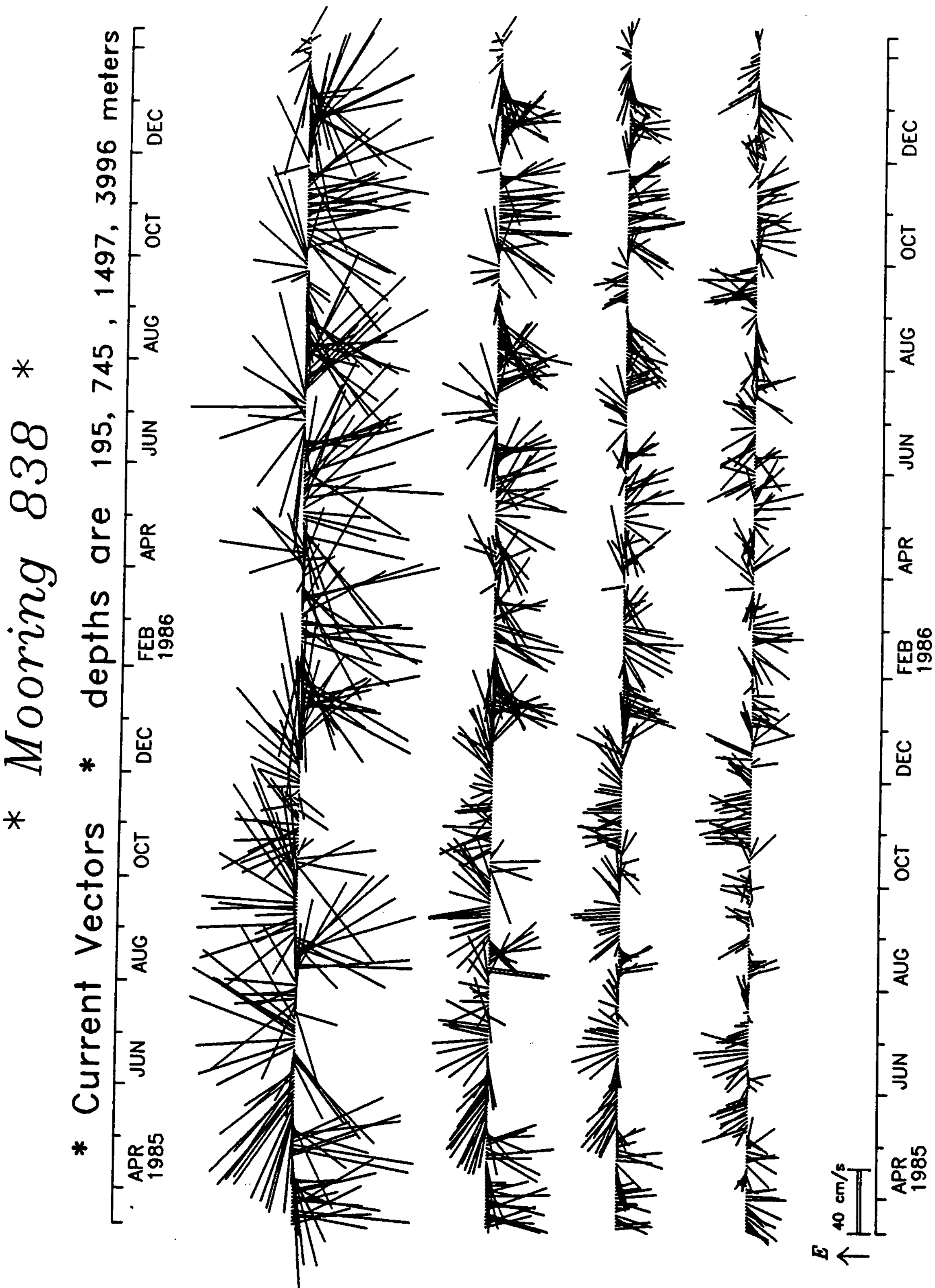

* Mooring 838 *
* Current Vectors * depths are 195, 745, 1497, 3996 meters
APR 1985
JUN
AUG
OCT
DEC
FEB 1986
APR
JUN
AUG
OCT
DEC
E
40 cm/s

Figure 15

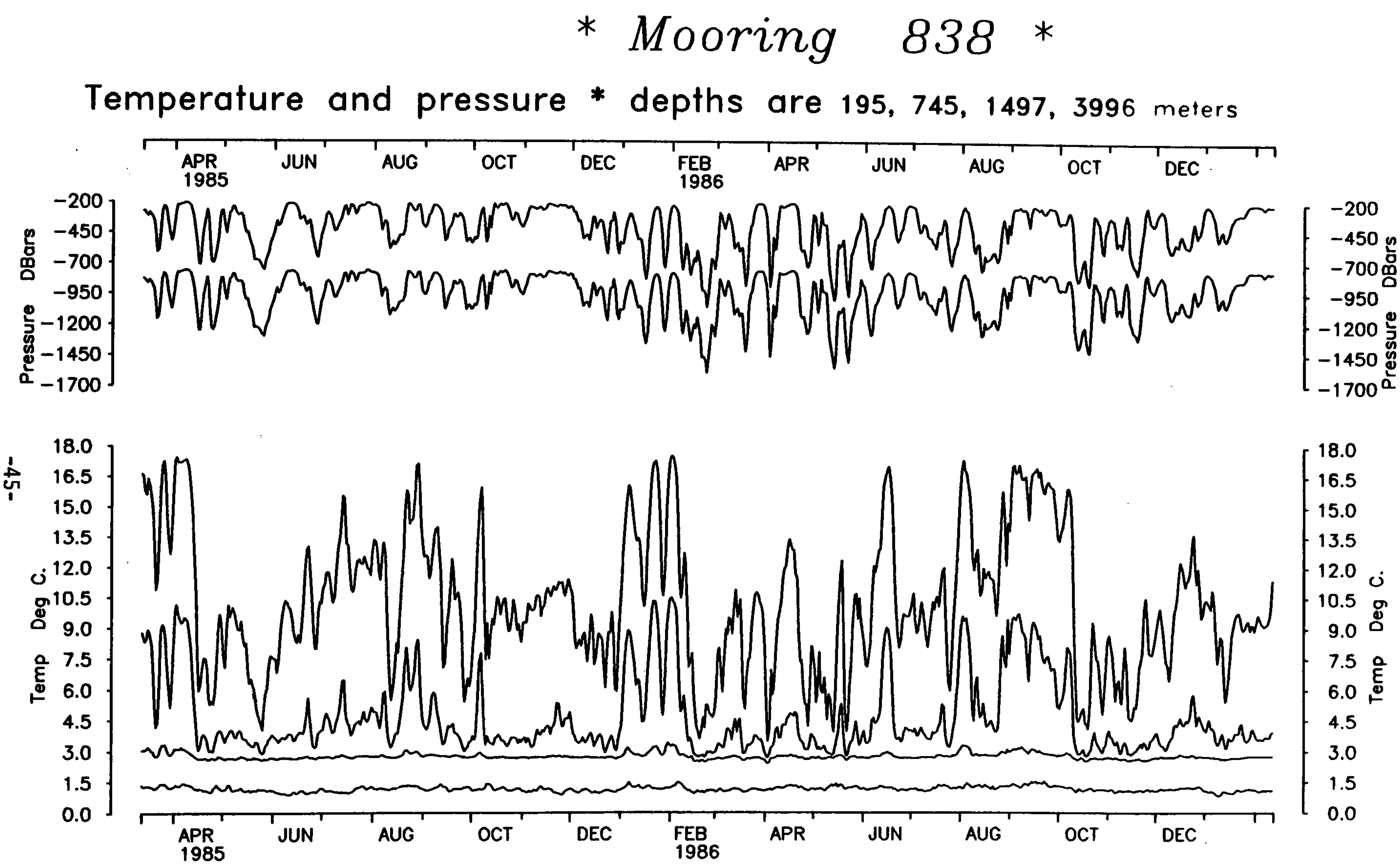

* Mooring 838 *
Temperature and pressure * depths are 195, 745, 1497, 3996 meters
APR 1985
JUN
AUG
OCT
DEC
FEB 1986
APR
JUN
AUG
OCT
DEC
Pressure DBars
-200
-450
-700
-950
-1200
-1450
-1700
Temp Deg C.
18.0
16.5
15.0
13.5
12.0
10.5
9.0
7.5
6.0
4.5
3.0
1.5
0.0

Figure 16

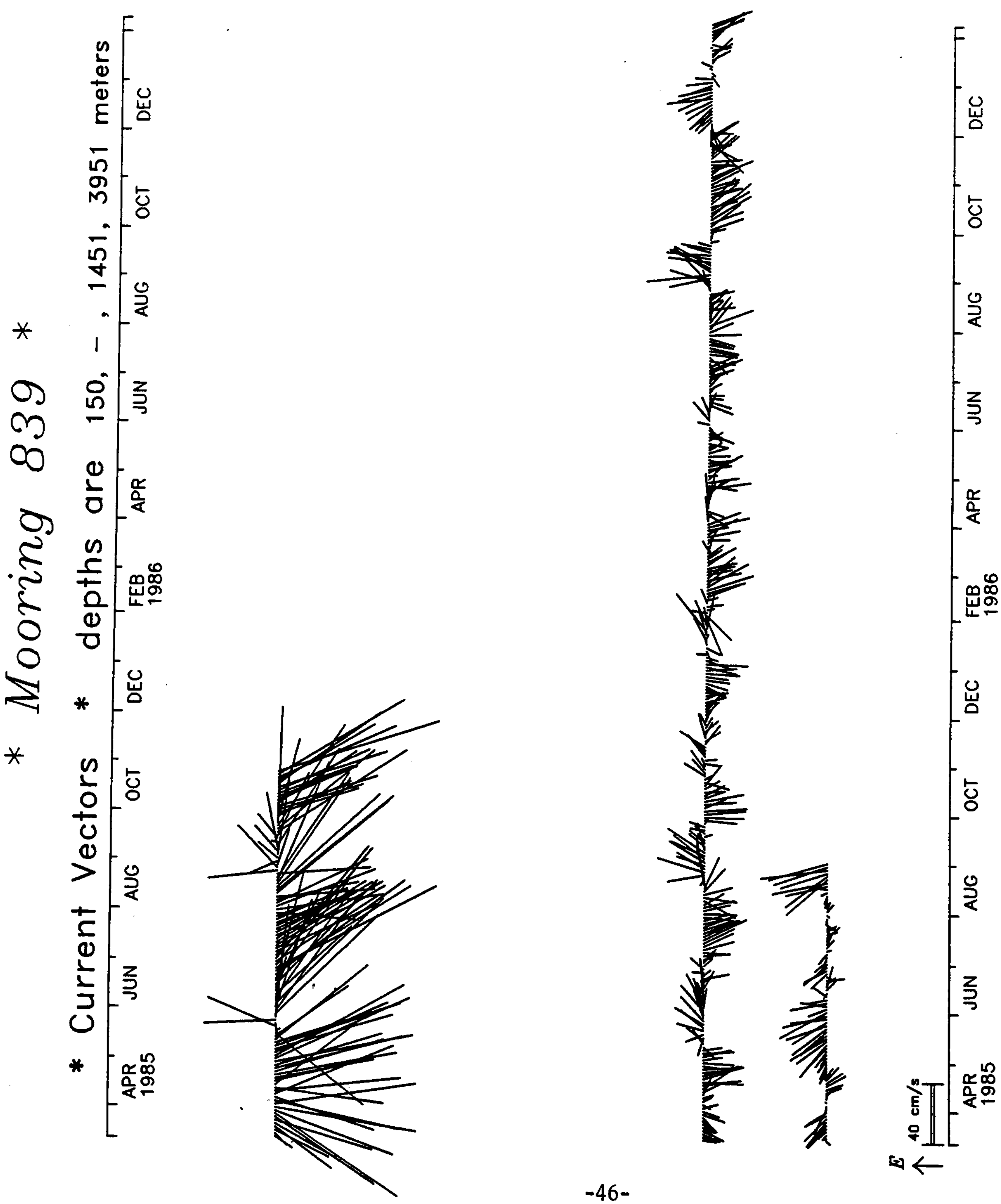

* Mooring 839 *
* Current Vectors * depths are 150, - , 1451, 3951 meters
APR 1985
JUN
AUG
OCT
DEC
FEB 1986
APR
JUN
AUG
OCT
DEC
40 cm/s
E

Figure 17

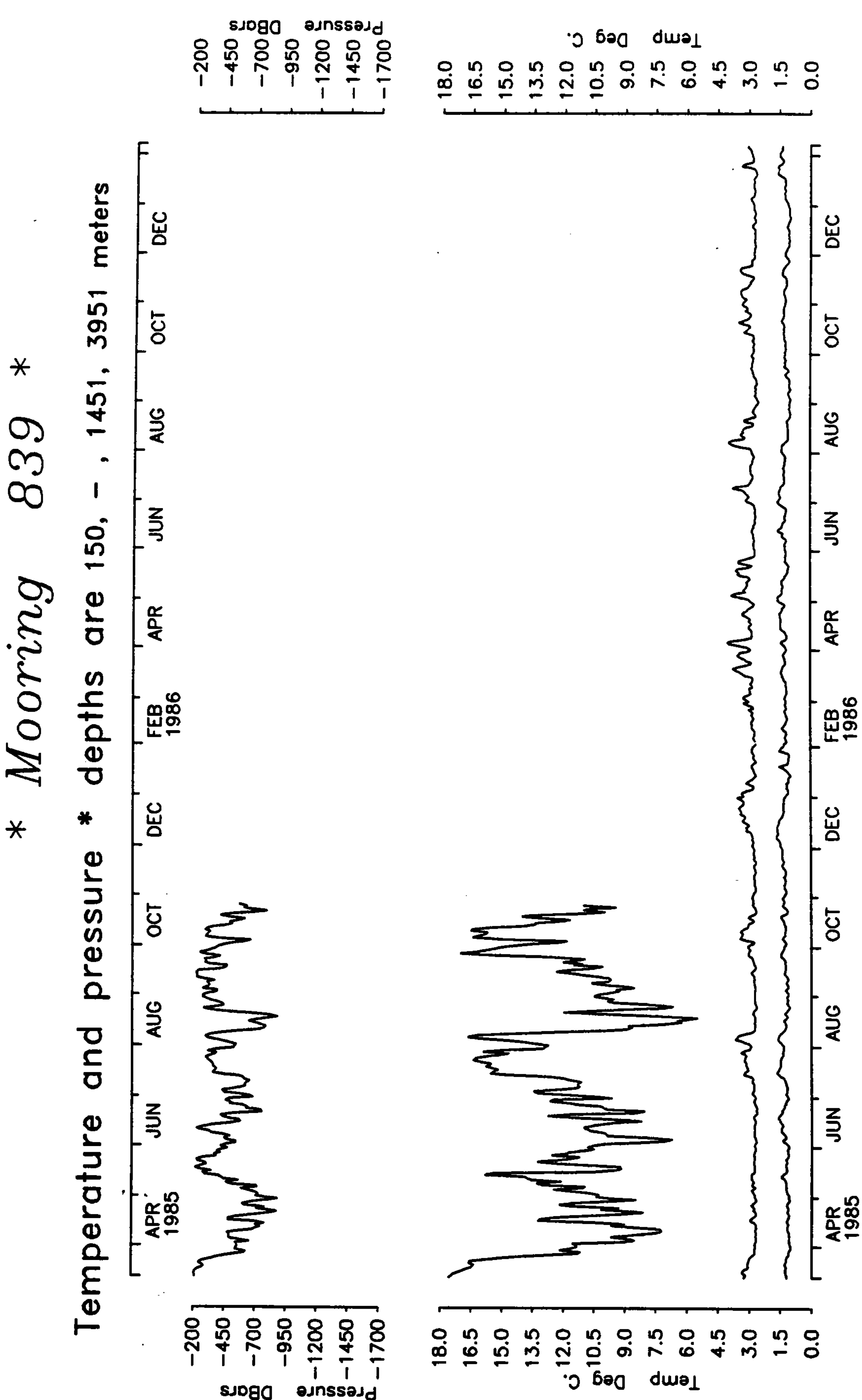

* Mooring 839 *
Temperature and pressure * depths are 150, - , 1451, 3951 meters
APR 1985
JUN
AUG
OCT
DEC
FEB 1986
APR
JUN
AUG
OCT
DEC
-200
-450
-700
-950
-1200
-1450
-1700
Pressure DBars
18.0
16.5
15.0
13.5
12.0
10.5
9.0
7.5
6.0
4.5
3.0
1.5
0.0
Temp Deg C

Figure 18

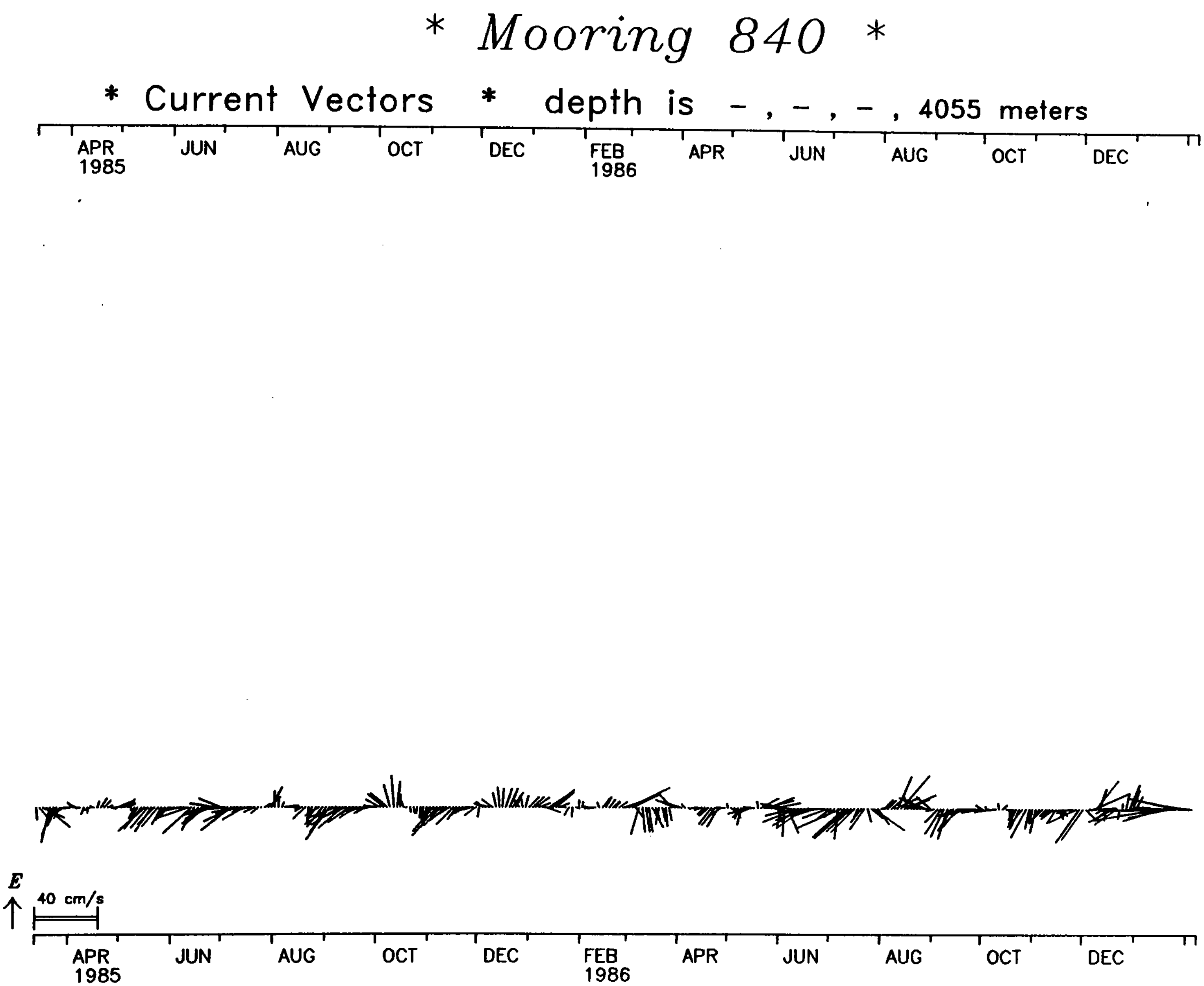

* Mooring 840 *
* Current Vectors * depth is - , - , - , 4055 meters
APR 1985
JUN
AUG
OCT
DEC
FEB 1986
APR
JUN
AUG
OCT
DEC
E
40 cm/s

Figure 19

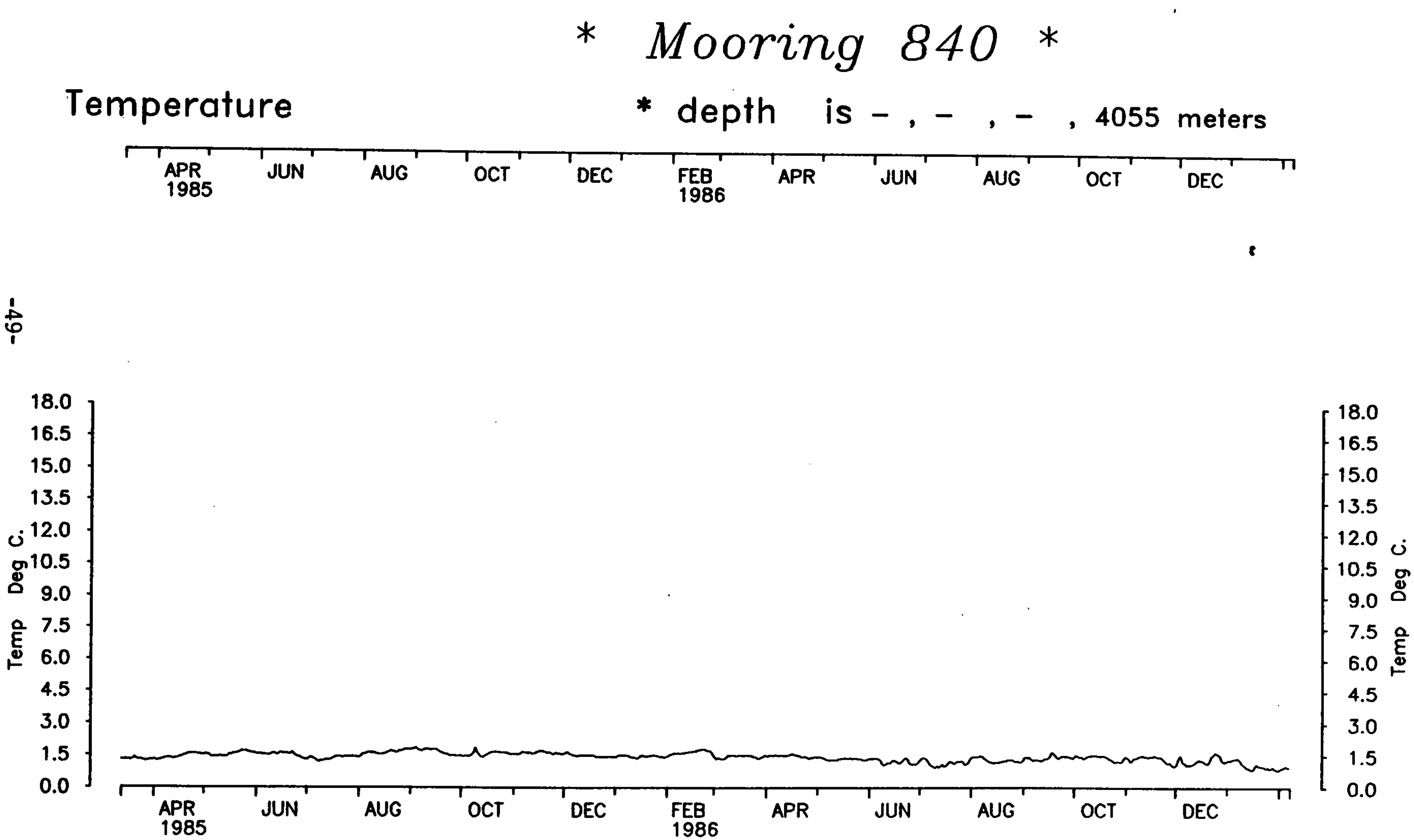

* Mooring 840 *
Temperature
* depth is - , - , - , 4055 meters
APR 1985
JUN
AUG
OCT
DEC
FEB 1986
APR
JUN
AUG
OCT
DEC
Temp Deg C.
18.0
16.5
15.0
13.5
12.0
10.5
9.0
7.5
6.0
4.5
3.0
1.5
0.0

Figure 20

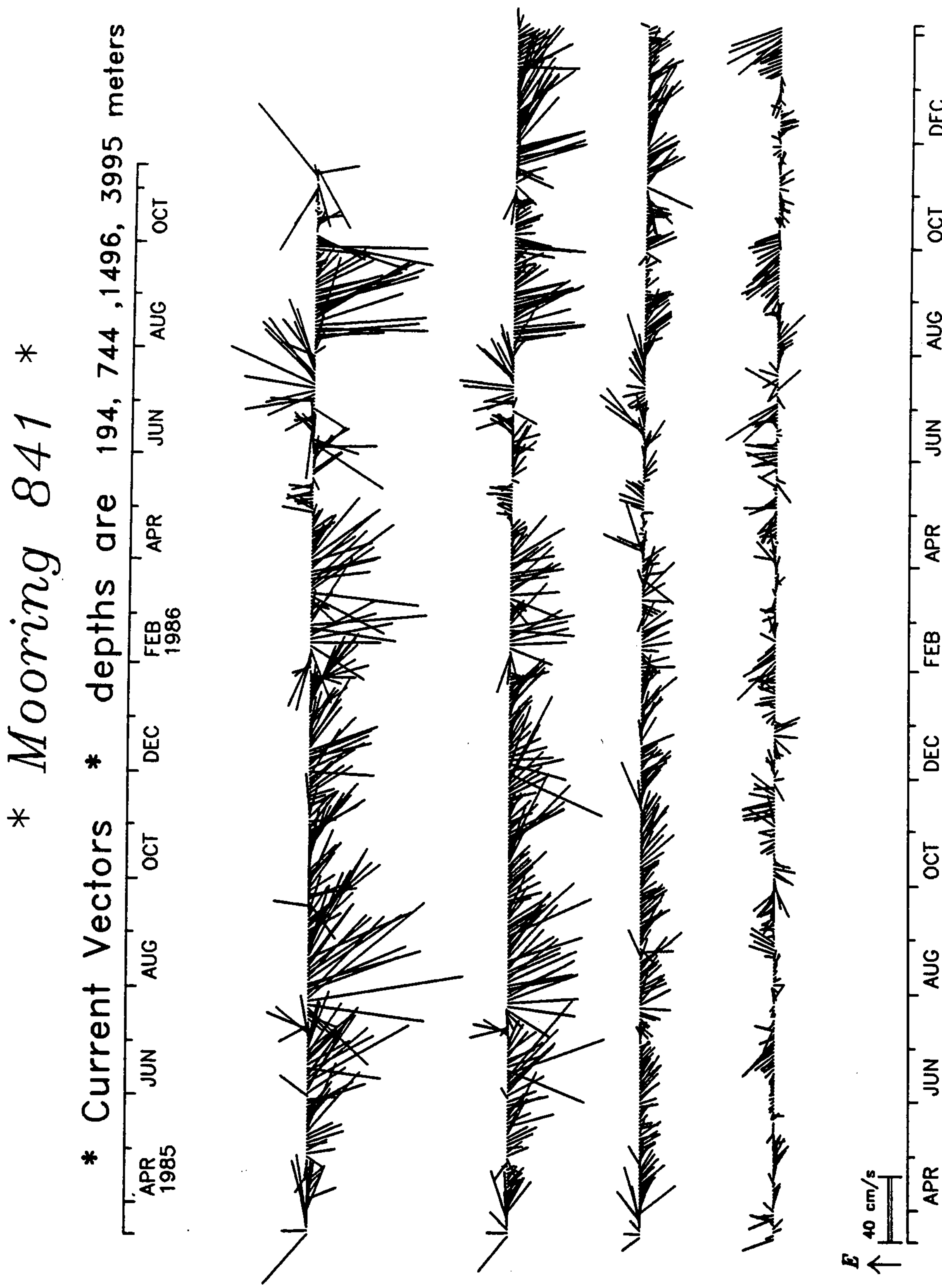

* Mooring 841 *
* Current Vectors * depths are 194, 744 ,1496, 3995 meters
APR 1985
JUN
AUG
OCT
DEC
FEB 1986
APR
JUN
AUG
OCT
DEC
E
40 cm/s

Figure 21

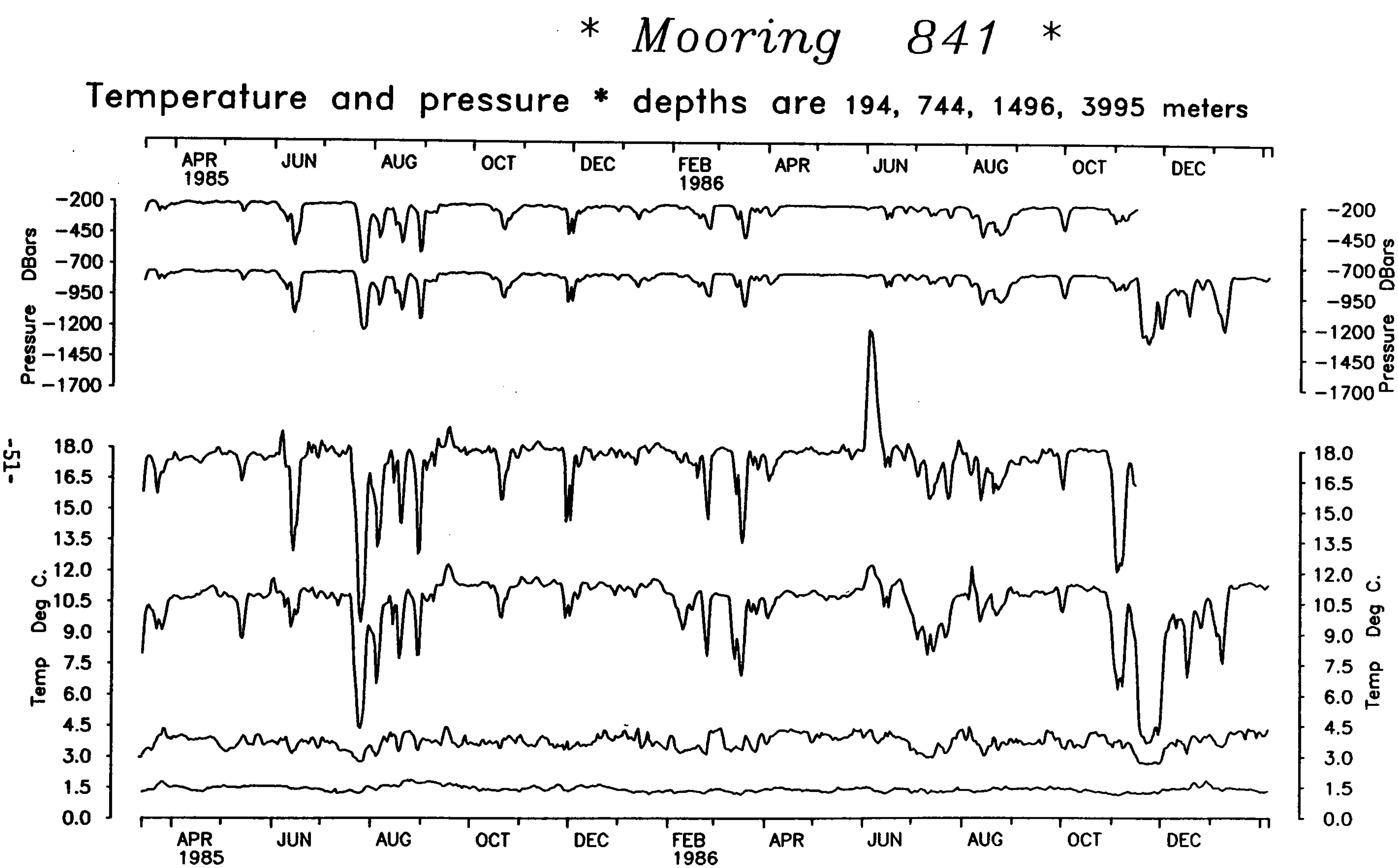

* Mooring 841 *
Temperature and pressure * depths are 194, 744, 1496, 3995 meters
APR 1985
JUN
AUG
OCT
DEC
FEB 1986
APR
JUN
AUG
OCT
DEC
Pressure DBars
-200
-450
-700
-950
-1200
-1450
-1700
Temp Deg C.
18.0
16.5
15.0
13.5
12.0
10.5
9.0
7.5
6.0
4.5
3.0
1.5
0.0

Figure 22

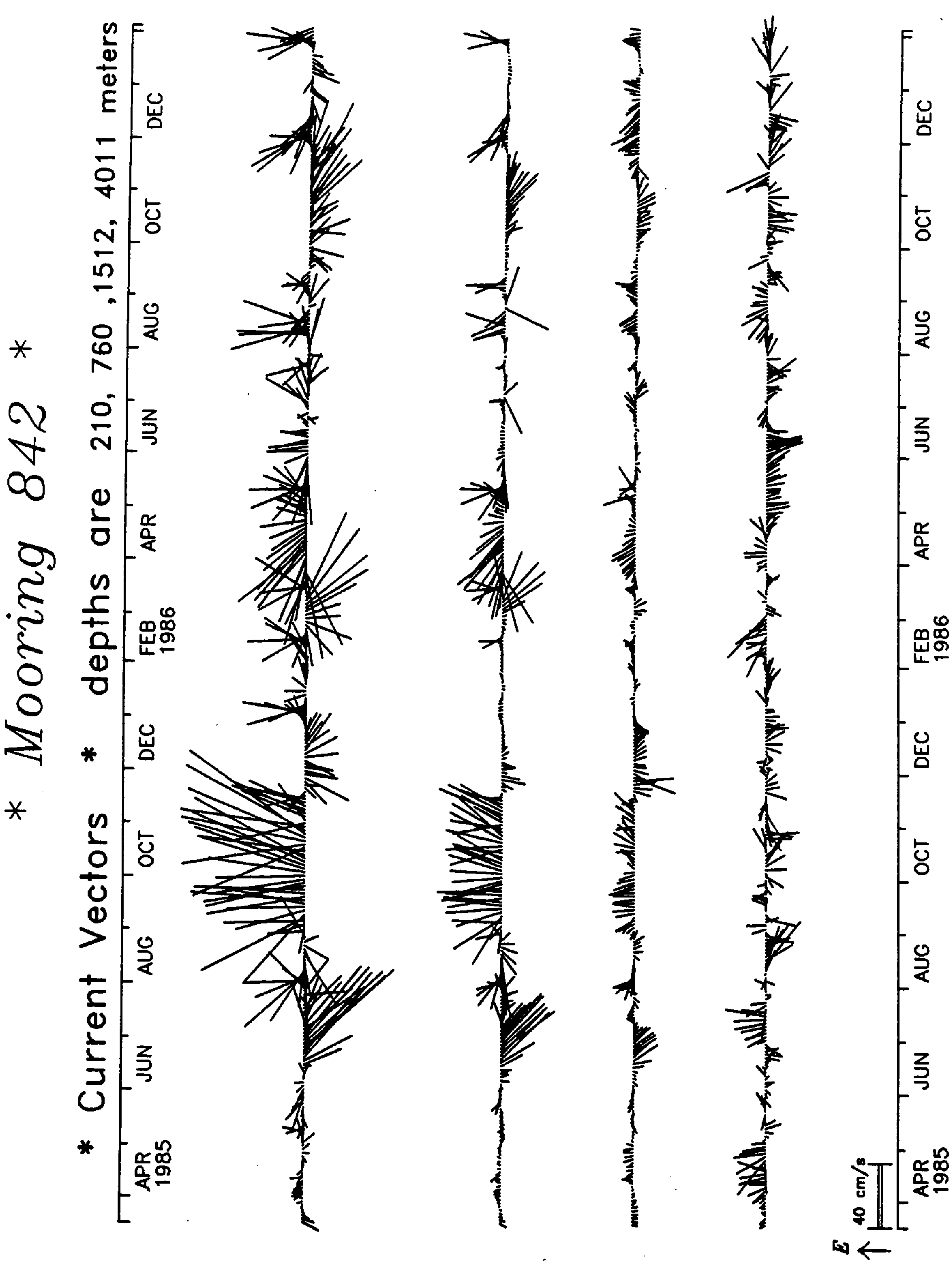

* Mooring 842 *
* Current Vectors * depths are 210, 760 ,1512, 4011 meters
APR 1985
JUN
AUG
OCT
DEC
FEB 1986
APR
JUN
AUG
OCT
DEC
40 cm/s
E

Figure 23

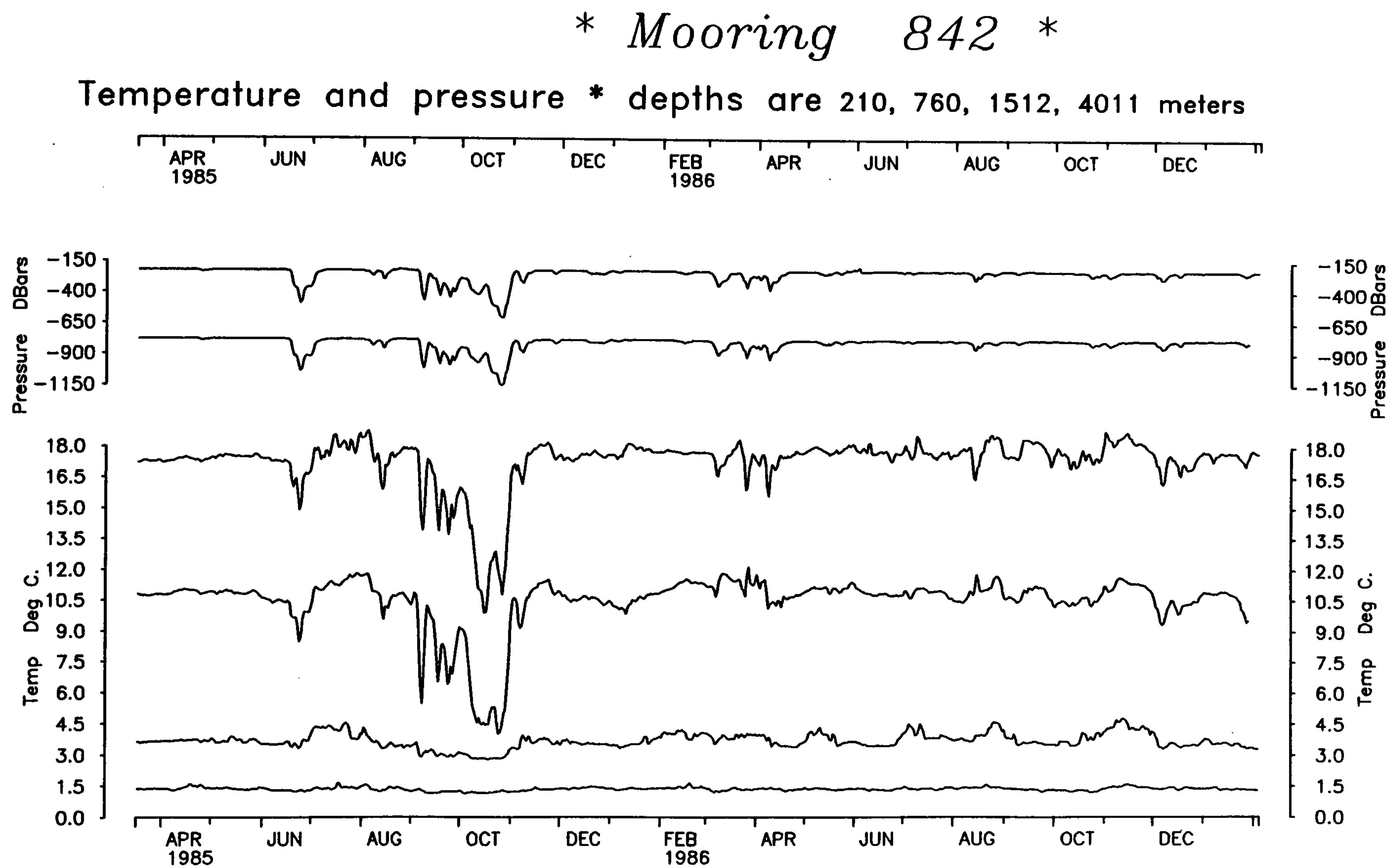

* Mooring 842 *
Temperature and pressure * depths are 210, 760, 1512, 4011 meters
APR 1985
JUN
AUG
OCT
DEC
FEB 1986
APR
JUN
AUG
OCT
DEC
Pressure DBars
-150
-400
-650
-900
-1150
Temp Deg C.
18.0
16.5
15.0
13.5
12.0
10.5
9.0
7.5
6.0
4.5
3.0
1.5
0.0

Figure 24

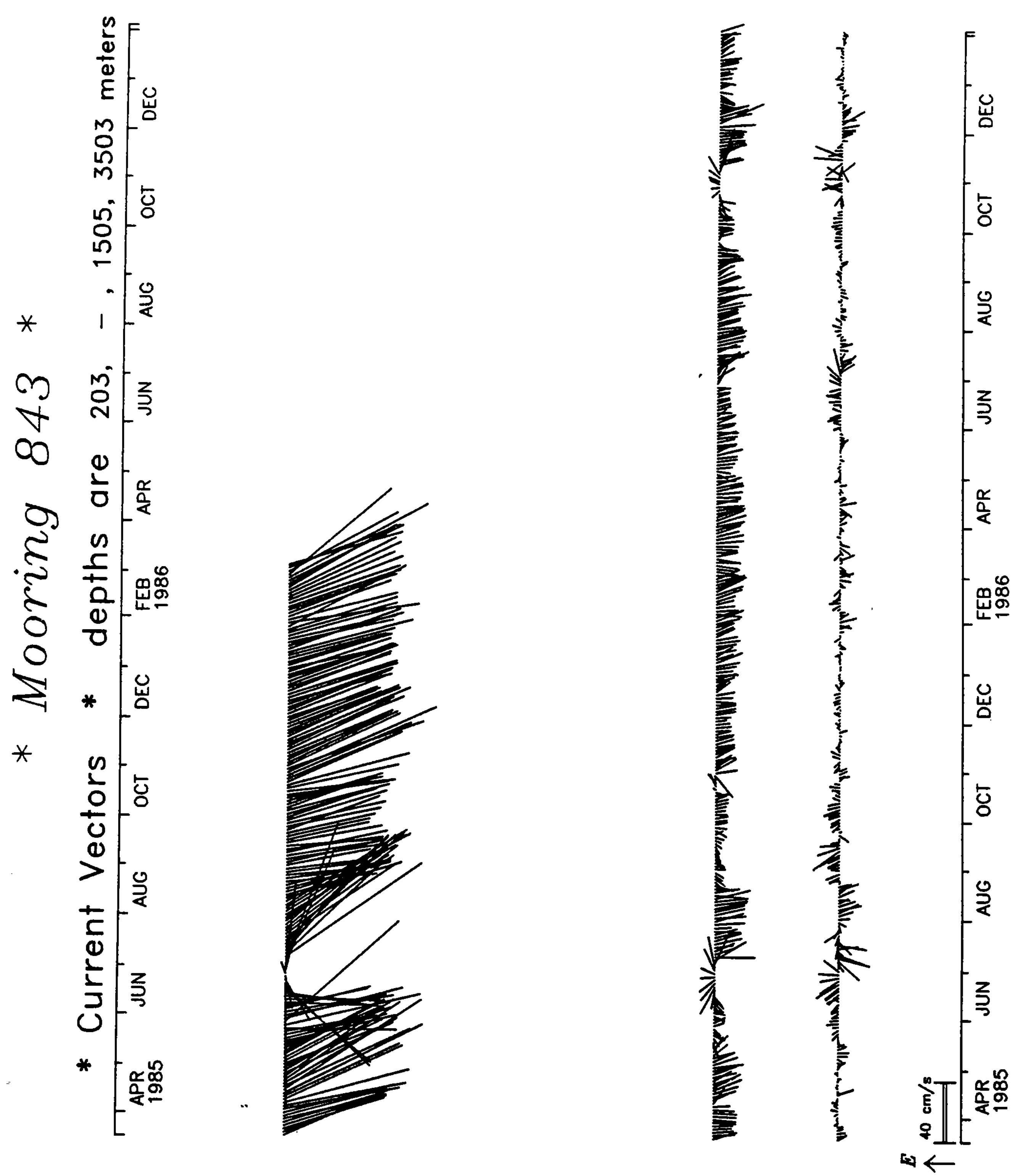

* Mooring 843 *
* Current Vectors * depths are 203, - , 1505, 3503 meters
APR 1985
JUN
AUG
OCT
DEC
FEB 1986
APR
JUN
AUG
OCT
DEC
40 cm/s
E

Figure 25

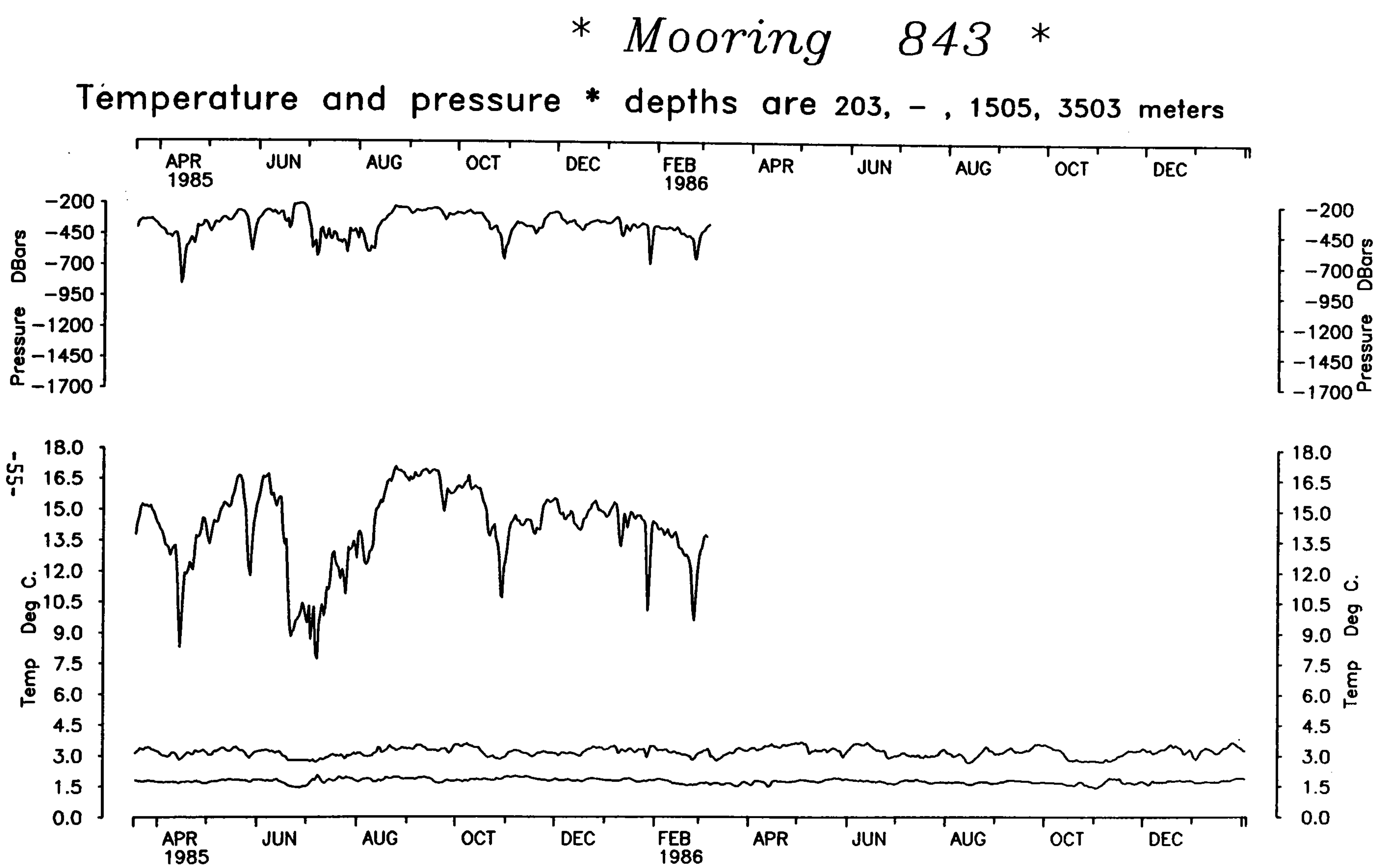

* Mooring 843 *
Temperature and pressure * depths are 203, - , 1505, 3503 meters
APR 1985
JUN
AUG
OCT
DEC
FEB 1986
APR
JUN
AUG
OCT
DEC
Pressure DBars
-200
-450
-700
-950
-1200
-1450
-1700
Temp Deg C.
18.0
16.5
15.0
13.5
12.0
10.5
9.0
7.5
6.0
4.5
3.0
1.5
0.0

Figure 26

SECTION 2

Satellite Infrared Images of the Agulhas Retroflexion Region

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Discussion

NOAA-9 satellite thermal infrared images, acquired in Local Area Coverage (LAC) format by the CSIR Satellite Remote Sensing Center in Hartebeeshoek (South Africa), were purchased by WHOI in support of the Agulhas Retroflection Experiment for the period 28 January 1985 to 28 January 1986.

The images were processed on the WHOI remote-sensing VAX. The processing system used software described by Young and Fahle (1981) and Luetkemeyer (1987). The images were geometrically corrected for Earth rotation and curvature and mapped to a common Mercator grid with a pixel size of 4.4 km. The coordinates of the corners and center of the grid are given in Table 1. Only channel 4, the thermal infrared channel (1.5 μm to 11.5 μm) commonly used to estimate sea-surface temperature, was processed.

It was not possible to decode temperature calibration information from the telemetry data because CSIR tapes were written in a format different from the format used in the United States. Ten-bit raw sensor counts in the range 0–500 were converted to 8-bit pixels in the range 0–200; raw sensor counts in the range 501–1023 correspond to cold clouds and were set to 255. A crude equation to calibrate pixel values x in the range 0–200 shown in this report to Celsius temperature T is:

$$T = 190 - 1.172\,x$$

Temperatures of 15°C, 20°C, and 25°C correspond approximately to pixel values of 150, 145, and 140.

We began to process the images sequentially, starting with March, 1985, but it soon appeared that a major problem using thermal infrared images in this region is cloud cover. Figure 1, reproduced from Lutjeharms and Valentine (1988), shows the percentage of cloud-free images south of Africa. A sharp gradient is seen from $\sim$ 30% at 35°S to less than 5% at 40°S.

To select images worth processing, the film browse-file archived in Hartebeeshoek was examined visually. Table 2 lists, for the period November, 1984 to February, 1987, partially cloudless images and their cloud cover for five areas A–B–C–D–E of the Agulhas Current. Upper case letters indicate a clear image, lower case letters indicate scattered clouds. The distribution of these images is graphed in Figure 2. In Table 2, the images processed at WHOI are marked by $*$. The processed images are shown in microfiche 5. On the negative film, cold temperatures are represented by light shades and warm temperatures by dark shades. A calibration wedge and a normalized histogram are shown above each image.

Four one-week periods contained a sufficient number of clear images to construct composite images of sea-surface temperature: February 29 to March 9, March 24 to March 27, August 12 to August 18, and October 16 to October 21. Composites were constructed by selecting, at each pixel, the warmest temperature among all the images available for the period. The composites were further filtered by a 3 × 3 median filter, to reduce the clutter due to small clouds. Although this procedure biases temperatures high, the main motivation for constructing the composites is visual interpretation of ocean features rather than absolute temperature determinations. The composite images are shown color-coded in the main report and in black-and-white in microfiche 5.

Copies of the raw data tapes for the period January 28, 1985 to January 28, 1986 are archived at WHOI. Tapes for other times can be purchased from:

Satellite Remote Sensing Center
National Institute for Telecommunication Research
Post Office Box 3718
Johannesburg 2000, South Africa
T. 27-12-265271

Bibliography

Luetkemeyer, K., 1987. Satellite image processing for the Agulhas retroflection region. Technical Report 87-27, Woods Hole Oceanographic Institution, 76 pp.

Lutjeharms, J. R. E., and H. R. Valentine, 1988. Eddies at the Subtropical Convergence South of Africa. *Journal of Physical Oceanography*, **18**, 761–774.

Young, T. L., and J. H. Fahle, 1981. User's manual for preliminary satellite image processing: extraction, calibration, and location. Reference 81-36, Scripps Institution of Oceanography, 85 pp.

Table 1: Geographic Grid

Point	Row	Column	Latitude	Longitude
Upper Left	1	1	27°04′S	13°23′E
Upper Right	1	512	27°04′S	38°44′E
Center	256.5	256.5	37°10′S	26°04′E
Lower Left	512	1	47°16′S	13°23′E
Lower Right	512	512	47°16′S	38°44′E

Table 2: list of partially clear images

year	month/day	hour/min (UT)	clear in	processed
1984	1231	1512	C	
1985	0101	1459	bcd	
1985	0117	1301	ab	
1985	0205	1336	B	
1985	0205	1426	abd	
1985	0214	1340	c	
1985	0215	1329	bcd	
1985	0216	1318	bc	
1985	0217	1308	abde	
1985	0217	1519	bd	
1985	0223	1346	C	
1985	0226	0047	c	
1985	0228	1251	ab	*
1985	0301	1240	a	*
1985	0302	1240	a	*
1985	0304	1240	b	*
1985	0305	1339	b	*
1985	0306	1328	bc	*
1985	0307	1318	b	*
1985	0308	1307	abcd	
1985	0309	1256	ab	*
1985	0311	1234	a	*
1985	0312	1224	ae	*
1985	0313	1335	b	*
1985	0314	1344	d	*
1985	0315	1333	b	*
1985	0316	1322	b	*
1985	0317	1312	b	*
1985	0319	1250	b	*
1985	0320	1239	b	*
1985	0324	1338	c	*
1985	0325	1327	d	*
1985	0326	0501	bcd	
1985	0326	1317	bCd	*
1985	0327	0437	BcD	
1985	0327	1307	abd	*
1985	0403	1332	B	
1985	0416	1305	AB	
1985	0417	0017	A	
1985	0515	1249	aB	
1985	0526	0005	aBc	
1985	0530	1330	c	*
1985	0531	1321	b	
1985	0601	0042	Bcd	
1985	0601	1309	Bc	
1985	0602	1257	bCd	
1985	0603	1246	aBd	
1985	0609	1324	ABd	
1985	0617	1339	aB	
1985	0618	1328	aB	

year	month/day	hour/min (UT)	clear in	processed
1985	0621	1256	abD	
1985	0621	1731	ABD	
1985	0626	1344	C	
1985	0627	1333	BcD	
1985	0628	1322	abcd	
1985	0630	1300	abcd	
1985	0701	0024	abcd	
1985	0702	0013	ABCde	
1985	0710	1255	Ad	
1985	0717	0054	bc	
1985	0717	1321	bcd	
1985	0718	0043	bcd	
1985	0718	1310	abcde	
1985	0719	0034	abcde	
1985	0728	1304	B	
1985	0730	1242	AbcdE	*
1985	0731	1231	ABCDE	
1985	0801	1220	ae	
1985	0804	1330	B	
1985	0805	0054	ABd	
1985	0805	1319	ABd	
1985	0810	1827	ABd	
1985	0811	1805	AdE	
1985	0812	1348	c	
1985	0813	1335	C	
1985	0815	1313	abcde	*
1985	0815	1818	Abcde	
1985	0816	1302	ABcd	*
1985	0816	1756	ABcD	
1985	0817	1251	ABCDe	*
1985	0817	1735	Ade	
1985	0818	1241		
1985	0821	1351	Bc	*
1985	0825	1308	bcd	
1985	0825	1801	aBcd	
1985	0826	0030	abc	
1985	0826	1256	ABc	
1985	0830	1753	C	
1985	0913	1305	cde	
1985	0914	1255	cDe	
1985	0916	2357	abcde	
1985	1009	1331	BC	
1985	1010	0055	bcd	
1985	1010	1321	ABc	
1985	1011	1309	Ae	
1985	1012	0031	AE	
1985	1012	1259	AE	
1985	1014	1239	ae	
1985	1016	1356	bd	*
1985	1017	1346	bcd	*
1985	1018	1336	BCDE	
1985	1019	1326	BD	*

year	month/day	hour/min (UT)	clear in	processed
1985	1020	1315	Abcde	*
1985	1021	1303	bDe	*
1985	1022	0020	Bcd	
1985	1103	1406	bc	*
1985	1111	1242	ade	
1985	1113	1400	bc	
1985	1115	1339	ABc	
1985	1117	1318	AbD	
1985	1204	1337	cd	
1985	1214	1330	bc	
1985	1216	0043	bc	
1986	0101	1339	AbE	
1986	0109	1355	c	
1986	0110	1346	B	
1986	0111	1333	B	
1986	0119	1349	Bc	
1986	0120	1338	cd	
1986	0127	1403	C	
1986	0128	1354	c	
1986	0129	1242	bc	
1986	0201	1310	bce	
1986	0202	0034	abce	
1986	0202	1301	BcdE	
1986	0203	1250	ade	
1986	0206	1358	c	
1986	0207	1347	bcd	
1986	0217	1341	Ac	
1986	0218	1331	AB	
1986	0317	1344	BcD	
1986	0326	1348	ABcE	
1986	0327	1338	ABc	
1986	0405	1341	BcD	
1986	0406	1331	ABc	
1986	0407	1320	Ab	
1986	0413	1357	AB	
1986	0414	1345	c	
1986	0415	1335	abd	
1986	0423	1350	bc	
1986	0506	0045	ABc	
1986	0507	0034	abc	
1986	0608	1400	ABCD	
1986	0609	0122	ABc	
1986	0609	1349	ABc	
1986	0903	1334	ABc	
1986	0904	0056	ABc	
1986	0912	1337	Abcde	
1986	0913	1326	ADE	
1986	0928	1407	BCD	
1986	0930	1346	A	
1986	1008	1400	AB	
1986	1011	1327	ABc	
1986	1017	1406	AB	

year	month/day	hour/min (UT)	clear in	processed
1986	1019	1343	BDE	
1986	1106	1352	AB	
1986	1123	1408	abcd	
1986	1124	1358	ABdE	
1986	1125	0120	Bde	
1986	1208	0042	bcd	
1986	1208	1309	bcd	
1986	1215	1334	ABcDE	
1986	1217	1313	AB	
1986	1219	1432	BCD	
1986	1220	1421	ABcd	
1986	1224	1338	BCDE	
1986	1226	1316	BCDE	
1986	1230	1414	C	
1987	0101	1353	A	
1987	0102	0115	bc	
1987	0102	1342	BCD	
1987	0103	1331	BD	
1987	0104	1320	C	
1987	0108	1418	BC	
1987	0111	1345	Ade	
1987	0112	1334	AD	
1987	0113	1324	AE	
1987	0127	1415	Ab	
1987	0128	1404	b	
1987	0130	1342	b	
1987	0131	1331	AE	
1987	0204	1430	BC	
1987	0205	1419	A	
1987	0206	1408	bc	
1987	0207	0130	A	
1987	0208	0117	Bc	
1987	0208	1346	ABd	
1987	0209	1335	AE	
1987	0211	0045	a	
1987	0211	0112	Bc	
1987	0214	1423	A	
1987	0215	1411	bd	
1987	0216	1400	bc	
1987	0217	0122	bc	
1987	0217	1350	AE	
1987	0219	1328	a	

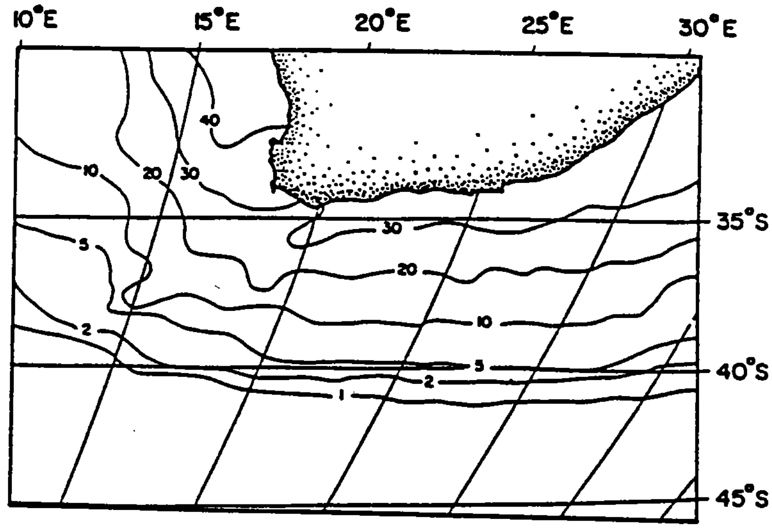

Fig. 1. Percentage of cloud-free time south of Africa, from 6 years of METEOSAT images.

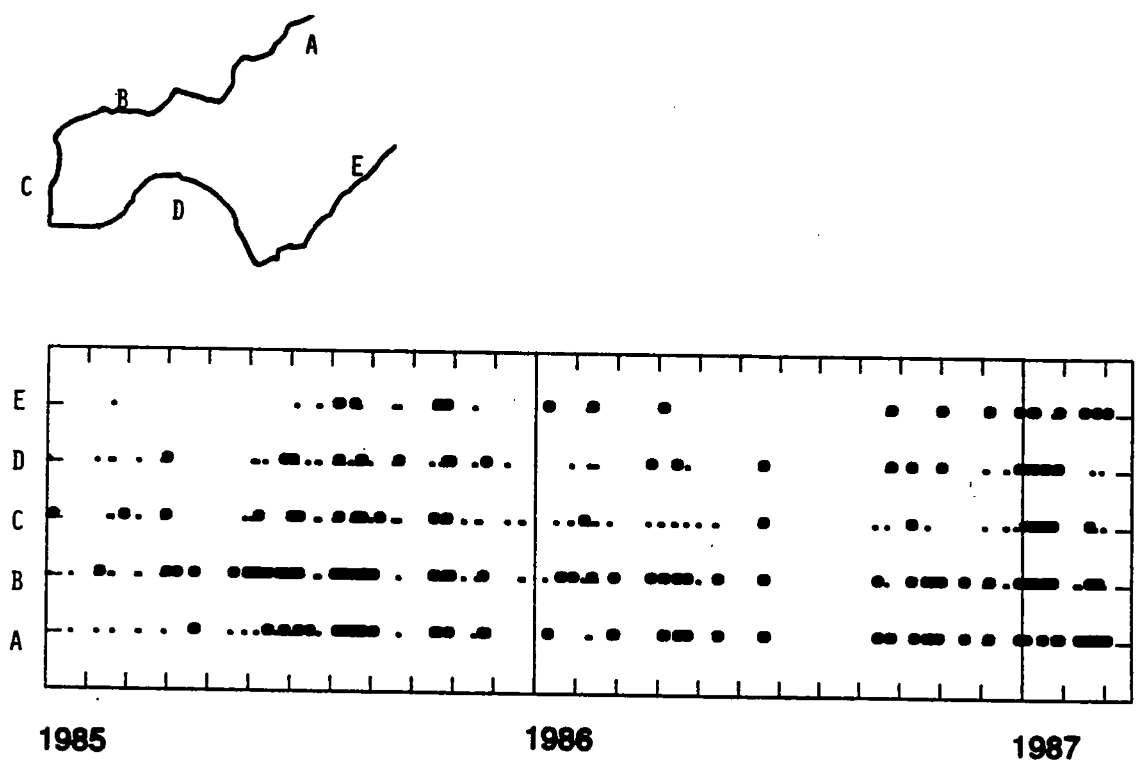

Fig. 2. Graph of clear images over each region of the retroflection: • cloudless, · scattered clouds. Note the unusually clear conditions in January 1987.

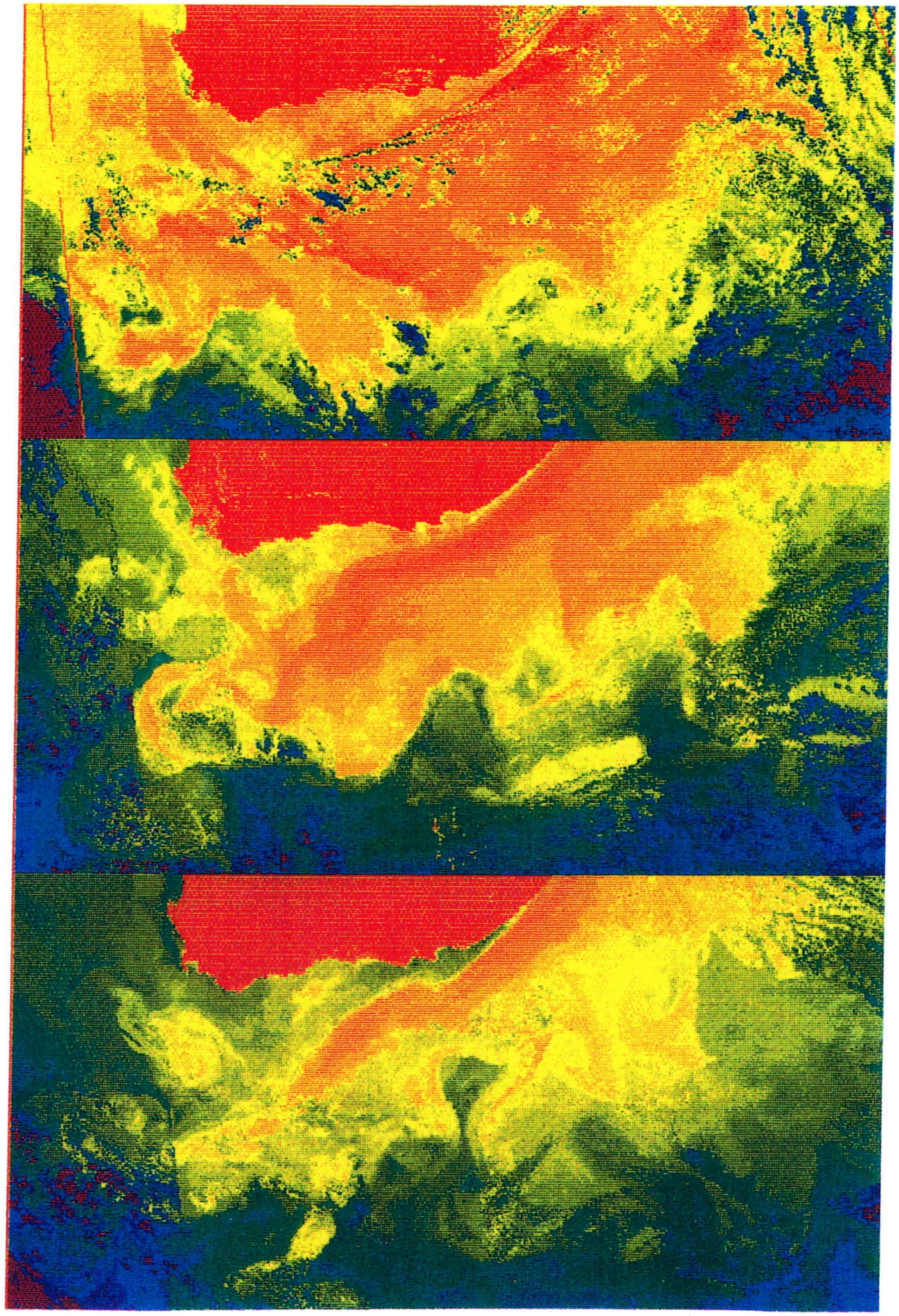

Figure 3: Composite image of sea-surface temperatures for 24 March to 27 March (top), 12 August to 18 August (center) and 16 October to 21 October, 1985 (bottom), constructed by selecting, at each pixel, the warmest temperature for the period. A rainbow color code with cold water/blue and warm water/red is used.

SECTION 3

Conductivity–Temperature–Depth–Dissolved Oxygen (CTD/O_2) Observations in the Agulhas Retroflexion February/March, 1985

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Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543
[†]Department of Oceanography, Dalhousie University, Halifax, N.S., B3H 4J1, Canada

Introduction

The Agulhas Current is the poleward-directed western boundary current of the South Indian Ocean. The current axis is typically found just offshore from the continental shelf break along the southwest African coast, Figure 1. At approximately 35°S, the extreme southern extent of the Agulhas Bank, the current separates from the shelf and shortly thereafter turns back to the east: a feature termed the Retroflection (Bang and Pearce, 1970). The eastward directed portion of the flow after the retroflection is called the Agulhas Return Current.

A series of 92 oceanographic stations were occupied in the Agulhas Retroflection region during a current meter deployment cruise aboard the *R/V Thomas Washington* in February/March 1985, Figure 2. The Agulhas cruise was the third leg of a multi-investigator study of the South Atlantic Ocean from the *Washington*. Station numbering was consecutive on the three cruises; the Agulhas data set consists of stations 207–298. The sampling constituted a spatial survey of the temperature, salinity and dissolved oxygen concentration fields of the Agulhas Current, the Return Current and several rings discovered in the area (both warm- and cold-cored). The observations significantly increased the data base south of the African continent; previous surveys were conducted in 1969 by South African investigators (Harris and van Foreest, 1978) and 1983 by a U.S. team (Gordon *et al.*, 1987). The present data set is notable for its good spatial resolution (station spacing on cross-stream transects is 20–60 km) and coverage of the deep and bottom waters (all but 20 stations extend to within 200 m of the ocean bottom). The following section outlines the instrumentation used and methods of data reduction. The synopsis section gives a brief overview of the hydrographic conditions observed on the cruise. Station listings are contained on microfiche which are part of this report.

Instrumentation and Data Reduction Methods

A Neil Brown Instrument Systems Conductivity–Temperature–Depth-dissolved Oxygen (CTD/O_2) profiler was employed on the cruise. A single instrument was employed for the entire cruise (WHOI CTD number 9). CTD 9 exhibited very stable sensors throughout the voyage. Water samples were collected with a General Oceanics Inc. 24-place/1.2-liter rosette during upcasts and analyzed for salinity and dissolved oxygen content. Salinity samples were processed on a Guildline Inc. Autosal salinometer. Manual oxygen titration was conducted using a modified Winkler technique. A 12 kHz pinger was mounted on the CTD underwater package to facilitate sampling close to the ocean bottom. Because of the large terminal velocity of the small underwater package, lowering rates of order 120 m/min were achieved. Consequently, full ocean depth casts were completed in 2-2.5 hours.

Data calibration and reduction followed the discussion of Millard (1982). Pre- and post-cruise laboratory calibrations of the CTD sensors were made in the WHOI calibration facility. Pre-cruise calibrations were conducted on 30 July, 1984 and post-cruise calibrations were on 20 May, 1985. Differences in the two calibrations were small; since it was closer in time to the actual at-sea data acquisition, the post-cruise calibration was utilized exclusively for the present data set.

These laboratory data provided the sole calibration information for the temperature and pressure data obtained with the CTD (*i.e.*, no thermometry was conducted at sea). A cubic polynomial, fit to the CTD/dead-weight-testor pressure calibration data (obtained when pressure was increasing with time), was applied to the raw CTD data:

PRESSURE

Bias	Slope	Quadratic	Cubic
11.22870	0.993526E−1	0.258851E−7	−0.290407E−12

In similar fashion, a quadratic polynomial, fit to the CTD/precision-standard temperature data obtained during measurement in the calibration bath, was applied to the CTD temperature data:

TEMPERATURE

Bias	Slope	Quadratic
0.989354E−2	0.499616E−3	0.601988E−11

The water sample data are used to obtain calibration information for the conductivity and dissolved oxygen cells. A linear regression fit to CTD conductivity data and conductivity derived from rosette water sample data was used to determine the final conductivity scaling factors. The entire station data set (with the exception of 6 casts) was used in the regression. A fit was first done for the conductivity bias and slope correction terms over the full water column. The data was subsequently refit, after applying the conductivity bias term determined above, for conductivity slope in the deep water (temperatures below 3°C). Our ability to employ a single calibration for the conductivity data is evidence of the stability of this sensor during the cruise.

CONDUCTIVITY

Bias	Slope	Based on Fit to Stations
0.01794593	0.99914385966E−3	207–298 (less 215, 216, 243, 251, 256, 292)

Unlike the other sensors, the oxygen sensor on CTD 9 was not stable during the Agulhas cruise. Multiple station groups were used for fitting the CTD profile data to the corresponding water sample data. This calibration work resulted, however, in stable deep water potential temperature/oxygen relations in the study region.

Ultimately the accuracy of the derived salinity and oxygen data hinges on the accuracy of the water sample data. Noise in water sample data typically results in large part from imperfect sampling and analysis procedures. Chief among these problems on the *Washington* cruise was radio frequency electrical interference which affected the salinometer. This difficulty was minimized by scheduling salinometer operations during quieter periods of the day. Sensor stability allows averaging across multiple stations with a commensurate reduction of random noise error. Based on water sample data and consistency of potential temperature–salinity–oxygen profiles within sub-regions of the Retroflection area, we believe the Agulhas cruise salinity and oxygen data are internally accurate to 0.001 psu and 0.03 ml/l respectively. Comparison to previous observations from the area, particularly the data of Gordon *et al.* (1987), suggests the 1985 salinity data have an absolute accuracy of order 0.003 psu.

Synopsis of the Observations

The Agulhas Current during the 1985 *Washington* cruise retroflected back to the east around 15°E, Figure 1, nearly its extreme westernmost extension based on previous observations (Lutjeharms and Ballegooyen, 1988). The CTD/O_2 observations consist of a series of transects across this current system. Station locations were dictated by two constraints: a plan to obtain several "closed boxes" of stations suitable for making mass budget calculations, and the requirement that the ten-mooring current meter array be deployed when weather permitted. A consequence of this latter constraint is that station positions lie roughly along transects connecting mooring positions. Table 1 lists the station positions, times and depths sampled.

A detailed analysis of these hydrographic data was conducted by S. Bennett in her dissertation, "Where Three Oceans Meet: The Agulhas Retroflection." She discussed the structure of the current observed during the 1985 cruise. The Agulhas system is strongly baroclinic as evidenced by sections which span the current, Figure 3. Lateral density gradients (and hence vertical shear of the horizontal velocity) extend throughout the water column. The mass transport of the surface-intensified Agulhas Current is order 90 Sv but varies radically with distance along the current track in the 1985 survey (Bennett, 1988). Water mass characteristics indicate the Retroflection region contains waters of both Atlantic and Indian Ocean origin, as well as waters that are locally formed by winter cooling. Analysis of the water characteristics and mass transport field suggests that the Agulhas is chiefly located above 2000 db depth. This finding is corroborated by the observation in 1985 that the axis of the Agulhas Return Current passed directly over the Agulhas Plateau, a bathymetric feature extending shallower than 3000 m depth.

Also sampled during the cruise were two warm-core rings southwest of the African continent, and a cold-core ring between the Agulhas Current and Return Current, Figure 1. This latter feature was the first observation of a cold feature within the Agulhas/Return Current loop. The Agulhas transport field was strongly distorted in the vicinity of the cold ring; evidence suggests that a portion of the current field retroflected back to the east upstream from the ring.

Acknowledgements

This final CTD/O_2 data set is the product of careful work by numerous individuals both at sea and ashore. We thank the members of the sea-going scientific party and the crew and officers of the *R/V Thomas Washington* for their efforts during the cruise. Special kudos go to S. Allen for processing the salinity and oxygen samples. Also, M. Stalcup was helpful in diagnosing some problems with the salinometer data and R. Millard was instrumental as always in helping treat the occasional "problem" station. This work was supported by the Office of Naval Research, contract No. N00014-85-C-0001, NR 083-004 and N00014-87-K-0007, NR 083-004 with the Woods Hole Oceanographic Institution.

References

Bennett, S. L., 1988. "Where three oceans meet: The Agulhas Retroflection Region." Ph.D. Thesis, MIT/WHOI Joint Program in Physical Oceanography. Woods Hole Oceanographic Institution Technical Report No. WHOI-88-51, 350 pp.

Bang, N. D., and F. C. Pearce, 1970. Hydrological data. Agulhas Current Project, March 1969. Institute of Oceanography, University of Cape Town. *Data Report No. 4*, 26 pp.

Gordon, A. L., J. R. E. Lutjeharms, and M. L. Grundlingh, 1987. Stratification and circulation at the Agulhas Retroflection. *Deep-Sea Research*, **24**, 565–599.

Harris T. F. W., and D. van Foreest, 1978. The Agulhas Current in March 1969. *Deep-Sea Research*, **25**, 549–561.

Lutjeharms, J. R. E., and R. C. van Ballegooyen, 1988. Retroflection of the Agulhas Current. *Journal of Physical Oceanography*, **18**, 1570–1583.

Millard, R. C., 1982. CTD calibration and data processing techniques at WHOI using the 1978 practical salinity scale. *Proceedings of International STD Conference and Workshop*, La Jolla, CA 92037, 19 pp.

Table 1: CTD station positions, times, and maximum pressures occupied on *R/V Thomas Washington* cruise in Feb/Mar 1985.

THOMAS WASHINGTON CRUISE #3
MARATHON LEGS 11 & 12
AGULHAS CURRENT
STATION SUMMARY

<CTD.TW003D030>

SH	CRU	STAT	DV	CST	CTD	DA	MO	YR	ST GMT	END GMT	LATITUDE	LONGITUDE	P MAX
TW	3	207	X	000	9	20	2	85	1312	1342	-34 25.15	18 23.08	135.0
TW	3	208	X	000	9	20	2	85	1443	1458	-34 27.81	18 16.09	285.0
TW	3	209	X	000	9	20	2	85	1617	1636	-34 30.87	18 4.87	281.0
TW	3	210	X	000	9	20	2	85	1751	1823	-34 31.14	18 3.36	635.0
TW	3	211	X	000	9	20	2	85	2104	2155	-34 39.91	17 48.04	1391.0
TW	3	212	E	001	9	20	2	85	2340	114	-34 45.13	17 37.63	2085.0
TW	3	213	X	000	9	21	2	85	233	326	-34 52.55	17 21.21	2765.0
TW	3	214	X	000	9	21	2	85	718	812	-35 5.58	16 54.82	3411.0
TW	3	215	X	000	9	21	2	85	1159	1249	-35 17.08	16 27.12	4079.0
TW	3	216	X	000	9	21	2	85	1700	1836	-35 32.31	16 0.31	4573.0
TW	3	217	X	000	9	21	2	85	2240	2336	-36 1.05	15 54.64	4509.0
TW	3	218	X	000	9	22	2	85	331	505	-36 30.00	15 48.90	4657.0
TW	3	219	X	000	9	22	2	85	919	1020	-36 59.70	15 43.40	4707.0
TW	3	220	X	000	9	22	2	85	1421	1555	-37 29.07	15 36.81	4755.0
TW	3	221	X	000	9	22	2	85	2350	48	-38 0.16	15 30.82	4809.0
TW	3	222	X	000	9	23	2	85	1140	1240	-38 19.01	15 10.31	4703.0
TW	3	223	X	000	9	23	2	85	1648	1835	-38 38.48	14 46.31	4805.0
TW	3	224	X	000	9	24	2	85	441	635	-39 0.54	14 12.73	4303.0
TW	3	225	X	000	9	24	2	85	1402	1538	-39 14.20	15 0.95	4655.0
TW	3	226	X	000	9	24	2	85	2038	2207	-39 24.89	15 32.38	3241.0
TW	3	227	X	000	9	25	2	85	333	436	-39 43.33	16 0.59	3603.0
TW	3	228	X	000	9	25	2	85	1342	1433	-40 8.16	16 31.59	3811.0
TW	3	229	X	000	9	25	2	85	1857	2003	-40 43.45	17 2.25	2677.0
TW	3	230	E	000	9	26	2	85	17	113	-41 20.38	17 31.24	4031.0
TW	3	231	X	000	9	26	2	85	1223	1320	-41 59.08	17 49.73	4535.0
TW	3	232	X	000	9	26	2	85	1736	1855	-42 30.30	17 59.30	5007.0
TW	3	233	X	000	9	26	2	85	2346	45	-42 59.55	17 59.57	4807.0
TW	3	234	X	000	9	27	2	85	457	604	-43 30.51	17 56.80	4803.0
TW	3	235	X	000	9	27	2	85	1012	1104	-43 58.94	17 58.02	4613.0
TW	3	236	X	000	9	27	2	85	1505	1606	-44 27.50	17 52.50	4807.0
TW	3	237	X	000	9	27	2	85	2019	2122	-45 1.66	17 58.35	4309.0
TW	3	238	X	000	9	1	3	85	512	700	-40 5.28	19 44.18	5009.0
TW	3	239	X	000	9	7	3	85	2208	2214	-35 59.74	19 59.81	159.0
TW	3	240	X	000	9	7	3	85	2326	2334	-36 5.79	19 49.58	257.0
TW	3	241	X	000	9	8	3	85	100	119	-36 13.77	19 40.41	1193.0
TW	3	242	X	000	9	8	3	85	247	327	-36 19.59	19 29.44	2655.0
TW	3	243	X	000	9	8	3	85	640	726	-36 41.34	19 18.05	3617.0
TW	3	244	E	000	9	8	3	85	1223	1334	-37 0.56	18 57.68	4003.0
TW	3	245	X	000	9	8	3	85	1804	1910	-37 33.24	18 43.99	4557.0
TW	3	246	X	000	9	8	3	85	2311	100	-38 0.45	18 30.30	4605.0

Table 1: CTD station positions, times, and maximum pressures occupied on *R/V Thomas Washington* cruise in Feb/Mar 1985.
(cont.)

SH	CRU	STAT	DV	CST	CTD	DA	MO	YR	ST GMT	END GMT	LATITUDE	LONGITUDE	P MAX
TW	3	247	X	000	9	9	3	85	930	1026	-38 30.72	18 29.00	4739.0
TW	3	248	X	000	9	9	3	85	1651	1752	-38 29.66	19 29.94	4629.0
TW	3	249	X	000	9	10	3	85	19	121	-38 30.01	20 30.13	5217.0
TW	3	250	X	001	9	10	3	85	1045	1206	-37 51.89	21 7.56	4705.0
TW	3	251	X	000	9	10	3	85	1707	1835	-38 29.93	21 33.11	5055.0
TW	3	252	X	000	9	10	3	85	2250	2358	-38 30.19	22 16.11	5139.0
TW	3	253	X	000	9	11	3	85	857	1000	-38 25.50	22 59.40	5291.0
TW	3	254	X	000	9	11	3	85	1318	1425	-38 4.16	22 59.37	4883.0
TW	3	255	X	000	9	11	3	85	1812	1920	-37 34.49	22 58.67	5001.0
TW	3	256	X	000	9	12	3	85	910	917	-36 12.44	21 58.11	211.0
TW	3	257	X	000	9	12	3	85	1031	1041	-36 20.31	22 8.04	405.0
TW	3	258	X	000	9	12	3	85	1143	1202	-36 26.96	22 14.19	915.0
TW	3	259	X	000	9	12	3	85	1333	1405	-36 31.77	22 27.11	2267.0
TW	3	260	X	000	9	12	3	85	1646	1718	-36 51.02	22 42.67	2477.0
TW	3	261	X	000	9	12	3	85	2031	2144	-37 9.96	23 7.42	3309.0
TW	3	262	E	000	9	13	3	85	146	254	-37 35.89	23 32.59	5425.0
TW	3	263	X	000	9	13	3	85	717	816	-37 59.10	23 59.80	5171.0
TW	3	264	X	000	9	13	3	85	1200	1307	-38 0.26	24 29.00	4853.0
TW	3	265	X	000	9	13	3	85	1640	1743	-38 1.36	24 58.43	4065.0
TW	3	266	X	000	9	13	3	85	2113	2158	-37 59.51	25 30.92	3509.0
TW	3	267	X	000	9	14	3	85	101	139	-37 58.92	26 1.40	2979.0
TW	3	268	X	000	9	14	3	85	518	555	-37 29.83	26 15.01	2819.0
TW	3	269	X	001	9	14	3	85	958	1040	-37 0.04	26 30.21	3191.0
TW	3	270	X	000	9	14	3	85	1453	1542	-36 30.39	26 45.70	3549.0
TW	3	271	X	000	9	15	3	85	7	103	-35 54.26	26 56.15	4689.0
TW	3	272	X	000	9	15	3	85	353	457	-35 40.14	26 41.20	4635.0
TW	3	273	X	000	9	15	3	85	11	1205	-35 19.29	26 20.58	4225.0
TW	3	274	X	000	9	15	3	85	1924	2012	-35 6.30	25 52.01	4131.0
TW	3	275	X	000	9	15	3	85	2257	1	-34 52.93	25 51.72	3501.0
TW	3	276	X	000	9	16	3	85	156	239	-34 46.36	25 43.91	2103.0
TW	3	277	X	000	9	16	3	85	432	459	-34 37.13	25 37.32	1715.0
TW	3	278	X	000	9	16	3	85	634	657	-34 30.65	25 33.10	607.0
TW	3	279	E	000	9	22	3	85	1853	1931	-38 17.84	26 11.62	2529.0
TW	3	280	X	000	9	22	3	85	2202	2244	-38 36.34	26 24.43	2807.0
TW	3	281	X	000	9	23	3	85	121	211	-38 51.41	26 35.99	2613.0
TW	3	282	X	000	9	23	3	85	622	704	-39 11.82	26 46.56	3009.0
TW	3	283	X	001	9	23	3	85	954	1032	-39 30.46	26 58.22	2611.0
TW	3	284	X	000	9	23	3	85	1625	1710	-39 59.36	26 0.12	2337.0
TW	3	285	X	001	9	23	3	85	2017	2053	-39 50.06	25 37.74	2501.0
TW	3	286	X	000	9	23	3	85	2357	43	-39 39.32	25 16.20	2709.0
TW	3	287	X	000	9	24	3	85	358	450	-39 26.23	24 54.05	2961.0
TW	3	288	X	000	9	24	3	85	734	824	-39 17.31	24 30.96	3533.0
TW	3	289	X	000	9	24	3	85	1154	1308	-38 59.82	23 58.46	3999.0
TW	3	290	E	000	9	24	3	85	1639	1751	-38 45.65	23 26.63	5293.0
TW	3	291	X	000	9	26	3	85	559	655	-38 0.16	19 59.57	4829.0
TW	3	292	X	000	9	26	3	85	902	917	-37 50.38	19 59.35	1229.0
TW	3	293	X	000	9	26	3	85	1044	1130	-37 39.64	19 59.69	4397.0
TW	3	294	X	000	9	26	3	85	1338	1352	-37 29.69	19 59.47	1005.0
TW	3	295	X	000	9	26	3	85	1512	1552	-37 19.92	19 57.59	2659.0
TW	3	296	X	000	9	26	3	85	1828	1847	-37 11.60	19 59.48	1263.0
TW	3	297	X	000	9	26	3	85	2106	2131	-36 59.97	20 0.02	1705.0
TW	3	298	X	000	9	26	3	85	2322	2351	-36 50.17	19 59.61	1509.0

CRUISE	MIN/MAX DATE	MIN LAT/LON	MX LAT/LON	INST	NV	MIN	MAX	TOT	P	WH
TW003D030	85- 2-20 85- 3-26	-45. 14.	-34. 27.	9 0 0 0	5	207	298	92	Y	

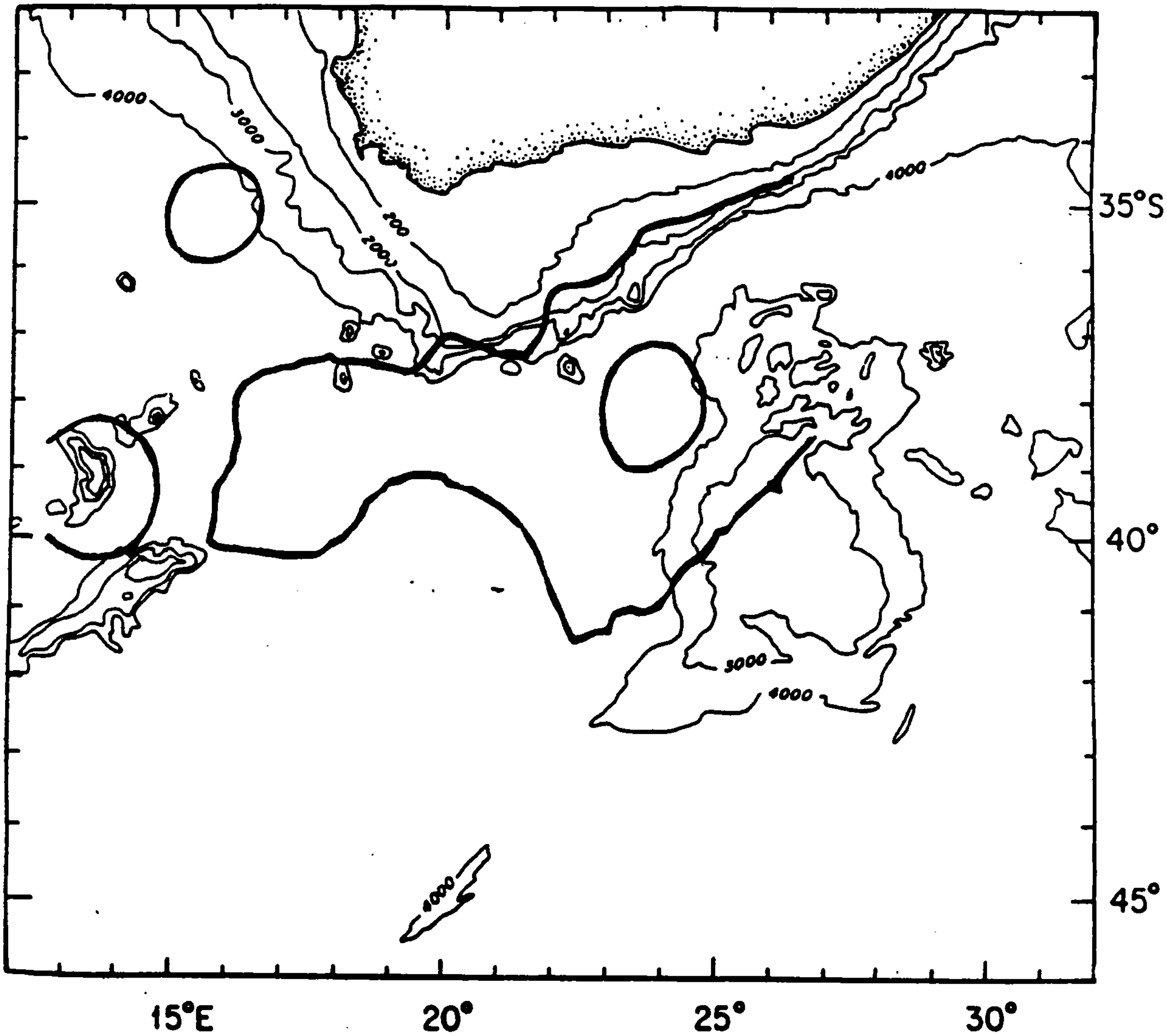

Figure 1. Map of the path of the Agulhas Current axis observed on the *R/V Thomas Washington* cruise in Feb/Mar 1985. Also shown are locations of two warm core rings southwest of the African continent and a cold core ring discovered between the Agulhas and Return Current.

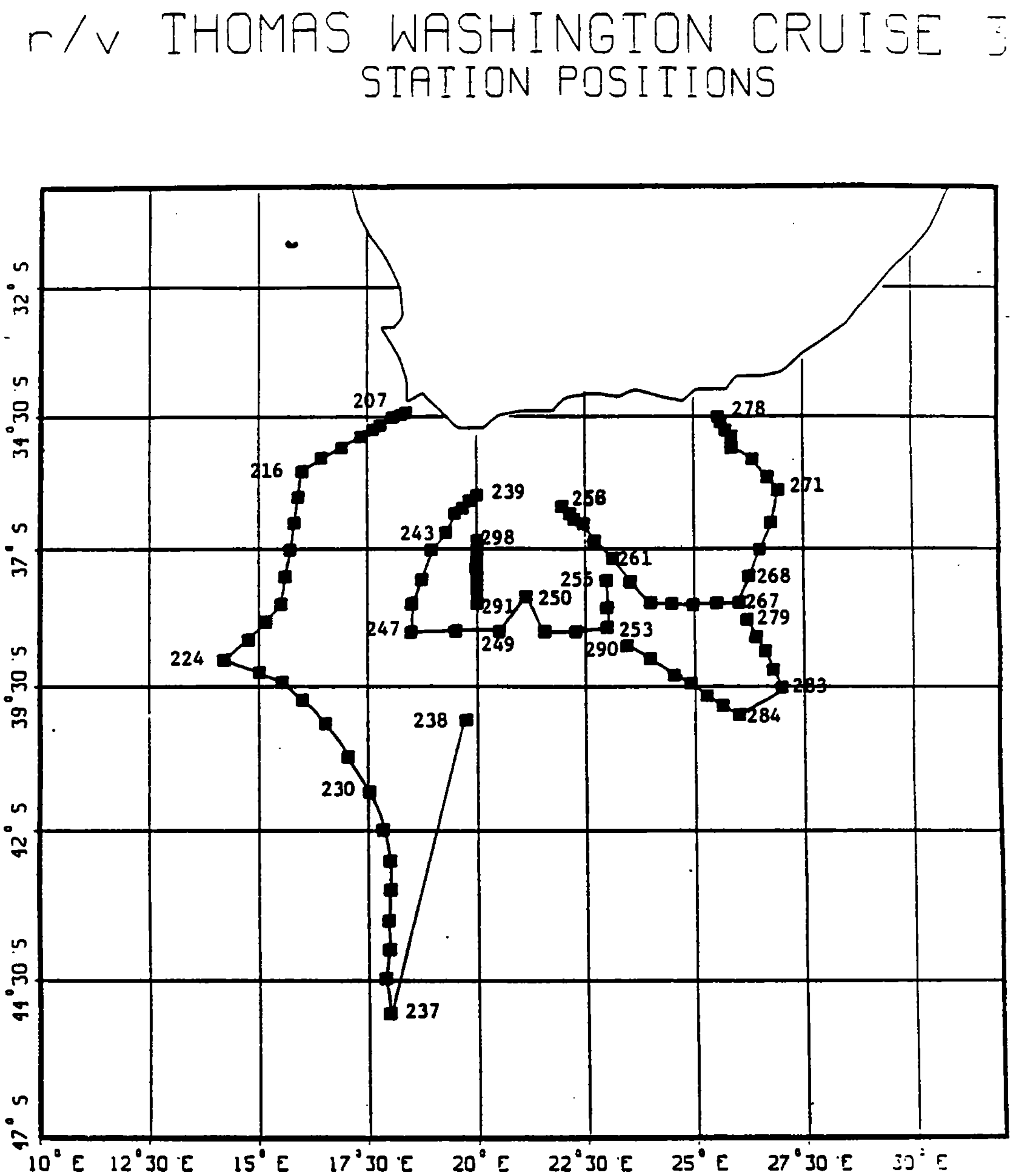

Figure 2. The location of CTD/O_2 stations occupied on the R/V *Thomas Washington* cruise in February/March, 1985. The Agulhas work on *Washington* was preceded by two other hydrographic cruises in the South Atlantic. The first station of the Agulhas cruise was number 207.

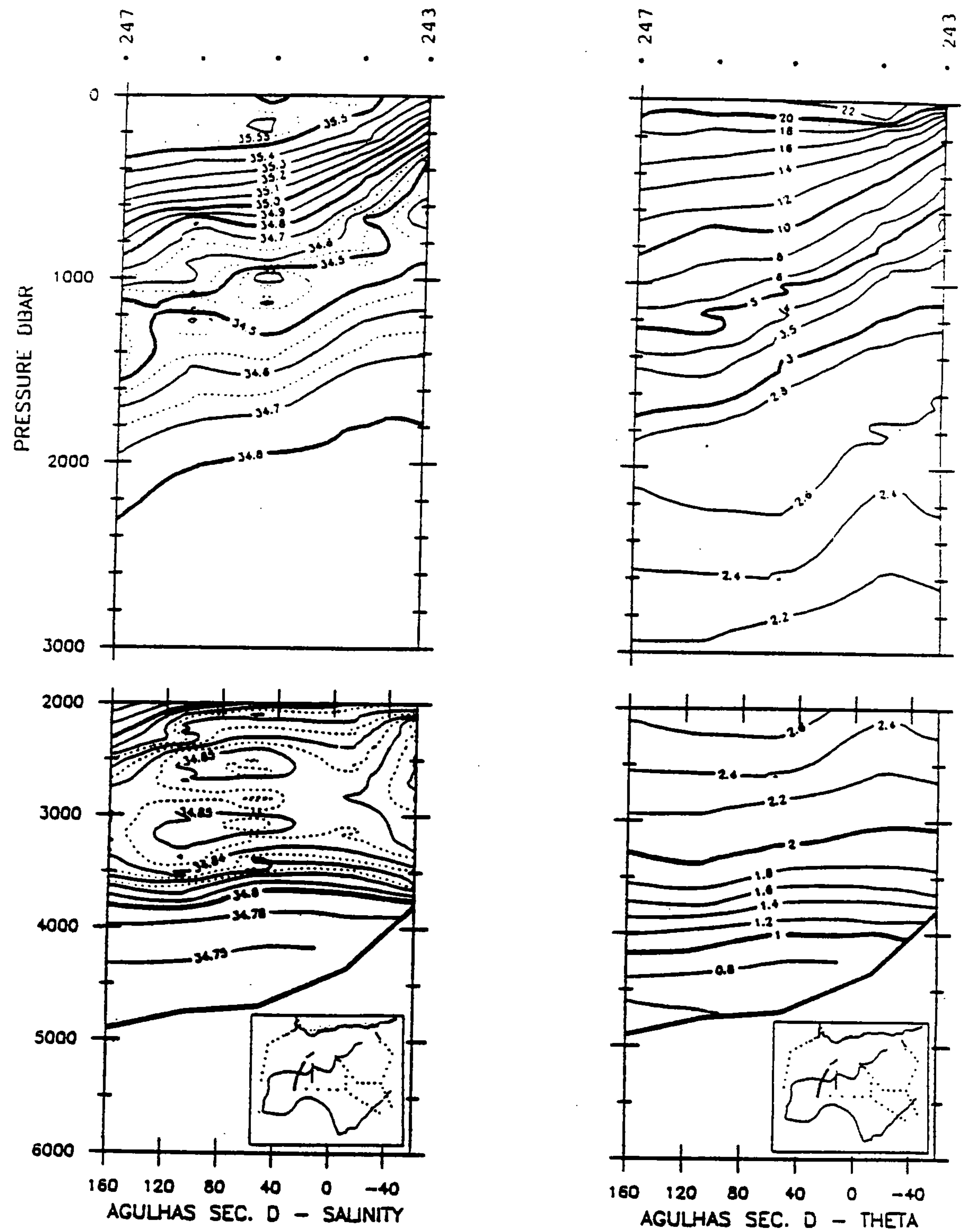

Figure 3. Vertical sections of salinity, potential temperature, dissolved oxygen and geostrophic velocity (relative to the deepest common level of adjacent stations) constructed from data which spanned the Agulhas Current just after it separated from the continental shelf (see inset).

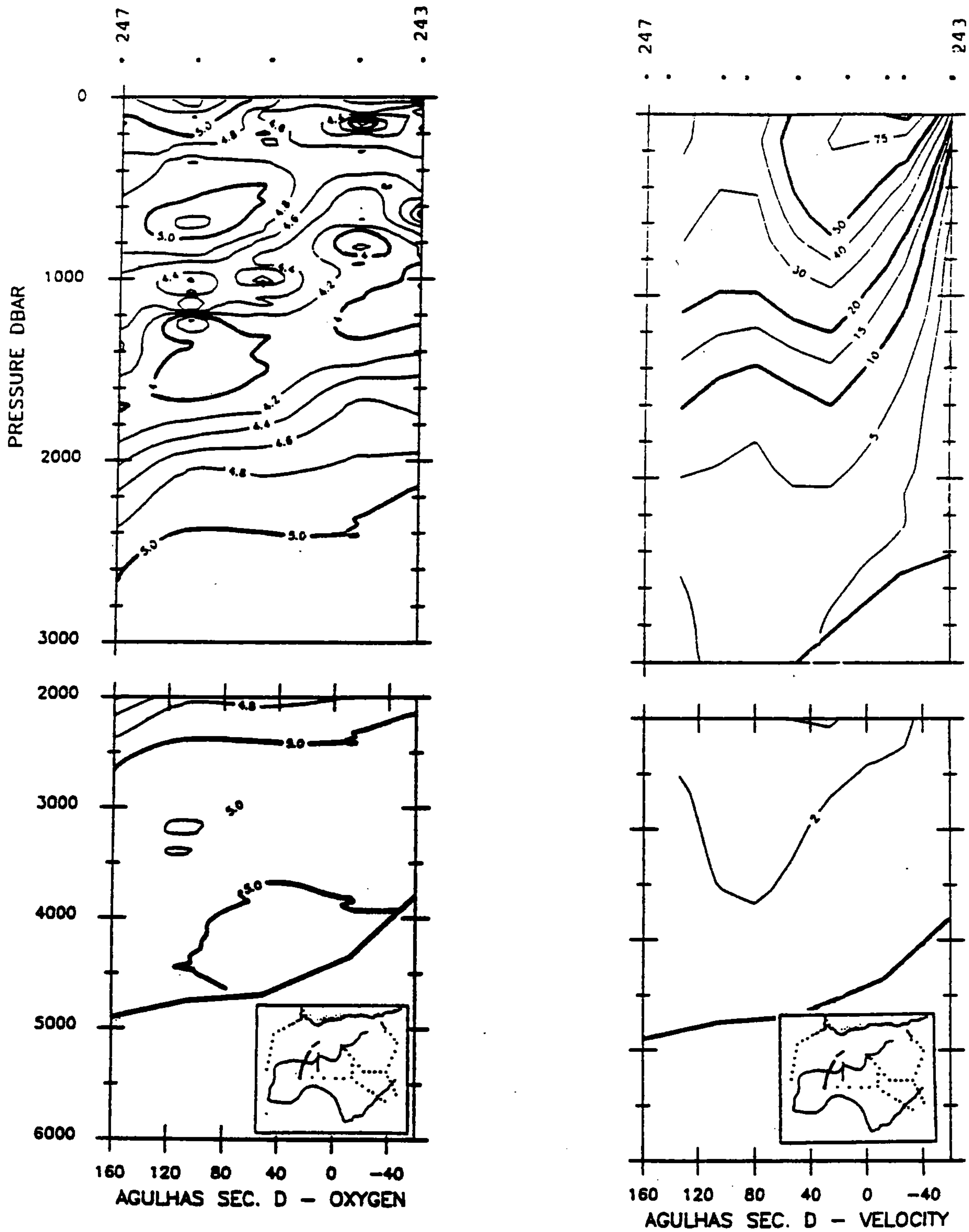

Figure 3. (Continued).

SECTION 4

Current Observations from ARGOS-Tracked Surface Drifters

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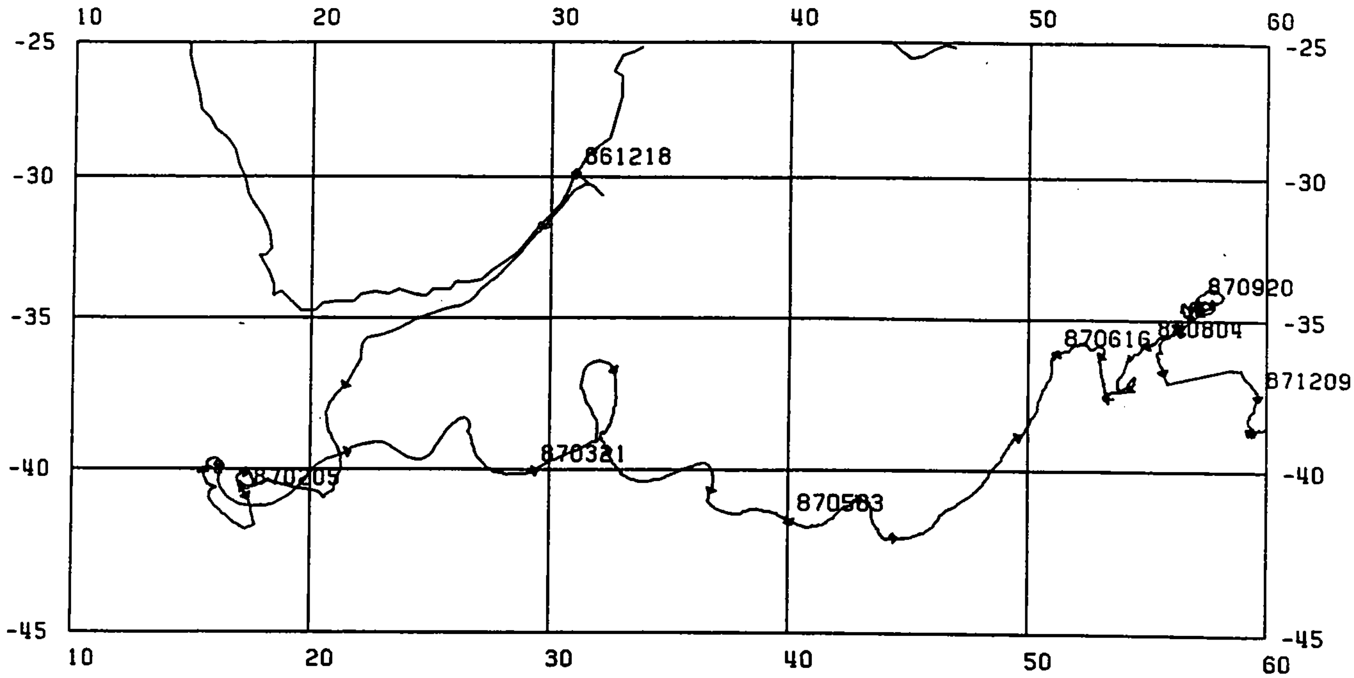
During the Agulhas Retroflexion Experiment, ten ARGOS-tracked surface drifters were deployed to trace the path of the Agulhas Current. Our original intention was to deploy drifters from the ship as we were tracking the current path using XBTs. Five of the drifters were supplied by Don Olson (RSMAS, University of Miami) and were deployed for him in rings during the *Thomas Washington* Cruise. One drifter was deployed for Robert Chase (WHOI) in the current during this cruise. Four additional drifters arrived in Capetown after the termination of the *Thomas Washington* cruise. These were deployed off Durban during 1986 by Johann Lutjeharms (CSIR/NRIO, Stellenbosch). The data from all of these drifters have been incorporated into the composite analyses of Evans and Olson (RSMAS, personal communication). Table 1 below summarizes time and location information. Plots of the tracks of nine of the drifters follow in Figure 1. Temperatures are not shown. The measurements are available in the drifter files on the disk in the back envelope of this report.

Table 1: Drifter Location and Times

Float	Launch Date (in water)	Launch Location Lat °S	Launch Location Lon °E	Launch Region	End Date of Track	Number of Days in Water
3451	12/18/86	29.86	31.03	East of Durban	02/07/88	416
3452	04/23/86	29.87	30.98	East of Durban	09/19/86	149
3453*	06/30/86	29.87	30.98	East of Durban	07/09/86	10
3454	03/21/86	29.87	30.98	East of Durban	06/27/87	463
3455	03/19/85	38.77	16.12	So. of Capetown	07/07/85	110
3795	02/24/85	38.30	15.25	Capetown Eddy	06/30/85	126
3796	03/17/85	38.51	18.67	S.W. of Port E.	06/30/85	105
3797	02/24/85	38.60	14.55	Capetown Eddy	06/30/85	126
3798	02/20/85	34.47	18.27	Off Capetown	06/30/85	130
3799	03/18/85	36.96	21.76	In Retroflexion	06/30/85	104

* Record was very short; data are not plotted.

Float 3451 Dec. 86 – Dec. 87



Float 3452 April 86 – Sept. 86

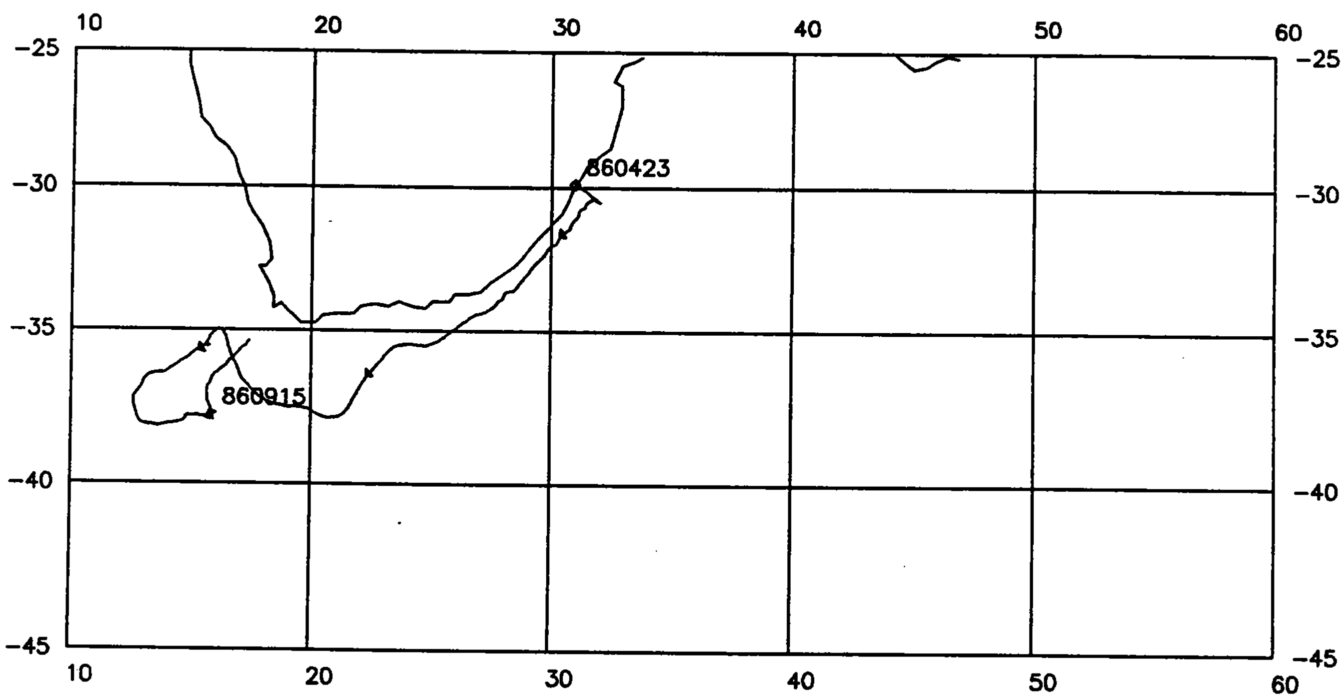
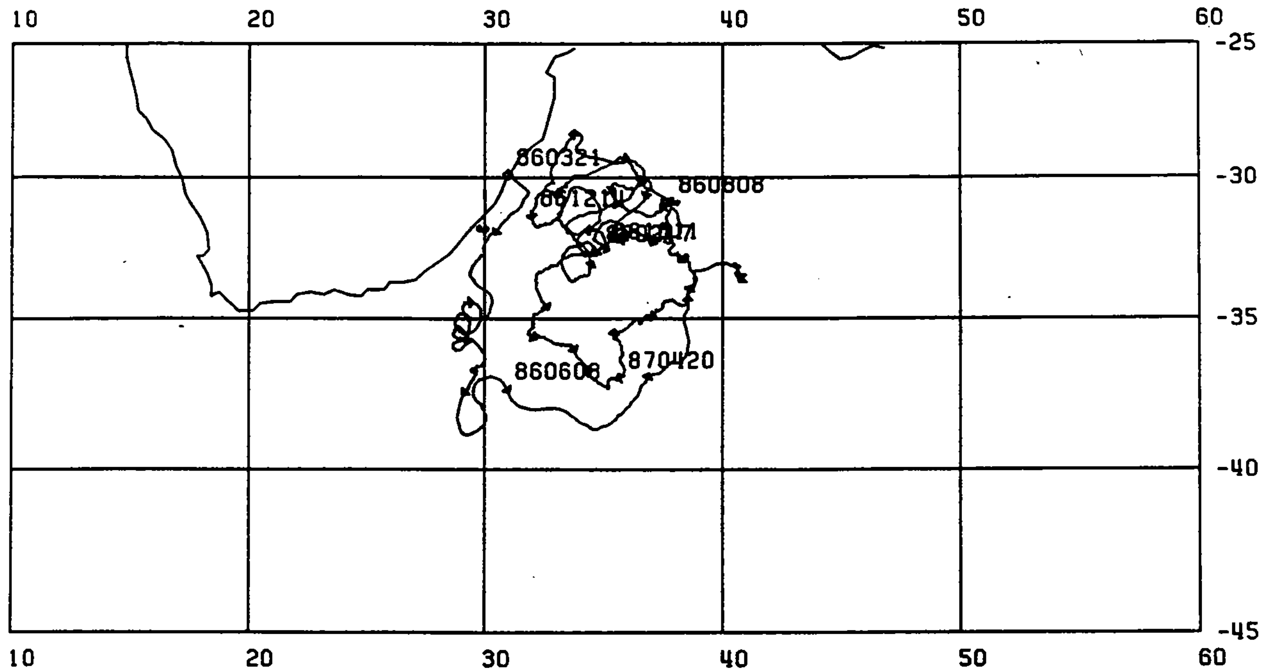


Figure 1
Drifter plots

Float 3454 March 86 - June 87



Float 3455 March 85 - July 85

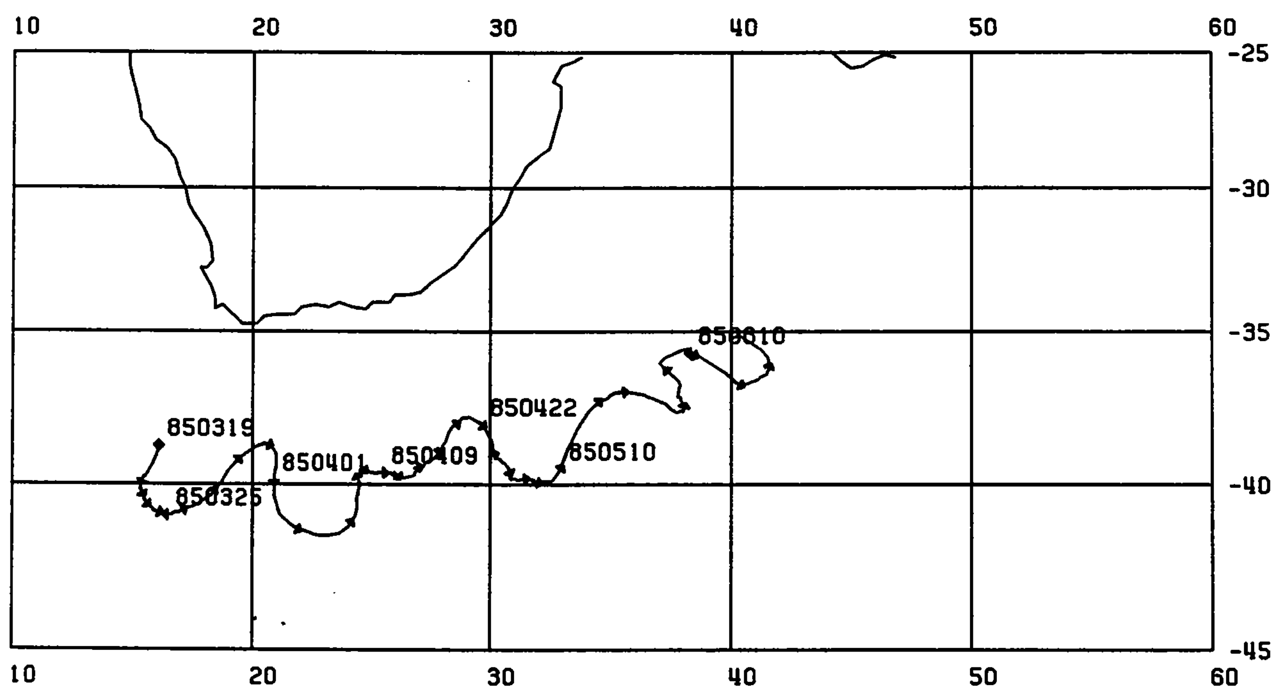
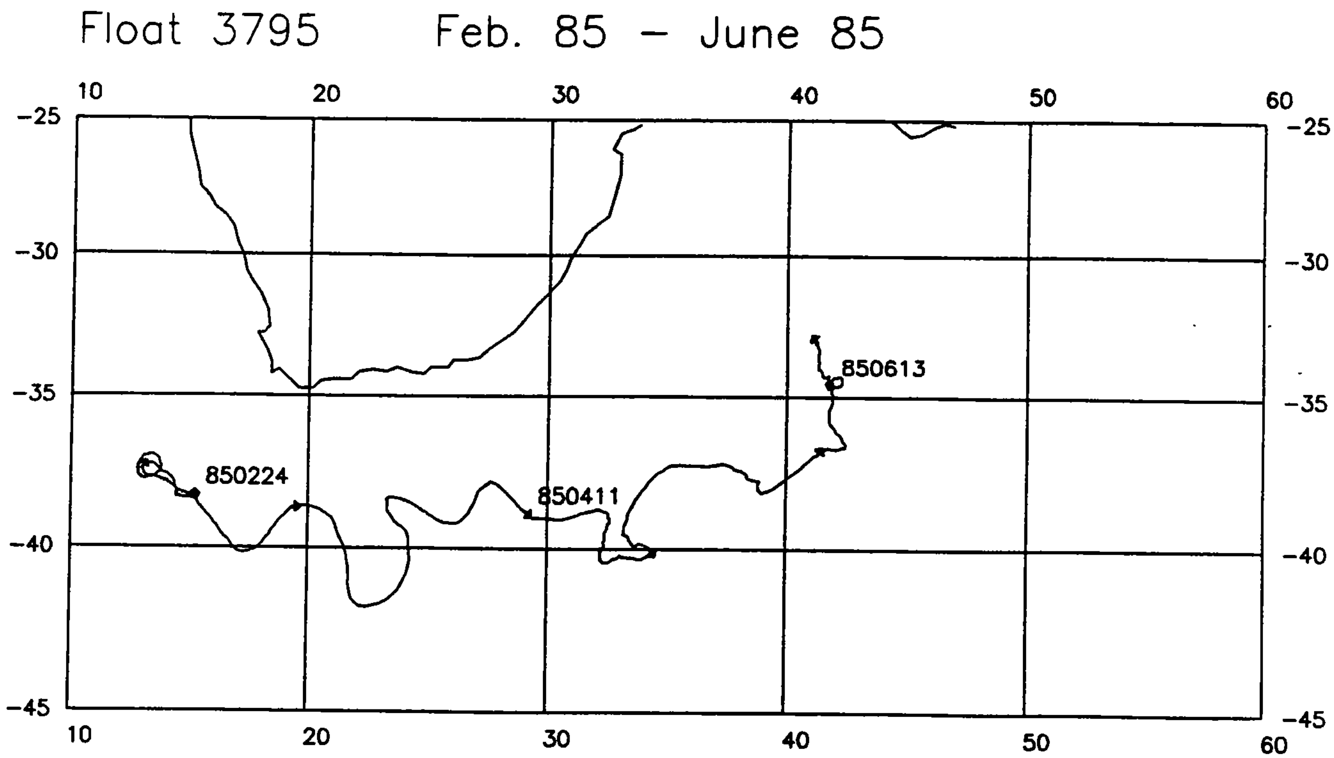


Figure 1 (cont.)



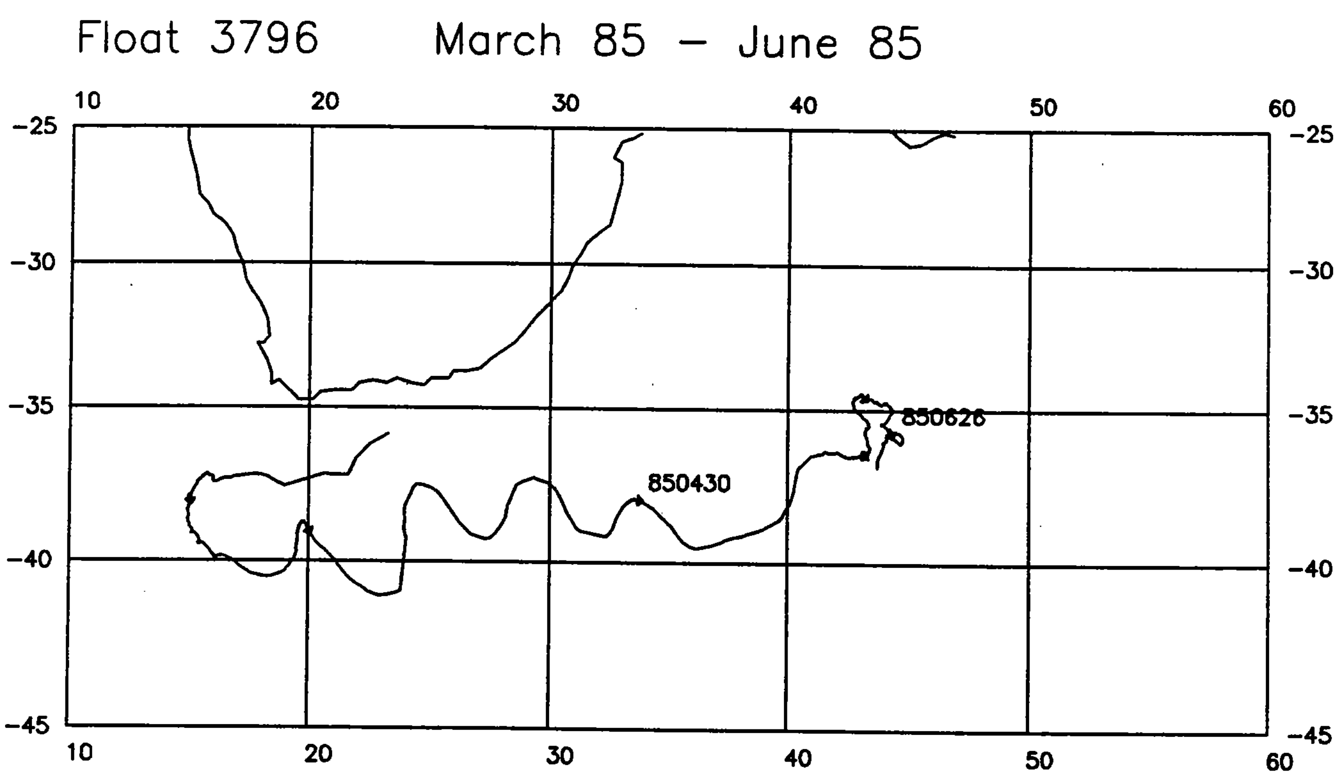
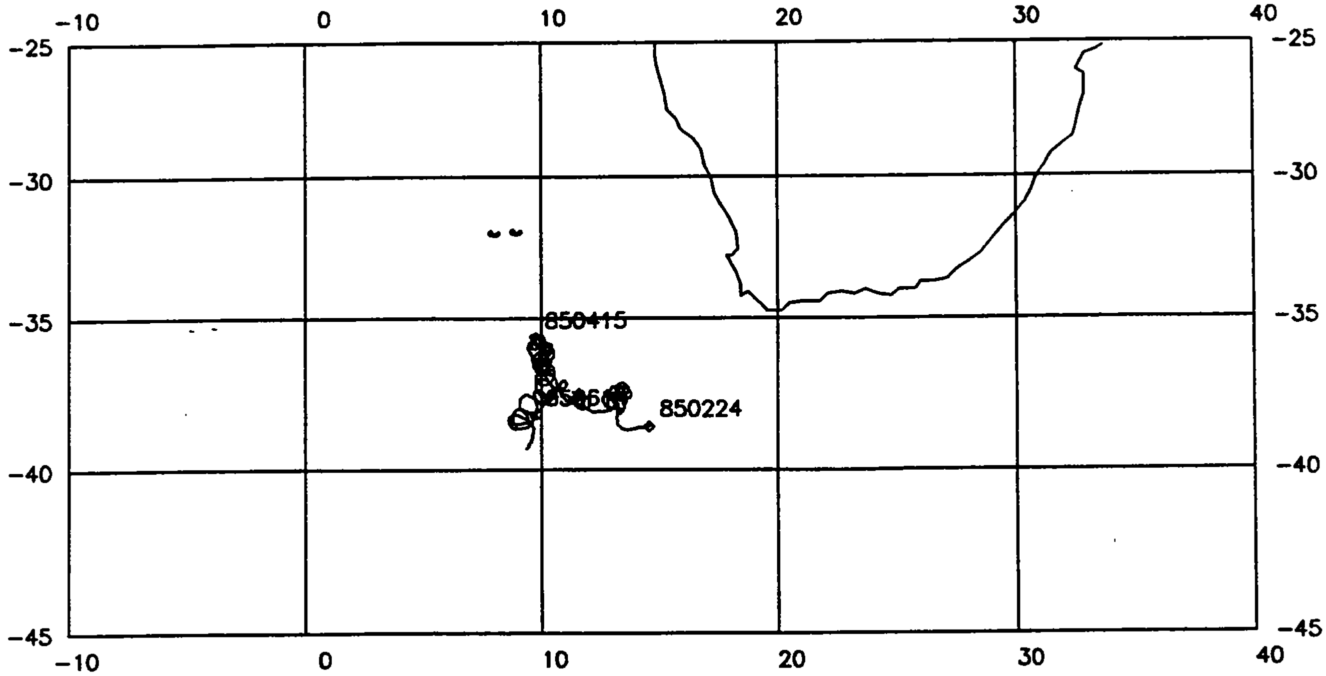


Figure 1 (cont.)

Float 3797 Feb. 85 – June 85



Float 3798 Feb. 85 – June 85

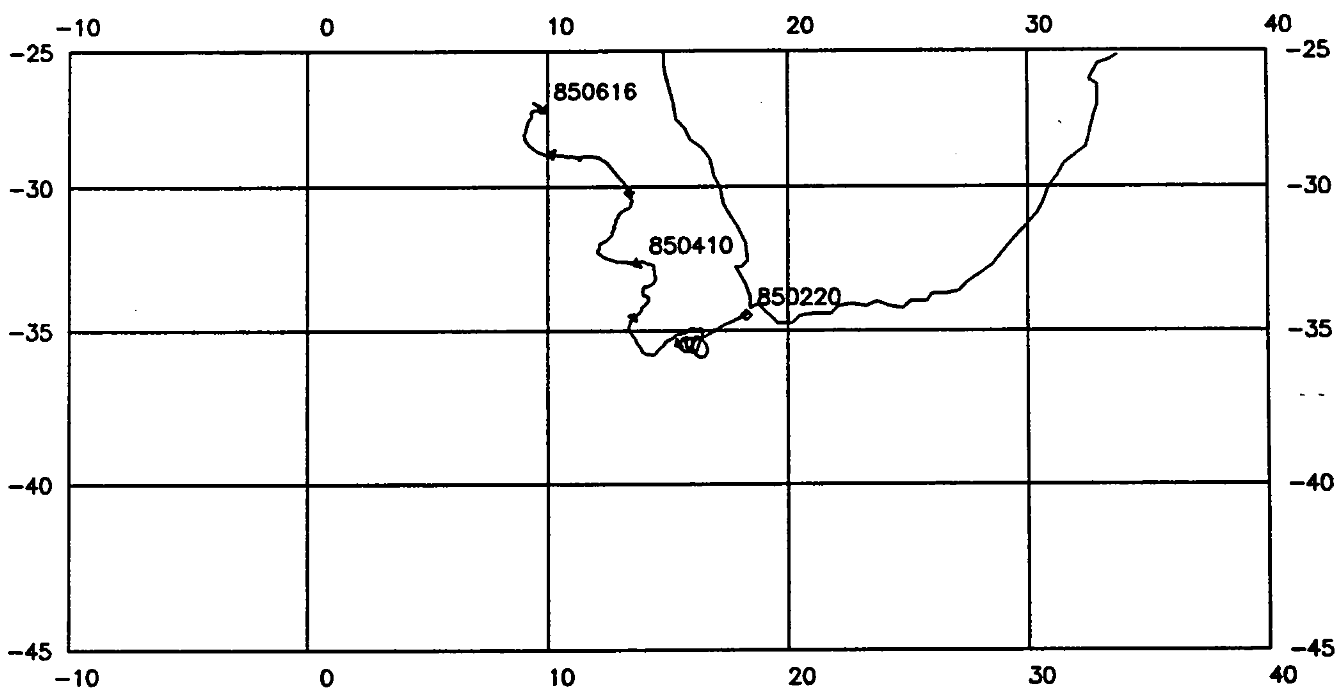


Figure 1 (cont.)

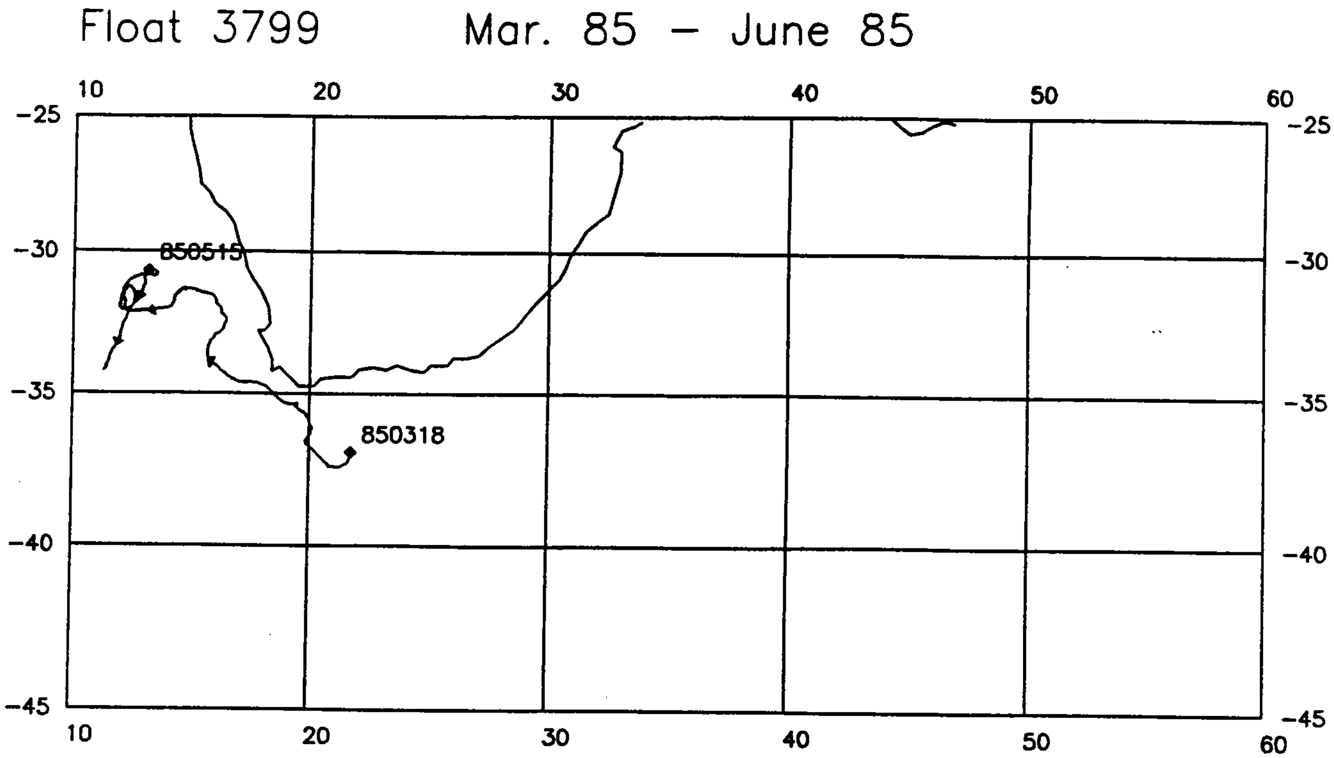


Figure 1 (cont.)

SECTION 5

Live Agulhas Atlas

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Agulhas Program and Data Files:

In the following sections, we describe the computer program and data files that are included with this Technical Report, so that anyone can access the reduced, combined data set, read the files and display the data. This section is organized as follows: the file structure is discussed, followed by descriptions of the reading and display programs. All of the programs are written using Microsoft QuickBasic 4.5. The source code is included in ASCII.

We encourage you to use the DOS Utility XCOPY to copy the contents of the disk, together with its subdirectory structure to a hard disk and then to alter the parameter DEFLT$, which is set to "a:," to whatever disk: \directory is chosen for the data files (see listings below).

The Data Files:

The data and program disk is organized into seven subdirectories as follows:

Directory of A:\AGULHAS

READ	ME	18902	3-30-90	9:45a	
CURRENT	<DIR>		8-24-89	1:55p	
SST	<DIR>		8-24-89	1:41p	SST Frontal Analyses
CTD	<DIR>		8-24-89	1:42p	CTD stations, RV *Thomas Washington*
DRIFT	<DIR>		8-24-89	1:42p	Argos Drifters
MAPS	<DIR>		8-24-89	1:42p	Bathymetry
PROGRAMS	<DIR>		8-24-89	1:42p	

Directory of A:\CURRENT

AGULCM	RAN	409600	8-13-89	4:28p
CMCONTRL	DAT	3410	8-14-89	9:21a
FIFTEEN	RAN	852	8-28-89	1:50p

The current meter data from the 31 velocity, temperature and pressure records has been filtered with a running mean Gaussian filter, 24-hour half-width, to remove variability with periods less than and equal to the inertial period, and subsampled once a day, at 1200Z. The basic control information and record length statistics from these observations are given in the file CMCONTRL.DAT (ASCII, see listing for the formats [initcms:]). This information is used by the program to assign the nominal depth and location to the data record. The velocity data are contained in a random-access file, AGULCM.RAN written by Microsoft QuickBasic 4.5. The data are stored in groups of four reels for 801 records. The first record gives the record number, latitude, longitude, and depth. The subsequent 800 records give values east (u) and north (v) in cm/sec, temperature (T) in °C and pressure (p) in decibars. These values are the subsampled values, corresponding to 1200 UTC, sequentially from 1 January 1985 to 11 March 1987. Missing data, for whatever reason, is given a value of −999.99. Thus the data from a particular day, j.year, and a particular current meter record, icm, are found at record number recno = 1 + (icm − 1) * 801 + j.year.

The path of the Agulhas Current was determined from a survey of the upper ocean thermal structure following the current using XBTs. The technique was developed by Fuglister and used extensively during Gulf Stream '60 and subsequent studies to define the path the Gulf Stream as the intersection of the 15°C temperature surface with 200-m-depth horizon. In the Gulf Stream, this has been associated with the strongest part of the near-surface horizontal flow, although other similar surfaces may be used as well (Rossby, personal communication). The position of this intersection is determined by interpolating between successive XBTs, on either side of the location of T15. The path of the Agulhas Current reported here was made near the end of the mooring deployment cruise aboard the RV *Thomas Washington*, between 17 and 22 March, 1985. This path is not an instantaneous snapshot, but extends over a five-day period.

The interpolated positions of the 15°C temperature at 200-m depth are found in the file FIFTEEN.RAN, a random-access file of latitude and longitude and sea-surface temperature (SST). The data are stored as three-integers/record. The first record consists of the number of data records (141), the initial day and final day of the series, successive records are lat*100, lon*100, and (SST-10)*1000.

Directory of A:\SST

AGPATH	DIR	1020	8-21-89	10:11a
AGPATH	RAN	78240	8-21-89	10:11a

The frontal analyses of the sea surface temperature from satellite images of the Agulhas region have been carried out by Eric Chassignet and Don Olson at RSMAS, University of Miami, and are included here with their permission. Any questions concerning the techniques of analysis or the interpretation should be addressed to them. The data are obtained from composite images over a nominal 14-day period, although some analyses are for 7 or 21 days. The data consists of two files — AGPATH.DIR, which gives the directory, and AGPATH.RAN which gives sequences of latitude, longitude, and SST for the frontal boundary. The program using subroutine initpaths, reads the AGPATH.DIR to obtain the starting date (sequential day from 0 January 1985), length of averaging interval (7, 14, or 21 days), number of data points and the initial record number in the data file, AGPATH.RAN. The data in AGPATH.RAN are stored as three integers, lat*100, lon*100, and (SST-10)*1000. Breaks in the front for rings or whatever, are indicated by a record with both lat=0 and lon=0.

Directory of A:\CTD

ALLCTD	DAT	235026	8-30-89	2:44p
AGSTNLL	DAT	552	6-14-88	1:19p
STATIONS	DIR	1288	8-30-89	2:44p

The file AGSTNLL.DAT consists of the positions, latitude and longitude, for the stations occupied on RV *Thomas Washington*, during the cruise in 1985. Data for all CTD stations are in the file ALLCTD.dat. These data are in the same format as used for the ATLAS program (Luyten and Stommel, 1988), and the file can be read and displayed using that program. Two programs are included in the "programs" directory, to read (CMREAD.BAS) and to display the data (AGULCTD.BAS). The observations have been discussed in detail by Bennett (1988).

Directory of A:\DRIFT

DRIFTER	DAT	71992	8-23-89	1:22p

During the RV *Thomas Washington* cruise in 1985, six drifters were deployed in the Agulhas Current. Five of these were provided by Don Olson, RSMAS, University of

Miami, and their trajectories are included with his permission. One was provided by Bob Chase and Jim Luyten. Another four drifters were supposed to have been deployed as well but the shipment failed to arrive in time. These drifters were subsequently deployed by Johann Lutjeharms, NRIO, Stellenbosch, RSA during 1986 and 1987.

The data from the ARGOS-tracked drifters are included in the file DRIFTER.DAT, a random-access file of fixed record length (eight bytes), consisting of day, lat*100, lon*100, (SST-10)*1000, for each of the 10 drifters. The data for a particular day, jy, and for drifter ifile is found at record=rec.drift = 1000 * (ifile - 1) + jy. The IDs of the nine drifters are 3451, 3452, 3454, 3455, 3795, 3796, 3797, 3798, and 3799. One-day averages of positions and SST values were constructed from the raw data files as the basic data here.

Directory of A:\MAPS

MERC0	DAT	1065	8-21-89	12:19p
AGULHAS0	DAT	116	8-29-89	10:31a
AGULHAS1	DAT	172	8-29-89	10:31a
AGULHAS2	DAT	204	8-29-89	10:31a
AGULHAS3	DAT	408	8-29-89	10:31a
AGULHAS4	DAT	512	8-29-89	10:31a

These data files provide the bottom topography contours at 0, 1000, 2000, 3000, and 4000-m-depth, abstracted from the data base maintained by the Information Processing and Computer Laboratory at WHOI. The data appropriate to our region of interest are included here as random-access files, with records consisting of two integers, lat*100,lon*100. Jumps in position greater than two units are assumed to be discontinuities.

The file MERC0.DAT contains the latitude conversion table for the mercator projection used in the display. The file is read by the subroutine merc0, and is used by the subroutine merc to display any of the [lat,lon] positions. The table is generated by integrating 1/cos (latitude).

Directory of A:\PROGRAMS

AGULHAS	BAS	30709	8-31-89	9:29a
CMREAD	BAS	9198	8-31-89	8:53a
CTDPLOT	BAS	21604	8-30-89	3:43p

The programs that are included here are all written using Microsoft QuickBasic, version 4.5, and assume a VGA (640 × 480, 16 colors) display adapter for the graphics.

This choice is initialized near the beginning of each program with the statement SCREEN 12: PALETTE. There are also statements which use the command LOCATE c,r where c = 29 or 30. If one modifies the code for an EGA adapter, both SCREEN 9 and LOCATE c,r where c< = 25 should be used. The graphics can be handled by using the WINDOW SCREEN (0,0)-(640,480) command which will define the screen coordinates to be as they would be for a VGA display.

Programs are provided which access the individual data files — current meters, drifters, frontal paths, CTD data, etc. These programs are also incorporated into the main program which displays all of the velocity data, AGULHAS.BAS, and the other program which displays the CTD data, AGULCTD.BAS. Only these two programs are described here in detail.

AGULHAS.BAS

The structure of the program is as follows:

First some house-keeping, mercator projection, etc. Data files are initialized for current meters, paths, drifters. Display menu giving key definitions:

Menu:

Agulhas Retroflexion Array:

Data available from (sources given below):
Current meters, surface drifters, SST frontal analyses,
XBT track of T (200 meters) = 15°C

Use cursor keys in the numeric keypad to change time in days

Increase time	+ 1 Day	+ 5 Days	+ 10 Days
Decrease time	− 1 Day	− 5 Days	− 10 Days

Keys:		
	m	for means
	u	to change velocity scale
	r	to restart
	t	for T15
	c	to refresh display
	a	for animation
	e	for velocity ellipses
	s	for station locations
	q	to quit
	?	to see this display at any time
	...	any key to continue

SST Frontal Analyses	–	Eric Chassignet	RSMAS
Current Meters, XBT Track	–	Buoy Group	WHOI
Surface Drifters	–	Don Olson	RSMAS
	–	Jim Luyten	WHOI
CTD Stations	–	John Toole	WHOI

Select levels for current meter display, level 1 corresponds to 200-m-depth (nominal), 2 = 750 m, 3 = 1500 m and 4 = 4000 m.

Begin display of data.

Time is in days, from 0 January 1985. The cursor keys can be used to step time forward or backward, with the appropriate current meter velocity vectors displayed for that day. Time is displayed both as the day in the upper part of the display, and as a yellow strip on the timeline along the bottom. The SST frontal analysis is shown for the closest analysis, indicated by the red band along the timeline.

For the most part, both the program and its operation are self-explanatory, typing the key ? will suspend the display, show the menu and then again, re-establish the display at the same day.

CTDPLOT.BAS

This program displays the CTD data from the RV *Thomas Washington* cruise in February–March, 1985, as part of the Agulhas Retroflexion cruise. The emphasis of the data display is the diagnostic diagrams of temperature *vs.* salinity, and dissolved oxygen *vs.* salinity. The data are selected from the complete 93-station file. The cursor keys are used to select stations for display and analysis. The cursor keys can then be used to select regions of the T/S diagram to display in detail, highlighting the location of the observations in the section and geographical display. The color of the highlighted data points depends upon the value of dissolved oxygen, according to the color bars at the extreme left of the display.

In order to keep track of the data within the data file, a very large temporary file is created, often of 6–8 Mbytes, so it is impractical to run this program from the floppy disk. The temporary file will not overwrite existing files on your disk, only free space. This file is removed at the completion of the program.

The procedure for running the program is as follows:

Menu is displayed, giving definition of keys, etc. Domain in T, S, and O_2 space is chosen. File is selected, data loaded and displayed. Cursor keys are activated to move through the Diagnostic T/S space. Typing q terminates the program.

References

Bennett, S. L., 1988. "Where Three Oceans Meet: The Agulhas Retroflection Region." Ph.D. Thesis, MIT/WHOI Joint Program in Physical Oceanography, Woods Hole Oceanographic Institution Technical Report No. WHOI-88-51, 350 pp.

Luyten, J. R., and H. Stommel, 1988. "Exploring the North Atlantic Ocean on Floppy Disks." Woods Hole Oceanographic Institution Technical Report No. WHOI-88-59, 65 pp, 4 disks.

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16. Abstract (Limit: 200 words)

Data are presented from an experiment designed to explore the spatial and temporal structure of the Agulhas Current and Retroflexion by direct means. Included are the current meter results from 10 moorings in the Retroflexion region, CTD stations occupied on the deployment cruise in 1985, data from satellite tracked (ARGOS) freely drifting surface buoys and numerous images of the sea surface temperature.

In addition, this report includes a floppy disk on which can be found the one-day average currents, the path of the Agulhas Current, CTD stations in "Live Atlas" format, SST frontal analyses (Chassignet and Olson, personal communication) as well as programs written in QuickBASIC which allow one to access and display these observations. The programs are stored in ASCII and can be run under the Microsoft QuickBasic (Version 4.0 or higher). Instructions for running the programs can be found in a file entitled "read.me" on the disk.

Additional copies of the floppy disk may be obtained from James R. Luyten, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, 02543.

17. Document Analysis a. Descriptors

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2. ocean temperature
3. retroflexion

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